GENERAL SPECIFICATION

FOR

AIR-CONDITIONING, REFRIGERATION, VENTILATION

AND

CENTRAL MONITORING & CONTROL SYSTEM

INSTALLATION

IN

GOVERNMENT BUILDINGS

OF

THE HONG KONG SPECIAL ADMINISTRATIVE REGION

2017 EDITION
(INCORPORATING CORRIGENDUM NO. GSAC01-2017)

ARCHITECTURAL SERVICES DEPARTMENT
THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION

PREFACE

This General Specification aims to lay down the technical requirements of materials and equipment, the standards of workmanship, the requirements on testing and commissioning and operation and maintenance as well as requirements on document submissions for Air-conditioning, Refrigeration, Ventilation and Central Monitoring & Control System Installation in Government Buildings of the Hong Kong Special Administrative Region (HKSAR).

The present edition (incorporating Corrigendum No. GSAC01-2017) of this General Specification was developed from the 2017 edition by the Air-conditioning Specialist Support Group that was established under the Building Services Branch Technical Information and Research & Development Committee of the Architectural Services Department (ArchSD). It incorporates updated international standards and codes as well as technological developments which find applications in Hong Kong. To be in line with the Department's endeavour to reduce the environmental burden on our neighbours and to help preserving common resources while improving the quality of our service, this General Specification puts emphasis on green features and green practices for construction as well as initiatives for enhancement of client satisfaction on completed projects.

With the benefit of information technology, electronic version of this edition is to be viewed on and free for download from the ArchSD Internet homepage. As part of the Government's efforts to limit paper consumption, hard copies of this General Specification will not be put up for sale.

The draft of the 2017 edition has been circulated to stakeholders within and external to the Government before finalisation. Nevertheless, the ArchSD welcomes comments on its contents at any time since the updating of this General Specification is a continuous process for the inclusion of any developments that can help meeting the needs of our community.

DISCLAIMER

This General Specification is solely compiled for Air-conditioning, Refrigeration, Ventilation and Central Monitoring & Control System Installation carried out for or on behalf of the ArchSD in Government buildings of the HKSAR.

There are no representations, either expressed or implied, as to the suitability of this General Specification for purposes other than that stated above. Users who choose to adopt this General Specification for their works are responsible for making their own assessments and judgement of all information contained here. The ArchSD does not accept any liability and responsibility for any special, indirect or consequential loss or damages whatsoever arising out of or in connection with the use of this General Specification or reliance placed on it.

The materials contained in this document may not be pertinent or fully cover the extent of the installation in non-government buildings and there is no intimated or implied endorsement of the sales, supply and installation of the materials and equipment specified in this General Specification within the territory of the HKSAR.

TABLE OF CONTENTS

PART A - SCOPE AND GENERAL REQUIREMENTS

SECTION A1 SCOPE OF SPECIFICATION

A1.1 Installations to comply with this General Specification
A1.2 Scope of the Installations
A1.3 Terms and Definitions
A1.4 Singular and Plural

SECTION A2 STATUTORY OBLIGATIONS AND OTHER REGULATIONS

A2.1 Statutory Obligations and Other Requirements
A2.2 Case of Conflict
A2.3 Mechanical Fire Service Installation

SECTION A3 EXECUTION OF INSTALLATIONS

A3.1 The International System of Units (SI)
A3.2 Programme of Installations
A3.3 Builder's Work
A3.4 Coordination of Installations
A3.5 Cooperation with Other Contractors
A3.6 Site Supervision
A3.7 Sample Board
A3.8 Advice of Order Placed
A3.9 Record of Materials Delivery
A3.10 Protection of Materials and Equipment
A3.11 Label
A3.12 Warning Notice
A3.13 Guard and Railing for Moving and Rotating Parts of Equipment
A3.14 Service Condition
A3.15 Voltage Covered by This General Specification
A3.16 Material and Equipment
A3.17 Workmanship
A3.18 Surveys and Measurements

SECTION A4 DRAWINGS AND MANUALS

A4.1 Drawings in Electronic Format
A4.2 Installation Drawings
A4.3 As-built Drawings
A4.4 Operation and Maintenance (O&M) Manual and User Manual

PART B - GENERAL TECHNICAL REQUIREMENTS (INSTALLATION METHODOLOGY)

SECTION B1 AIR CLEANING EQUIPMENT

B1.1 General
B1.2 Washable Panel Filter
B1.3 Automatic Viscous Filter
B1.4 Disposable Panel Filter
B1.5 Disposable Pleated Panel Filter
B1.6 Renewable Panel Filter
B1.7 Automatic Fabric Roll Filter
B1.8 Bag Filter
B1.9 Cartridge Filter
B1.10 High Efficiency Particulate Arrestance (HEPA) Filter
B1.11 Automatic Recleanable Filter
B1.12 Automatic Recleanable HEPA Filter
B1.13 Automatic Recleanable High Voltage Electrostatic Filter
B1.14 Gas Filter
B1.15 Activated Oxygen Air Purifier
B1.16 Ultra-Violet (UV) Sterilising Light
B1.17 Water Scrubber

SECTION B2 DUCTWORK

B2.1 General
B2.2 Design and Accessories
B2.3 Hangers and Supports
B2.4 Flexible Duct Joints
B2.5 Flexible Ductwork
B2.6 Ductwork Acoustic Treatment
B2.7 Extract Hoods and Valances for Kitchens
B2.8 Grease Filter
B2.9 Ductwork Cleaning Points
B2.10 Testing

SECTION B3 AIR HANDLING AND TREATMENT

B3.1 General

B3.2 Air Handling Units (AHUs)
B3.3 Axial Flow Fans
B3.4 Ceiling Fans
B3.5 Centrifugal Fans
B3.6 Fan Coil Units
B3.7 Cassette Type Fan Coil Units
B3.8 Mixed Flow Fans
B3.9 Mechanical Roof Extract Units
B3.10 Propeller Fans
B3.11 Protectively Coated Fans and Fans for Corrosive or Hazardous Applications
B3.12 Rotary Fans
B3.13 In-line Centrifugal Fans
B3.14 EC Plug Fans
B3.15 Jet Fans
B3.16 Conducting Fans
B3.17 Terminal Air Control Devices
B3.18 Grilles and Diffusers
B3.19 Domestic Exhaust Fans

SECTION B4 AUTOMATIC CONTROL

B4.1 Automatic Control System (ACS)
B4.2 General Requirements
B4.3 Air Cooling Control
B4.4 Air Heating Control
B4.5 Electrical/Electronic (Localised) Control System

SECTION B5 CENTRAL CONTROL AND MONITORING SYSTEM (CCMS)

B5.1 General Requirements
B5.2 System Architecture
B5.3 Electrical Wiring
B5.4 Hardware Installation
B5.5 Software Installation

SECTION B6 CENTRAL REFRIGERATION MACHINE, DIRECT EXPANSION EVAPORATORS AND HEAT REJECTION PLANT

B6.1 General

B6.2 Layout and Isolation of Plant Components
B6.3 Delivery of Equipment
B6.4 Refrigeration Pipework and Fittings
B6.5 Air-cooled Packaged Refrigeration Machine
B6.6 Water-cooled Packaged Refrigeration Machine
B6.7 Air-cooled Condenser
B6.8 Air-cooled Evaporator
B6.9 Cooling Tower
B6.10 Heat Recovery Chillier
B6.11 Total Energy Heat Pump
B6.12 Vibration Isolation
B6.13 Electrical Work
B6.14 Safety Ancillaries for Ammonia Refrigeration Machine
B6.15 Solar Heating System

SECTION B7 ELECTRIC MOTORS AND ELECTRICAL EQUIPMENT

B7.1 Low Voltage - General
B7.2 Low Voltage - Electric Motors
B7.3 Low Voltage - Variable Speed Drives
B7.4 Low Voltage - Motor Switchgear, Starter and Control Panels
B7.5 Low Voltage - Automatic Power Factor Correction Capacitors
B7.6 High Voltage - Electric Equipment

SECTION B8 NOISE AND VIBRATION CONTROL

B8.1 General
B8.2 Equipment Bases
B8.3 Vibration Isolators
B8.4 Plant/Equipment Vibration Isolation
B8.5 Pipe work Vibration Isolation
B8.6 Ductwork Vibration Isolation
B8.7 Ductwork Acoustic Insulation
B8.8 Acoustic Duct lags
B8.9 Ductwork Silencers
B8.10 Acoustic Doors
B8.11 Acoustic Louvers
B8.12 Acoustic Enclosures

B8.13 Plant Room Acoustic Linings
B8.14 Floating Floors
B8.15 Specialist Manufacturer's Inspection
B8.16 Independent Inspections

SECTION B9 PIPEWORK, VALVES, COCKS AND STRAINERS

B9.1 General
B9.2 Automatic Air Vents
B9.3 Bellow Expansion Joints/Anchors and Guides
B9.4 Changes in Pipe Size
B9.5 Connections in Pipe work
B9.6 Flow Measuring
B9.7 Flushing Down and Drainage
B9.8 Joints and Fittings for Steel Pipe work
B9.9 Joints and Fittings for Copper Tubes
B9.10 Pipe work General Details
B9.11 Pipe work Layout
B9.12 Pipe work Supports, Expansion Joints and Anchor Points
B9.13 Pipe work Vibration De-couplers
B9.14 Plastic Pipe work
B9.15 Specialised Hydraulic System Balancing Valves
B9.16 'T' and 'Y' Fittings
B9.17 Supports for Pipe work
B9.18 Welding and Brazing
B9.19 Labelling and Circuit Control Diagram of Valves

SECTION B10 SYSTEM MONITORING INSTRUMENT

B10.1 General
B10.2 System Static Pressure Gauges for Air Distribution Systems
B10.3 Thermometers - Air Immersion
B10.4 Thermometers - Liquid Immersion
B10.5 Pressure Gauges for Water Systems
B10.6 Self Sealing Test Points
B10.7 Voltage and Current Readings
B10.8 Power Factor Monitoring
B10.9 Power Consumption Metering
B10.10 Liquid Flow Rate Metering
B10.11 Other Types of Metering Devices

B10.12 Provision of Metering Facilities

SECTION B11 THERMAL INSULATION

B11.1 General
B11.2 Types of Thermal Insulation Materials
B11.3 Pipe work Fittings
B11.4 Chilled Water Pumps and Accessories
B11.5 Ductwork and Air Handling Plant - Methods of Application
B11.6 Chilled Water Pipe work and Equipment - Materials and Finishes
B11.7 Chilled Water Pipe work and Equipment - Methods of Application
B11.8 Painting and Identification

SECTION B12 UNITARY AIR-CONDITIONER

B12.1 General
B12.2 Installation and Servicing
B12.3 Anti-Vibration Mounting
B12.4 Casing
B12.5 Compressor
B12.6 Supply Air Fan and Motor
B12.7 Cooling and Heating Coils
B12.8 Air Filter
B12.9 Air-cooled Condensers
B12.10 Electric Ductwork Heaters
B12.11 Refrigerant Piping
B12.12 Condensate Drain Pipe
B12.13 Minimum Installation Requirements of Safety and Operational Control for Unitary Air-Conditioners
B12.14 Single Packaged Air-Conditioner
B12.15 Packaged Air-Conditioner with Remote Condenser
B12.16 Split Condensing Unit and AHU
B12.17 Variable Refrigerant Volume System
B12.18 Maintenance Servicing Platform

SECTION B13 WATER HANDLING EQUIPMENT

B13.1 General Pump Installation Requirements

B13.2 Storage
B13.3 Centrifugal Water Pumps
B13.3.1 Common Installation for Boiler Feed-water, Fresh Water and Saline Water Pumps
B13.3.2 Sump Pumps
B13.3.3 Bore Well Pumps
B13.4 Plant Room Location
B13.5 Pump Foundation
B13.6 Pump Alignment
B13.7 Grouting of Pump Base
B13.8 Support for Piping
B13.9 Connection Piping to Pump
B13.9.1 Suction Piping
B13.9.2 Delivery Piping
B13.9.3 Pipe Flanges
B13.9.4 Expansion Joints
B13.9.5 Intake
B13.10 Suction Strainers
B13.11 Venting Valves for Pump-Set
B13.12 Drains for Pump-Set
B13.13 Instrumentation
B13.14 Feed and Expansion Tank
B13.15 Water Filters
B13.16 Plate Type Heat Exchanger
B13.17 Sea Water Strainer

PART C - GENERAL TECHNICAL REQUIREMENTS (MATERIAL AND EQUIPMENT SPECIFICATION)

SECTION C1 AIR CLEANING EQUIPMENT

C1.1 General
C1.2 Standards
C1.3 Washable Panel Filter
C1.4 Automatic Viscous Filter
C1.5 Disposable Panel Filter
C1.6 Disposable Pleated Panel Filter
C1.7 Renewable Panel Filter
C1.8 Automatic Fabric Roll Filter
C1.9 Bag Filter
C1.10 Cartridge Filter
C1.11 High Efficiency Particulate Arrestance (HEPA) Filter
C1.12 Automatic Recleanable Filter
C1.13 Automatic Recleaable HEPA Filter
C1.14 Automatic Recleanable High Voltage Electrostatic Filter
C1.15 Gas Filter
C1.16 Activated Oxygen Air Purifier
C1.17 Ultra-Violet (UV) Sterilising Light
C1.18 Water Scrubber
C1.19 Washing Facilities for Washable Filter
C1.20 Filter Pressure Differential Measurement and Indication
C1.21 Additional Requirements (Spare Filter Media)

SECTION C2 DUCTWORK AND ACCESSORIES

C2.1 General
C2.2 Off Site Pre-Fabrication
C2.3 Specification and Standards
C2.4 Flexible Ductwork
C2.5 Ductwork for Corrosive Fumes
C2.6 Glass Fibre Ductwork
C2.7 Foam Duct Board Ductwork
C2.8 Dampers - General
C2.9 Butterfly, Bifurcating and Multi leaf Dampers
C2.10 Self-Closing (Non-Return) Dampers

C2.11 Fire, Smoke and Combined Fire and Smoke Stop Dampers
C2.12 Motorized Shut-Off Dampers
C2.13 Terminal Dampers
C2.14 Access Doors and Panels to Ductwork, Cabinets, Cold Stores
C2.15 Ductwork Flanges
C2.16 Ductwork Cleaning Points
C2.17 Test Holes
C2.18 Transfer Ductwork

SECTION C3 AIR HANDLING AND TREATMENT EQUIPMENT

C3.1 General
C3.2 Air Handling Units (AHUs)
C3.3 Axial Flow Fans
C3.4 Ceiling Fans
C3.5 Centrifugal Fans
C3.6 Fan Coil Units
C3.7 Cassette Type Fan Coil Units
C3.8 Mixed Flow Fans
C3.9 Mechanical Roof Extract Units
C3.10 Propeller Fans
C3.11 Protectively Coated Fans and Fans for Corrosive or Hazardous Applications
C3.12 Rotary Fans (Wall or Ceiling Mounted)
C3.13 In-line Centrifugal Fans
C3.14 EC Plug Fans
C3.15 Jet Fans
C3.16 Conducting Fans
C3.17 Terminal Air Control Devices
C3.18 Grilles and Diffusers
C3.19 Energy Efficiency and Performance
C3.20 Desiccant Dehumidifiers
C3.21 Domestic Exhaust Fans
C3.22 Heat Pipe

SECTION C4 AUTOMATIC CONTROL

C4.1 Electrical Wiring
C4.2 Air Cooler Control
C4.3 Air Heater Control

C4.3.1 2-way or 3-way Modulating Valves
C4.3.2 Electric Ductwork Heaters
C4.3.3 Differential Pressure Switches
C4.4 Electrical/Electronic (Localised) Control System
C4.4.1 Standalone Direct Digital Controllers/Outstation (DDC/O)
C4.4.2 ACMV Sub-System Controllers
C4.4.3 Control Panel
C4.4.4 ACMV Sub-system DDC Controller Resident Software Features – Energy Conversation
C4.4.5 ACMV Sub-system DDC Controller Resident Software Features – Other Features
C4.4.6 DDC Sensors
C4.4.7 Electric / Electronic Damper Actuators
C4.4.8 Control Valves
C4.4.9 Automatic Dampers
C4.4.10 Digital Temperature Display

SECTION C5 CENTRAL CONTROL AND MONITORING SYSTEM (CCMS)

C5.1 CCMS Architectural Overview
C5.2 Terminology
C5.3 Relevant Standards
C5.4 Manufacturing Standards
C5.5 CCMS Inter-Networking Standard
C5.6 CCMS Configuration
C5.7 CCMS Operator Workstation
C5.8 Uninterrupted Power Supply
C5.9 Portable Operator Terminal Hardware
C5.10 DDC Controller Hardware
C5.11 Unitary Controller Hardware
C5.12 Gateway/Interfacing Hardware
C5.13 CCMS Central Database Repository
C5.14 CCMS Software - Access Control
C5.15 CCMS Software - Input Process
C5.16 CCMS Software - Information Access
C5.17 CCMS Software - Change-Of-State (COS) and Reporting
C5.18 CCMS Software - Alarm Processing and Reporting
C5.19 CCMS Software - Event Processing
C5.20 CCMS Software - Scheduling

C5.21 CCMS Software - Graphic Display
C5.22 CCMS Software - Error Messages
C5.23 CCMS Software - Operator’s Messages
C5.24 CCMS Software - Report Generator
C5.25 CCMS Software - Lockout Summary
C5.26 CCMS Software - Alarm Summary
C5.27 CCMS Software - Message and Graphic Summary
C5.28 CCMS Software - Point Involvement Summary
C5.29 CCMS Software - Signal Priority
C5.30 CCMS Software - System Log
C5.31 CCMS Software - Historical Profiles
C5.32 CCMS Software - Predictor Generator
C5.33 CCMS Software - Preventive Maintenance
C5.34 Controller Software Programming Standard
C5.35 Controller Software - Input/output Processing
C5.36 Controller Software - Digital Run-Time Totalising
C5.37 Controller Software - Analogy Totalising/Averaging
C5.38 Controller Software - Time Based Control
C5.39 Controller Software - Automatic Sequence
C5.40 Controller Software - General Polynomial Curve Fit
C5.41 ACMV Sub-System Controller Software - Energy Calculation
C5.42 ACMV Sub-System Controller Software - Duty Cycle
C5.43 ACMV Sub-System Controller Software - Power Demand Monitoring/Load Shedding
C5.44 ACMV Sub-System Controller Software - Optimum Start Time
C5.45 ACMV Sub-System Controller Software - Supply Air Reset (SAR)
C5.46 ACMV Sub-System Controller Software - Chilled Water Optimization (CHO)
C5.47 ACMV Sub-System Controllers
C5.48 ACMV Sub-System Field Device - Smart Sensors
C5.49 ACMV Sub-System Field Device - Smart Actuators
C5.50 ACMV Sub-System Field Device - Control Valves
C5.51 ACMV Sub-System Field Device - Automatic Dampers
C5.52 ACMV Sub-System Field Device - Damper Actuator
C5.53 ACMV CCMS Sub-System Field Device - VAV Box Control
C5.54 Other CCMS Sub-system
C5.55 Schedule of Function for CCMS

SECTION C6 CENTRAL REFRIGERATION MACHINE, DIRECT EXPANSION EVAPORATOR AND HEAT REJECTION PLANT

C6.1 General
C6.2 Absorption Units
C6.3 Cold Storage Refrigeration
C6.4 Compressors, Reciprocating Type
C6.5 Compressors, Centrifugal Type
C6.6 Compressors, Screw Type
C6.7 Compressors, Scroll Type
C6.8 Condensers, Shell and Tube (Fresh Cooling Water Application)
C6.9 Condensers, Shell and Tube (Sea or Brackish Cooling Water Application)
C6.10 Condensers, Shell and Tube-General Requirement
C6.11 Condensers, Air-Cooled
C6.12 Condensers, Evaporative
C6.13 Cooling Tower
C6.14 Evaporators, Shell and Tube Water Chilling
C6.15 Evaporators, Air Cooling
C6.16 Plate Type Heat Exchanger
C6.17 Liquid Receivers (Refrigerant Recovery Unit)
C6.18 Pressure Testing
C6.19 Pump Down of System
C6.20 Refrigerant Pipe work
C6.21 Refrigeration Plant Accessories and Controls
C6.22 Roof Mounted Packaged Water Chillier/Heat Pump Plants
C6.23 Heat Recovery Chillier
C6.24 Heat Pump
C6.25 Energy Efficiency Performance
C6.26 Total Energy Heat Pump
C6.27 Automatic Condenser Tube Cleaning System
C6.28 Solar Heating System

SECTION C7 ELECTRIC MOTORS AND ELECTRICAL EQUIPMENT

C7.1 Low Voltage - General
C7.2 Low Voltage - Wiring for Refrigerated Situations
C7.3 Low Voltage - Electric Equipment
C7.4 High Voltage - Electric Equipment

SECTION C8 NOISE AND VIBRATION CONTROL

C8.1 General
C8.2 Equipment Bases
C8.3 Vibration Isolators
C8.4 Plant/Equipment Vibration Isolation
C8.5 Pipe work Vibration Isolation
C8.6 Ductwork Vibration Isolation
C8.7 Ductwork Acoustic Insulation
C8.8 Acoustic Duct lag
C8.9 Ductwork Silencers
C8.10 Acoustic Doors
C8.11 Acoustic Louvers
C8.12 Acoustic Enclosures
C8.13 Plant Room Acoustic Linings

SECTION C9 PIPE MATERIAL, VALVES, COCKS AND STRAINERS

C9.1 Automatic Air Vents
C9.2 Ball Float Valves
C9.3 Butterfly Valves
C9.4 Check Valves
C9.5 Pipe work Applications
C9.6 Plug Cocks
C9.7 Pressure Reducing Valves
C9.8 Strainers
C9.9 Specialised Control Valves
C9.10 Valve Applications
C9.11 Valves and Cocks

SECTION C10 SYSTEM MONITORING INSTRUMENT

C10.1 General
C10.2 System Static Pressure Gauges for Air Distribution Systems
C10.3 Thermometers - Air Immersion
C10.4 Thermometers - Liquid Immersion
C10.5 Pressure Gauges for Water Systems
C10.6 Pitot Static Tube
C10.7 Orifice Plate Metering

C10.8 Electromagnetic and Ultrasonic Flowmeters
C10.9 Energy Meters

SECTION C11 THERMAL INSULATION

C11.1 General
C11.2 Types of Thermal Insulation Materials
C11.3 Measures to Prevent Smoke, Noxious & Toxic Fumes Propagation in Event of Fire
C11.4 Vapour Barriers
C11.5 Insulation Thicknesses

SECTION C12 UNITARY AIR-CONDITIONER

C12.1 General
C12.2 Equipment Suitable for Local Electricity Supply
C12.3 Selection of Air-cooled Condensers and Condensing Units
C12.4 Casing of Condensing Unit
C12.5 Compressor
C12.6 Supply Air Fan and Motor
C12.7 Cooling and Heating Coils
C12.8 Air Filter
C12.9 Air-cooled Condensers
C12.10 Electric Ductwork Heater
C12.11 Refrigerant Piping
C12.12 Condensate Drain Pipe
C12.13 Safety Control
C12.14 Operational Control
C12.15 Single Packaged Air-Conditioner
C12.16 Packaged Air-Conditioner with Remote Condenser
C12.17 Split Condensing Unit and AHU
C12.18 Variable Refrigerant Volume System
C12.19 Energy Efficiency Performance

SECTION C13 WATER HANDLING EQUIPMENT

C13.1 Fresh Water Pumps
C13.1.1 Type
C13.1.2 Materials of Construction
C13.1.3 Standards

C13.2 Saline Water Pumps
C13.2.1 Type
C13.2.2 Materials of Construction
C13.2.3 Standards
C13.3 Boiler Feed Pump
C13.4 Sump Pump
C13.4.1 Materials of Construction of Dry Pit Pumps
C13.4.2 Materials of Construction of Submersible Pumps
C13.4.3 General Requirements
C13.5 Bore Well Pumps
C13.6 Pump Base Plate
C13.7 Valves
C13.8 Vibration Isolators
C13.9 Gauges
C13.10 Drain and Vent
C13.11 Flanged Connections
C13.12 Water Filters
C13.13 Sea Water Strainers and Travelling Band Screens
C13.14 Feed and Expansion Facility
C13.15.1 General
C13.15.2 Types of Cistern and Tank
C13.15 Plate Type Heat Exchangers

PART D - INDOOR AIR QUALITY (IAQ)

D1 General
D2 Outdoor Air Quality
D3 Design Parameters of Indoor Air Quality
D4 Installation - Part B: Treatment and Conditioning Process
D5 Equipment/Materials - Part C: Treatment and Conditioning Media
D6 Conformities of IAQ Design Objective and Compliance
D7 IAQ Assessment and Methodologies
D8 Operation and Maintenance
D9 Housekeeping and Energy Efficiency Relating to IAQ Issue
D10 Training and Licensing Requirements
D11 Certification and Registration

PART E - ENERGY EFFICIENCY AND ENERGY CONSERVATION

E1 General
E2 Minimum Coefficient of Performance (COP) of Major Air Conditioning and Ventilation Equipment
E3 Minimum Efficiency of Fans, Pumps and Motors
E4 Thermal Insulation
E5 Sensing Device
E6 Motion Detecting Sensing Device
E7 Devices for Enthalpy Control of Free Air Cooling
E8 Automatic Condenser Tube Cleaning System
E9 Heat Pipe Installation
E10 Solar Heating Installation
E11 Dehumidifier
E12 Outdoor Air Pre-Conditioner

PART F - ACMV SYSTEM WATER TREATMENT

F1 General
F2 Form of Water Treatment
F3 Sea Water Treatment by Electrochlorinator
F4 Sea Water Treatment by Biocides
F5 Cooling Tower/Condenser Cooling Water Treatment by Chemical Agents
F6 Cooling Tower/Condenser Cooling Water Treatment by Ozone
F7 Close Circuit Chilled Water or Low Pressure Hot Water Heating Systems Treatment by Chemical Agents
F8 Water Testing Equipment
F9 Training, Operation and Maintenance Facilities
F10 Pre-treatment for Dumping of Chemical Wastes

PART G - PAINTING, FINISHING AND PROTECTIVE TREATMENT

G1 General
G2 Number of Paint Coats Required
G3 Identification of Pipelines
G4 Schedule of Colours
G5 Machinery and Pipework
G6 Copper Pipe and Fitting
G7 Pipes and Ductwork
G8 Protection of Plant, Equipment, Pipework, etc.
G9 Protective Measures against Corrosion

PART H - INSPECTION, TESTING AND COMMISSIONING DURING CONSTRUCTION PERIOD

SECTION H1 GENERAL REQUIREMENTS

H1.1 General
H1.2 Methods and Procedures
H1.3 Notices of Inspection, Testing and Commissioning Works
H1.4 Labour and Materials
H1.5 Inspection, Measuring and Testing Equipment
H1.6 Readiness for Inspection, Testing and Commissioning
H1.7 “Type-test” Certificate
H1.8 Off-site Tests / Factory Tests
H1.9 Site Tests

SECTION H2 INSPECTION

H2.1 Inspection of Materials and Equipment Delivered to Site
H2.2 Visual Inspection and Checking
H2.3 Handover Inspection

SECTION H3 TESTING AND COMMISSIONING

H3.1 General
H3.2 Procedures, Standards and Requirements
H3.3 Master Programme for Testing and Commissioning Works

H3.4 Documentation and Deliverables
H3.5 Testing and Commissioning Engineer / Specialist

PART I – TRAINING, INSPECTION, ATTENDANCE, OPERATION AND MAINTENANCE DURING MAINTENANCE PERIOD

SECTION I1 GENERAL REQUIREMENT

I1.1 General
I1.2 Completion of Outstanding and Defective Works
I1.3 Repair and Maintenance Records

SECTION I2 TRAINING TO USERS AND OPERATION AND MAINTENANCE AGENTS

I2.1 General
I2.2 Other Training Requirements

SECTION I3 INSPECTION, ATTENDANCE, OPERATION AND MAINTENANCE REQUIREMENTS

I3.1 Response and Attendance to Emergency and Fault Calls
I3.2 Maintenance Schedule
I3.3 Inspection during Maintenance Period
I3.4 Joint Inspection at the End of Maintenance Period
I3.5 Level One Services – Mandatory Responsibilities during Maintenance Period
I3.6 Level Two Services – Specified Contractor's Maintenance Responsibilities during Maintenance Period
I3.7 Spare Parts and Special Tools

ANNEX I LIST OF TECHNICAL STANDARDS QUOTED IN THIS GENERAL SPECIFICATION

PART A - SCOPE AND GENERAL REQUIREMENTS

SECTION A1

SCOPE OF SPECIFICATION

A1.1 INSTALLATIONS TO COMPLY WITH THIS GENERAL SPECIFICATION

The Air-conditioning, Refrigeration, Ventilation and Central Monitoring and Control System Installation shall comply with this General Specification which details the intrinsic properties (including materials and workmanship) of the Installation sin so far as it is not overridden by the Conditions, Particular Specification, Drawings and/or written instructions of the Supervising Officer.

A1.2 SCOPE OF THE INSTALLATIONS

This General Specification, Particular Specification, Tender Equipment Schedule and Drawings detail the performance requirements of the Installations. The Installations to be carried out in accordance with this General Specification shall include the installation and supply of all materials necessary to form a complete installation including any necessary tests, adjustments, commissioning and maintenance as prescribed and all other incidental sundry components together with the necessary labour for installing such components, for the proper operation of the Installations.

A1.3 TERMS AND DEFINITIONS

In this General Specification, all words and expressions shall have the meaning as assigned to them under the Conditions unless otherwise herein. The following words or expressions shall have the meanings assigned to them except when the context otherwise requires: -

A/C	Air-conditioning
ACB	Air Circuit Breaker

A/C Contractor	The Nominated Sub-contractor or the Specialist Sub-contractor employed by the Building Contractor or the contractor directly employed by the Employer as appropriate for the execution of the Installations in accordance with the Contract
ACMV	Air-conditioning and Mechanical Ventilation
ACRA	The Hong Kong Air-Conditioning & Refrigeration Association Ltd.
ACS	Automatic Control System
AHU	Air Handling Unit
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
ArchSD	Architectural Services Department, the Government of the Hong Kong Special Administrative Region
ARI	Air-Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc.
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BAC	Building Automation and Control
B&ES	Building and Engineering Services Association
BS	British Standards, including British Standard Specifications and British Standard Codes of Practice, published by the British Standards Institution
BSB	The Building Services Branch of the ArchSD, the Government of the Hong Kong Special Administrative Region
BS EN	European Standard adopted as British Standard
Building Contractor	The Contractor employed by the Employer for the execution of the Works or the Specialist Contractor separately employed by the Employer to execute Specialist Works as appropriate

CAV	Constant Air Volume
CCMS	Central Control and Monitoring System
CFC	Chlorofluorocarbon
CFR	Code of Federal Regulation (Department of Transportation, USA)
CHO	Chilled Water Optimisation
CHW	Chilled Water
CIBSE	The Chartered Institution of Building Services Engineers
Conditions	The "Conditions of Contract" as defined in the Contract. For Nominated Sub-contract works, the "Main Contract Conditions" and the "Sub-contract Conditions" as defined in the Nominated Sub-contract as appropriate.
COS	Change-of-state
DCE	Data Circuit-terminating Equipment
DDC	Direct Digital Controllers
DDC/O	Direct Digital Controllers/Outstations
DIDW	Double Inlet Double Width
DIN	German Industry Standard
DOL	Direct-On-Line Starters
DOP	Di-Octal Phthalate
DTE	Data Terminal Equipment
EIA	Electronics Industries Association
EJMA	Expansion Joint Manufacturers Association
Electrical General Specification	The General Specification for Electrical Installation in Government Buildings of the Hong Kong Special Administrative Region issued by the ArchSD
E&M	Electrical & Mechanical

EMC	Electro-magnetic Compatibility
EMSD	Electrical and Mechanical Services Department, the Government of the Hong Kong Special Administrative Region
EPD	Environmental Protection Department, the Government of the Hong Kong Special Administrative Region
EPDM	Ethylene-propylene-diene elastomer
ETD	Embedded Temperature Detectors
FCC	Federal Communications Commission
FCU	Fan Coil Unit
FDA	Food and Drug Administration, USA
FRC	Fire Resistance Construction
FRP	Fibreglass Reinforced Polyester
FSD	Fire Services Department, the Government of the Hong Kong Special Administrative Region
G.I.	Galvanised Iron
GRP	Glass Reinforced Plastics
HBC	High Breaking Capacity
HCFC	Hydrochlorofluorocarbon
HCS	Hydrous Calcium Silicate
HEPA	High Efficiency Particulate Arrestance
HFC	Hydrofluorocarbon
HKIE	The Hong Kong Institution of Engineers
H.V.	High Voltage
IAQ	Indoor Air Quality
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers

IET	The Institution of Engineering and Technology
IGBTS	Insulated Gated Bipolar Transistors
IIAR	International Institute of Ammonia Refrigeration
IMO	International Maritime Organisation
Installations	The work or services for the Air-conditioning, Refrigeration, Ventilation and Central Monitoring and Control System Installation forming parts of the Works to be installed, constructed, completed, maintained and/or supplied in accordance with the Contract and includes Temporary Works
I/O	Input / Output
IP	Index of Protection
ISO	International Organisation for Standardization
ISO SQL	International Organisation for Standardization, Database Language SQL
KEMA	N.V. tot Keurig van Elekrotechnische Materialmen in Arnhem, the Netherlands
LAN	Local Area Network
LCD	Liquid Crystal Display
LED	Light Emitting Diode
Lon talk	Echelon Corporation Lon talk® Protocol
LPHW	Low Pressure Hot Water
LSOH	Low Smoke Zero Halogen
L.V.	Low Voltage
MCC	Motor Control Centre
MCR	Maximum Continuous Rating
MICS	Mineral Insulated Copper Sheathed
NAIMA	North American Insulation Manufacturers Association

NaOCl	Sodium Hypochlorite
NaOH	Sodium hydroxide
NC	Noise Criteria
NEMA	National Electrical Manufacturers Association
NES	Naval Engineering Specification
NFPA	National Fire Protection Association
NPSH	Net Positive Suction Head
OD	Outside Diameter
ODBC	Open Database Connectivity
O&M	Operation and Maintenance
or equivalent standards	Means internationally recognised standards acceptable to the Supervising Officer having similar requirements and specification as regards to the type of construction, functions, performance, general appearance and standard of quality of manufacture and approved by the Supervising Officer
ORP	Oxidation–reduction Potential
OSHA	Occupational Safety and Health Administration, USA
Particular Specification	The specifications drawn up specifically for the Installations of a particular project
PAU	Primary Air Handling Unit
PCP	Polychloroprene
PFAC	Pulverised Fuel Ash Cement
PID	Proportional Integral Derivative
PLC	Programmable Logic Controller
PN	Practice Note
POT	Portable Operator Terminal

Proprietary brand name products or materials	The phrase “or alternative products or material shaving equivalent functions or performance” is deemed to be included wherever products or materials are specified by proprietary brand names in the Contract. Alternative products or materials of different brands or manufacture having equivalent functions or performance may be submitted for the consideration of the Supervising Officer.
PSTN	Public Switched Telephone Network
PTFE	Polytetrafluoroethylene
PTTA	Partially Type-Tested Assemblies
PVC	Polyvinyl Chloride
PWM	Pulse Width Modulation
RAD	Rapid Application Development
RAM	Random Access Memory
RH	Relative Humidity
r.m.s.	Root Mean Square
RTC	Real Time Clock
RTD	Resistance Temperature Detector
SCR	Silicon Controlled Rectifier
SF6	Sulphur Hexafluoride
SMACNA	Sheet Metal and Air-conditioning Contractors’ National Association, USA
SRC	Sulphate Resisting Cement
Supervising Officer	The Supervising Officer or the Maintenance Surveyor defined in the Contract as appropriate
TBC	Total Bacteria Count
TEFC	Totally Enclosed Fan Cooled

Tender	The Contractor's tender for the Contract or the Nominated Sub-contractor's tender for the Nominated Sub-contract as appropriate
TIA	Telecommunication Industry Association
TL	Transmission Loss
UL	Underwriters Laboratories
UPS	Uninterrupted Power Supply
UPVC	Unplasticised Polyvinyl Chloride
UV	Ultra-violet
VAV	Variable Air Volume
VDE	Verband Deutscher Elektrotechniker
V/F	Voltage/Frequency
VOC	Volatile Organic Compound
VRV	Variable Refrigerant Flow
VSD	Variable Speed Drive
WSD	Water Supplies Department, the Government of the Hong Kong Special Administrative Region
XLPE	Cross-Linked Polyethylene
XLPE/SWA/PVC	Cross-linked polyethylene insulated, PVC-sheathed, galvanised steel wire armoured and PVC covered

A1.4 SINGULAR AND PLURAL

Words importing the singular only also include the plural and vice versa where the context requires.

SECTION A2

STATUTORY OBLIGATIONS AND OTHER REGULATIONS

A2.1 STATUTORY OBLIGATIONS AND OTHER REQUIREMENTS

The Installations shall conform in all respects with the followings: -

A2.1.1 Statutory Obligations

All Enactments and Regulations, in particular, the A/C Contractor's attention is drawn to the followings:

(a) Building (Ventilating Systems) Regulations under Buildings Ordinance (Cap. 123);

(b) Electricity Ordinance (Cap. 406), and other subsidiary legislation made under the Ordinance;

(c) Fire Service (Installations and Equipment) Regulations, Fire Services Ordinance (Cap. 95), and other subsidiary legislation made under the Ordinance;

(d) Noise Control Ordinance (Cap. 400), and other subsidiary legislation made under the Ordinance;

(e) Water Pollution Control Ordinance (Cap. 358), and other subsidiary legislation made under the Ordinance;

(f) Air Pollution Control Ordinance (Cap. 311), and other subsidiary legislation made under the Ordinance;

(g) Ozone Layer Protection Ordinance (Cap. 403), and other subsidiary legislation made under the Ordinance;

(h) Waste Disposal Ordinance (Cap. 354), and other subsidiary legislation made under the Ordinance;

(i) Environmental Impact Assessment Ordinance (Cap. 499), and other subsidiary legislation made under the Ordinance;

(j) Waterworks Ordinance (Cap. 102), and other subsidiary legislation made under the Ordinance;

(k) Dangerous Goods Ordinance (Cap. 295), and other subsidiary legislation made under the Ordinance;

(l) Places of Public Entertainment Ordinance (Cap. 172), and other subsidiary legislation made under the Ordinance; and

(m) Buildings Energy Efficiency Ordinance (Cap. 610), and other subsidiary legislation made under the Ordinance.

(n) Energy Efficiency (Labelling of Products) Ordinance (Cap. 598)

(o) Fire Safety (Buildings) Ordinance (Cap. 572)

A2.1.2 Other Requirements

(a) Fresh Water Cooling Towers Scheme (FWCT Scheme) published by the EMSD;

(b) Code of Practice for Fresh Water Cooling Towers published by the EMSD;

(c) Code of Practice for the Electricity (Wiring) Regulations published by the EMSD;

(d) Codes of Practice for Minimum Fire Service Installations and Equipment and Inspection, Testing and Maintenance of Installations and Equipment published by the FSD;

(e) Requirements and Circular Letters issued by the FSD;

(f) Code of Practice for Energy Efficiency of Building Services Installation issued by the EMSD, hereinafter referred as the "Building Energy Code" or "BEC";

(g) General Specification for Electrical Installation in Government Buildings of the Hong Kong Special Administrative Region, issued by the ArchSD;

(h) General Specification for Fire Service Installation in Government Buildings of the Hong Kong Special Administrative Region, issued by the ArchSD;

(i) Design Manual: Barrier Free Access 2008 published by the Buildings Department, the Government of the HKSAR;

(j) Code of Practice for Prevention of Legionnaires' Disease issued by Prevention of Legionnaires' Disease Committee, the Government of the HKSAR;

(k) Codes of Practice issued by the following international institutions: -

- American National Standard Institute
- Air-conditioning and Refrigeration Institute
- American Society of Mechanical Engineers
- American Society for Testing and Materials
- Committee for European Normalisation

- The Institute of Electrical and Electronic Engineers
- International Organisation for Standardization
- Japanese International Standard
- National Fire Protection Association;

(l) The Supply Rules and other requirements issued by the relevant local electricity supplier and water authority;

(m) Technical Memorandum to issue Air Pollution Abatement Notice to control Air Pollution from Stationary Processes, issued by EPD;

(n) Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites, issued by EPD;

(o) Code of Practice on the Handling, Transportation and Disposal of Asbestos Waste, issued by EPD;

(p) Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes, issued by EPD;

(q) Technical Memorandum - Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters, issued by EPD;

(r) Technical Memorandum on Environmental Impact Assessment Process, issued by EPD; and

(s) Testing and Commissioning Procedure for Air-conditioning, Refrigeration, Ventilation and Central Monitoring & Control System Installation in Government Buildings of the Hong Kong Special Administrative Region, issued by ArchSD.

A2.1.3 Safety Requirements

(a) Occupational Safety and Health Ordinance (Cap. 509), and other subsidiary legislation made under the Ordinance;

(b) Factories and Industrial Undertakings Ordinance (Cap. 59), and other subsidiary legislation made under the Ordinance;

(c) Public Health and Municipal Service Ordinance (Cap. 132), and other subsidiary legislation made under the Ordinance;

(d) Construction Sites (Safety) Regulations, Factories and Industrial Undertakings Ordinance (Cap. 59); and

(e) Construction Site Safety Manual issued by the Development Bureau, the Government of the HKSAR.

A2.1.4 Technical Standards

BS, BS EN, ISO Standards, IEC Standards and Codes of Practice, etc. shall be deemed to include all amendments, revisions and standards superseding the standards listed herein, which are published before the date of first tender invitation for the Contractor the Nominated Sub-contract (as appropriate) unless otherwise specified.

A summary of technical standards quoted in this General Specification to which the Installations shall comply is listed in Annex I.

A2.2 CASE OF CONFLICT

The documents forming the Contract are to be taken as mutually explanatory of one another but in case of ambiguities or discrepancies the same shall be dealt with in accordance with the Conditions.

A2.3 MECHANICAL FIRE SERVICE INSTALLATION

Mechanical fire service installation shall include ventilation/air conditioning control system, pressurisation of staircases system and smoke extraction system.

The A/C Contractor shall be in the List of Approved Suppliers of Materials and Specialist Contractors for Public Works in the Category of Air-conditioning Installation to carry out works for the mechanical ventilation system, smoke extraction system and pressurisation of staircases system in the buildings and shall also be a Registered Fire Service Installation Contractor of relevant Class registered with the FSD.

The A/C Contractor shall employ a Registered Professional Engineer in Hong Kong under the Engineers Registration Ordinance (Cap. 409) in Fire, Building Services, Mechanical or Electrical discipline (or equivalent approved professional qualification) with proof of experience of at least 3 years in relevant design works, who emphasises on and is specialised in mechanical ventilation and air handling installation to the approval of the Supervising Officer to carry out the design and supervision of the submission, installation and testing of the pressurisation of staircases system and smoke extraction system. The professional status and qualifications of the Registered Professional Engineer shall also be acceptable by FSD and the Supervising Officer.

Details of the above systems can be referred to relevant section of General Specification for Fire Service Installation in Government Buildings of HKSAR.

SECTION A3

EXECUTION OF INSTALLATIONS

A3.1 THE INTERNATIONAL SYSTEM OF UNITS (SI)

The International System of Units of weights and measures shall be used for all materials, equipment and measurements.

A3.2 PROGRAMME OF INSTALLATIONS

The A/C Contractor shall submit to the Supervising Officer a detailed programme of the Installations within 4 weeks from the acceptance of his Tender showing the intended method, stages and order of work execution in coordination with the building construction programme, together with the duration he estimated for each and every stage of the Installations. The programme shall include at least the following: -

(a) Dates for the placement of orders for equipment and materials;

(b) Expected completion dates for builder's work requirements, i.e. when work site needs to be ready;

(c) Delivery dates of equipment and materials to the Site;

(d) Dates of commencement and completion of every stage of the Installations in line with the building construction programme, i.e. each floor level and/or zone area;

(e) Dates of documents/drawings submissions to relevant Government departments to obtain the necessary approvals;

(f) Dates of requirement of temporary facilities necessary for testing & commissioning, e.g. electricity supply, water and town gas;

(g) Dates of completion, testing and commissioning; and

(h) Short term programmes showing the detailed work schedules of coming weeks and months shall also be provided to the Supervising Officer. Programmes shall be regularly updated to reflect the actual progress and to meet the A/C Contractors' obligations under the Contract.

In addition, detailed submission schedules for installation drawings, equipment and testing and commissioning shall be submitted to the Supervising Officer for approval. The formats and information to be included in the schedules shall be as directed by the Supervising Officer.

A3.3 BUILDER'S WORK

All builder's work including openings or holes through building structure or partition walls; trenches, ducts and cutting; and all plinths, concrete bases, supports, ducts, etc. required for the Installations will be carried out as part of the building works by the Building Contractor at the expense of the Employer provided that the A/C Contractor has submitted full details of such requirements within a reasonable time to the Supervising Officer for approval, so that due consideration may be given before the Building Contractor commences the building works in accordance with the building programme in the areas concerned. After obtaining the said approval of the Supervising Officer, the A/C Contractor is required to mark out at the relevant locations of the Site the exact positions and sizes of all such works and to provide detailed information of such works to the Building Contractor to facilitate him to carry out the builder's works as the Works proceed.

All "cutting-away" and "making-good" as required to facilitate the A/C Contractor's works will be carried out by the Building Contractor, except for minor provisions required for the fixing of screws, raw plugs, redhead bolts, etc. which shall be carried out by the A/C Contractor. The A/C Contractor shall mark out on Site and/or supply drawings of all "cutting-away" to the Building Contractor within a reasonable time.

All expenses properly incurred and losses suffered by the Employer as a result of the A/C Contractor's failure to comply with the above requirements are recoverable by the Employer from the A/C Contractor as a debt under the Contract or via the Building Contractor as if it is a debt liable to the Building Contractor under the Sub-contract as appropriate.

The A/C Contractor shall ensure that such works are essential for the execution of the Installations. In the event that any of such works is proved to be non-essential, unnecessary and/or abortive, the A/C Contractor shall bear the full cost of such works including but not limited to any unnecessary or incorrect cutting-away and making-good and shall reimburse the Employer for all cost incurred in this connection are recoverable by the Employer from the A/C Contractor as a debt under the Contract or via the Building Contractor as if it is a debt liable to the Building Contractor under the Sub-contract as appropriate.

Upon completion of the builder's works by the Building Contractor, the A/C Contractor shall forthwith check and examine that all builder's works so executed have been completed in accordance with his requirements. If at any time, it becomes apparent to the A/C Contractor that any builder's works completed by the Building Contractor does not comply with his requirements in any respect whatsoever, the A/C Contractor shall forthwith give notice in writing to the Supervising Officer and specify in details the extents and effects of such non-compliance in that notice. The A/C Contractor is deemed to have satisfied with the builder's works after a period of 14 days from the date of completion of the builder's works if the above notice is not served to the Supervising Officer within such period. All additional expenditure properly incurred and all loss suffered in this connection by the Employer in having such works re-executed and rectified shall be recoverable by the Employer from the A/C Contractor as a debt under the Contract or via the Building Contractor as if it is a debt liable to the Building Contractor under the Sub-contract as appropriate.

A3.4 COORDINATION OF INSTALLATIONS

The A/C Contractor shall coordinate the Installations with those works of the Building Contractor and any other contractors and sub-contractors of the Building Contractor.

The A/C Contractor shall note that the Drawings supplied to him only indicate the approximate locations of the Installations. He shall make any modification reasonably required of his programme, work sequence and physical deployment of his work to suit the outcome of work coordination or as necessary and ensure that all cleaning, adjustment, test and control points are readily accessible while keeping the number of loops, cross-overs and the like to a minimum.

The A/C Contractor shall pay particular attention to the building works programme and shall plan, coordinate and programme his works to suit and adhere to the building works in accordance with the building programme.

Any significant problems encountered during the coordination work, which are beyond the A/C Contractor's control, shall promptly be reported to the Supervising Officer.

A3.5 COOPERATION WITH OTHER CONTRACTORS

The A/C Contractor shall cooperate at all times with the Building Contractor and all other contractors and sub-contractors of the Building Contractor in order to achieve efficient workflow on the Site and keep the Site in a clean and tidy condition.

Any significant problems beyond the A/C Contractor's control shall promptly be reported to the Supervising Officer.

A3.6 SITE SUPERVISION

The A/C Contractor shall keep on the Site a competent and technically qualified site supervisor to control, supervise and manage all his Installations on Site. The site supervisor shall be vested with suitable powers to receive instructions from the Supervising Officer and his Representative.

The site supervisor shall be technically competent and have adequate site experience for the Installations. The qualified and competent site supervisor shall have minimum 5 years on site experience for similar type of installation works. The A/C Contractor shall also refer to the Particular Specification for other specific requirements, if any, on site supervision.

Approval by the Supervising Officer shall be obtained prior to the posting of the site supervisor on Site. The A/C Contractor shall immediately replace the site supervisor whose experience, skill or competency is, in the opinion of the Supervising Officer, found to be inadequate for the particular work.

All tradesmen must be experienced in the trade and the work carried out shall be consistent with good practice in Hong Kong and to the satisfaction of the Supervising Officer. In this connection, the A/C Contractor's attention is drawn to the Special Conditions of Contract under the Contract for the requirements relating to Qualified Tradesmen/Qualified Skilled Workers and Intermediate Tradesmen/Qualified Semi-Skilled Workers.

The A/C Contractor shall also employ a full time competent foreman on Site for each trade. All trade foremen shall be registered tradesmen/skilled workers of the relevant trade.

A3.7 SAMPLE BOARD

Within 6 weeks of the acceptance of his Tender and prior to the commencement of the Installations, the A/C Contractor shall submit to the Supervising Officer for approval a sample board of essential components proposed to be used in the Contract. However, the A/C Contractor may request the Supervising Officer in writing for a longer period for the submission, if 6 weeks are practically insufficient.

Items displayed shall be deemed to be adequate for the Installations unless otherwise clearly indicated. Each sample, with clear numbering and labelling, shall be firmly fixed onto a rigid wooden or metal board. A list shall also be affixed on the sample board to show the item description, make and brand, country of origin and locations of installation (if not generally used). Samples rejected by the Supervising Officer shall be replaced as soon as possible. Upon approval of all items, the Supervising Officer will endorse the list on the sample board and the A/C Contractor shall deliver the board to the site office of the Supervising Officer's Representative for reference.

The board shall contain samples of all "compact" sized materials and accessories to be used in the Installations. Written approval of all samples and technical details shall be obtained from the Supervising Officer before commencement of any installation work.

In the context of this General Specification the term "compact" means any item that will fit into a 300 mm cube.

The following items shall be included in the sample board as a minimum.

(a) Conduit and accessories;

(b) Trunking and accessories;

(c) Cable and accessories;

(d) Ductwork and accessories;

(e) Fire damper;

(f) Refrigerant pipework;

(g) Vibration isolator;

(h) Acoustic and thermal insulation;

(i) Valves; and

(j) Automatic air vent.

Additional items may be required by the Supervising Officer and/or specified in the Particular Specification.

A3.8 ADVICE OF ORDER PLACED

The A/C Contractor shall submit copies of all orders placed for major items of equipment and materials to the Supervising Officer for record.

A3.9 RECORD OF MATERIALS DELIVERY

All materials and equipment delivered to Site shall be accurately listed and recorded in the site record books maintained by the Supervising Officer's Representative on Site. Such materials and equipment shall not be removed from Site without the prior approval of the Supervising Officer in writing.

Where the Building Contractor is in overall control of the Site, the Building Contractor may also be required to record details of all incoming/outgoing materials and equipment. In this case, the A/C Contractor shall comply with the Building Contractor's arrangements.

The A/C Contractor shall print the major technical details on equipment/materials or supporting documents (e.g. delivery note), or else submit a written declaration to confirm compliance of the equipment/materials with the approved technical details so as to facilitate checking of equipment/materials delivered on site.

A3.10 PROTECTION OF MATERIALS AND EQUIPMENT

Unless the responsibility is clearly defined in the Contract that the protection on Site for delivered equipment, materials and installations is solely by other contractors, the A/C Contractor shall be responsible for the safe custody of all materials and equipment as stored or installed by him. In addition, the A/C Contractor shall protect all work against theft, fire, damage or inclement weather and carefully store all materials and equipment received on Site but not yet installed in a safe and secure place unless otherwise specified.

All cases of theft and fire must immediately be reported to the police, the Building Contractor, the Supervising Officer and the Supervising Officer's Representatives on Site with full details.

Where necessary the A/C Contractor shall provide lockable steel container or other equally secure enclosures placed within a securely fenced-in compound provided by the Building Contractor on Site for the storage of materials and equipment.

The A/C Contractor shall co-ordinate and arrange with the Building Contractor who shall provide clean, reasonably finished and lockable secure accommodation for the storage of sensitive and/or expensive items before installation.

If there is no Building Contractor, all the storage facilities and spaces shall be provided by the A/C Contractor.

A3.11 LABEL

A3.11.1 Labels and Related Instruction

In order to make cross reference to the Operation/Maintenance/Service Manuals and Schematic Drawings, etc., the A/C Contractor shall provide labels for marking all valves, pipework, filtration tanks, fuses, terminals, lamps, switches, handles, keys, instruments, gauges, control and other equipment, etc. and elsewhere to facilitate maintenance or as directed by the Supervising Officer with engraved multi-layer formica or similar material. Wording shall be submitted to the Supervising Officer for approval before manufacture.

Instructions for oiling and/or greasing of all motors, etc. shall be attached to the relevant greasing or oiling points.

All labels shall be of adequate size as to give clearance between lettering and fixings to ensure an aesthetic arrangement on completion. Pipeline labels shall generally be not smaller than 100 mm x 20 mm. Where applicable, labels shall be fixed utilising non-ferrous round head bolts and nuts or woodscrews. Adhesives or self-tapping screws are not acceptable.

For pipelines or valves, where applicable, labels shall be fixed by means of a key ring attached to the upper corner of the pipe mounting bracket or the hand wheel of valves. The labels shall be suspended from brass or stainless steel chain loops over the relevant pipe.

The A/C Contractor shall submit a schedule for all labels, notices, identifications and instructions for the Supervising Officer’s approval prior to order and installation. The information of the schedule shall include the description of the items, height and font type of the text, dimensions of the labels and material used.

All English lettering used on labels shall be "Bold" capitals (except otherwise directed) with black letters on white labels for normal purposes. Where special colours or details are required these shall be as specified or directed.

All labels and instructions shall be in English complete with translation in Chinese characters. The Chinese translations shall be referred to the “Glossaries of Terms Commonly Used in Government Departments” issued by Civil Service Bureau of the Government of the HKSAR. Sample of label and notice shall be submitted to the Supervising Officer for agreement. Heights for the English lettering shall be as follows with that for Chinese characters to match: -

(a) Pipelines, valves, motor valves, fans, doors, etc.8 mm;

(b) Greasing instructions for motors, fan bearings, etc.6 mm;

(c) Thermostats, sensors, thermometers, pressure gauges, general instructions, etc. 3 mm

For electrical panels or other items, lettering shall be: -

- Black on white for normal purposes;
- Red letters on white where connected to essential supply; and
- Green letters on white where operated by direct current.

For electrical components, the letter heights shall be as follows: -

(a) Identifying equipment in cabinets3 mm;

(b) Door cabinets8 mm;

(c) Switches & indicators on panel faces3 mm

Where proprietary type, rail mounted terminals are utilised in electrical cabinets, the manufacturer’s "clip-in" identification tabs shall be used.

A3.11.2 Coded Labels

Where appropriate, items such as valves, sensing points, etc. may also be identified by "Codes" on the labels which shall relate to the items as detailed on plant room mounted diagrammatic drawings or the mimic diagrams on operational control panels. At the diagram or control panels, the function of each coded item shall also be detailed. Such systems of labelling and related diagrams shall be approved by the Supervising Officer before implementation.

Valves etc. required for emergency shutdown purposes must under all circumstances be fully detailed at the valve.

A3.12 WARNING NOTICE

Warning notices shall be provided as required by the Electricity Ordinance (Cap. 406) and the Code of Practice for the Electricity (Wiring) Regulations (Cap. 406E). In addition, the following warning notices in English and Chinese shall be provided at the appropriate positions: -

(a) A label having minimum size of 65 x 50 mm marked with the words 'DANGER - HIGH VOLTAGE' in red lettering not less than 5 mm high to be fixed on every container or enclosure of equipment for operating at voltages exceeding "Low voltage"; and

(b) A label to be fixed in such a position that any person may gain access to any moving parts of an item of equipment or enclosure will notice or be warned of such a danger.

A3.13 GUARD AND RAILING FOR MOVING AND ROTATING PARTS OF EQUIPMENT

Everything moving or rotating parts of equipment shall be provided with an approved guard and railing complying with the Factories & Industrial Undertakings (Guarding and Operation of Machinery) Regulations, (Cap. 59Q), together with any amendments made thereto.

Guards shall be rigid and of substantial construction and shall consist of heavy mild steel angle frames, hinged and latched with either heavy galvanised mild steel wire crimped mesh securely fastened to frames or galvanised sheet metal of 1.2 mm minimum thickness. All apertures shall be such that finger access to dangerous part is not possible. All sections shall be bolted or riveted. Railings shall be made of 32 mm dia. galvanised mild steel pipe and railing fittings.

(a) Temporary Guards

During the execution of work, the A/C Contractor shall ensure that all moving parts are adequately guarded by temporary guards.

Adequate temporary guard railings etc. around dangerous floor/wall openings in the vicinity of any work for the protection shall be provided.

For the safety of workers, guard railings etc. are to be provided by the Building Contractor, but in case they are not provided, the A/C Contractor shall immediately report the matter to the Supervising Officer.

(b) Permanent Guards on Plant

Unless specified otherwise in the Particular Specification, the A/C Contractor shall provide removable guards or railing for protection from moving or rotating parts. The design and construction of safety guards for moving parts such as belt drives shall conform to the requirements laid down in the Factories & Industrial Undertakings (Guarding and Operation of Machinery) Regulations.

A3.14 SERVICE CONDITION

The following service conditions shall apply to material and equipment

(a) Climate : Hong Kong (tropical);

(b) Ambient temperature : Peak –5^{o}C to +40 ^{o}C (continuously 4 hours)
Average 0 ^{o}C to +35 ^{o}C (over 24 hours);

(c) Altitude : up to 2000 m above sea level; and

(d) Relative humidity : 99% maximum.

A3.15 VOLTAGE COVERED BY THIS GENERAL SPECIFICATION

Unless otherwise specified, all apparatus, equipment, materials and wiring shall be suitable for use with a 3-phase and neutral, 4-wire, 380/220V±6%, 50 Hz ±2%.

A3.16 MATERIAL AND EQUIPMENT

A3.16.1 Materials and Equipment Standards

All materials, equipment and installations work shall be carried out by adoption of the best available quality materials and workmanship and shall, where applicable, comply with the latest edition of the appropriate standards and/or codes of practice issued by the relevant international Institutes and Standards and as specified in this General Specification which are published before the date of first tender invitation for the Contract or the Nominated Sub-contract as appropriate. This requirement shall be deemed to include all amendments to these standards and codes up to the date of tendering.

The standards shown in brackets for the materials and equipment in this General Specification are also considered as acceptable standards for the respective materials and equipment.

When material or equipment complying with other standards that are not specified in this General Specification, the A/C Contractor shall satisfy the Supervising Officer that the quality of the material and equipment offered is equal to or better than that specified in this General Specification.

A3.16.2 Compatibility of Materials and Equipment

Where different components of equipment are interconnected to form a complete system, their characteristics of performance and capacities shall be matched in order to ensure efficient, economical, safe and sound operation of the complete system.

A3.16.3 Equipment Catalogues and Manufacturer's Specifications

The A/C Contractor shall submit catalogues and manufacturer's specification of the proposed equipment for the examination and approval of the Supervising Officer in writing before any equipment is ordered.

Equipment catalogue and manufacturer's specification related to proposed items of equipment shall be specific and shall include all information necessary for the Supervising Officer to ascertain that the equipment complies with the Specification and Drawings. Data and sales catalogue of a general nature are not acceptable. Unless agreed by the Supervising Officer in writing, all data and catalogues submitted must be in English and in pure SI units i.e. mm, m, kPa, m/s, Hz, kW, l/s, etc.

A3.16.4 Equipment Deviations

Subsequent to the acceptance of his Tender, and only in exceptional circumstances where it is demonstrated in writing by the A/C Contractor that the original equipment offered cannot be obtained, the Supervising Officer may, subject to the Conditions, consider and approve, in writing, alternative equipment and materials proposed by the A/C Contractor provided always that these equipment and materials are fully in compliance with the relevant Specifications and Drawings and do not impose any additional contractual or financial liabilities onto the Employer.

A3.16.5 Selection of Equipment

Selection of equipment shall be based on this the Specification and the technical data contained in the Drawings for a particular installation.

Where items of equipment are interconnected to form an integral part of the complete Installations, their characteristics of performance and capacities shall be so matched as to give safe, reliable, efficient and economical operation of the complete Installations.

A3.16.6 Manufacturers' Technical Support in Hong Kong

All equipment listed in the Equipment Schedule shall be supplied through authorised agencies of the manufacturers in Hong Kong or through the Hong Kong offices of the manufacturers. These local agencies or offices shall have adequate technical staff to provide pre-sale and after-sale services to the A/C Contractor. Unless otherwise specified in the Particular Specification, equipment supplied directly by the manufacturers, which do not have local agencies or offices will not be accepted. Spare parts should also be available in the local market easily.

A3.17 WORKMANSHIP

A3.17.1 Tools and Instruments

Proper tools shall be used for the works. Adequate and accurate testing/measuring instruments shall be used to demonstrate compliance of the Installations with the relevant specifications and regulations. The Supervising Officer has the right to stop any work in which the correct tools and/or instruments are not used.

Instruments used for acceptance tests shall be calibrated at a yearly interval unless otherwise as required in the Contract for a particular project.

A3.17.2 Workmanship Standard

The installation works shall be in line with the good practice accepted by the local industry and verified by commissioning and testing results.

The installation works shall be in compliance with the Specification and Drawings.

The Installations shall be in compliance with the statutory requirements as specified in Section A2 of this General Specification in respect of labour safety, fire safety, structural safety, electrical safety and environmental protection.

Apart from those requirements as stipulated in this General Specification and other statutory requirements, due care shall be taken to secure public safety and health both during the execution of the works and in the selection of equipment and materials for the Installations.

A3.17.3 Space for Plant

The A/C Contractor shall ensure that all plants, materials and equipment supplied by him can be accommodated and installed within the spaces as generally shown on the Drawings with adequate access and space for maintenance of all items supplied.

The A/C Contractor shall also ensure that access to plant is adequate to allow for its removal and/or ultimate replacement. Where this is considered not possible or necessary the Supervising Officer shall be consulted for alternative arrangements.

A3.17.4 Water Proofing

Where any work requires piercing waterproofing layers or structures, the method of installation must have prior approval, in writing, from the Supervising Officer.

Unless otherwise specified or instructed, the A/C Contractor shall provide all necessary sleeves, puddle flanges, caulking and flashing as appropriate to make these penetrations absolutely watertight.

A3.17.5 Quality Assurance Standards

All materials and equipment shall be manufactured by factories with acceptable quality assurance procedures. Factories having ISO 9001:2015 certification are deemed to have acceptable quality assurance procedures. Other similar quality assurance standards may be accepted by the Supervising Officer on their individual merits. Details of such other quality assurance standards shall be submitted with the Equipment Schedule.

A3.18 SURVEYS AND MEASUREMENTS

The A/C Contractor shall relate all horizontal and vertical measurements taken and/or applied, to establish bench marks such as design drawing grid lines, finished floor levels, etc. and shall thus establish satisfactory lines and levels for all works.

All works shall be installed to these established lines and levels and the A/C Contractor shall verify all measurements on Site and check the correctness thereof as related to the Installations.

Primary bench base line, datum level, horizontal reference grid, secondary grid and transferred bench mark on each structural level will be provided by the Building Contractor. The A/C Contractor shall co-ordinate with the Building Contractor to obtain all necessary datum and reference grids prior to their surveys and measurements.

SECTION A4

DRAWINGS AND MANUALS

A4.1 DRAWINGS IN ELECTRONIC FORMAT

The A/C Contractor shall provide drawings in electronic format as required in the following clauses. These drawings shall conform to the latest version of CAD Standard for Works Projects (CSWP) as posted in the website of the Development Bureau and in accordance with the latest version of CAD Manual for the ArchSD Projects. Should any technical conflict between the CSWP and the CAD Manual arise, the CSWP shall take precedence.

A4.2 INSTALLATION DRAWINGS

A4.2.1 Drawing Submission Schedule

The A/C Contractor shall submit a detailed installation drawing submission schedule and programme to the Supervising Officer. The A/C Contractor shall allow reasonable time in the programme for vetting of the installation drawings by the Supervising Officer and for drawing resubmissions as necessary.

The A/C Contractor shall submit to the Supervising Officer a comprehensive "Submission Schedule" of installation drawings and builder's work drawings within 2 weeks after the acceptance of Tender, taking into account of the overall programme of the Installations including any Specialist Works and works by the utility undertakings. No equipment shall be delivered to the Site and no work shall be executed until the installation drawings have been approved by the Supervising Officer. The A/C Contractor shall ensure that the installation drawings and builder's work drawings are progressively submitted in accordance with the approved "Submission Schedule".

The A/C Contractor shall provide at least 6hard copies and one electronic copy, unless otherwise specified in the Contract or the Sub-contract as appropriate, of the approved installation drawings to the Supervising Officer for distribution.

Unless otherwise indicated or instructed, the A/C Contractor shall, in the stated or in adequate time before each section of the work proceeds, prepare, and submit for acceptance by the Supervising Officer, detailed installation drawings and/or shop drawings (which may also be referred to as working drawings) to demonstrate how they propose to install the works. These drawings shall be fully dimensioned and shall be based on the basic intentions of the 'Drawings'.

Installation drawings and shop drawings in this context shall mean the drawings of items to be constructed by the A/C Contractor at a workshop away from the Site.

A4.2.2 Size of Installation Drawings

Drawings submitted by the A/C Contractor shall only be of standard sizes from A0 to A4 or B1 size as stipulated in ISO 5457:1999+A 1:2010.

A/C Contractor's installation drawings and/or shop drawings shall be prepared to such scales that will clearly show all necessary details.

A4.2.3 Contents of Installation Drawings

In accordance with the provisions of this General Specification and as stated elsewhere in the contract documents, the installation drawings must incorporate details of the actual plant and equipment items as approved by the Supervising Officer.

The A/C Contractor shall ensure all installation drawings are accurate representation of the Installations, before submitting them to the Supervising Officer. All installation drawings shall be fully dimensioned and suitably scaled showing construction, sizes, weights, arrangements, operating clearances and performance characteristics.

(a) "Installation drawings" shall generally include, but not limited to, the following: -

- Symbols and notations same as and compatible with the Employer's own Contract Drawings' standard;
- Complete layout/assemblies including all necessary minor items and accessories;
- Positions of all fixings, hangers and supports;
- Maintenance spaces for all withdrawable items, such as coils, heater elements, thermometers, thermostats, fan shafts and fan blowers, cleaning and replacement of tubes, removal of guards, etc.;
- Positions & sizes of all test holes, test pockets, thermostat pockets, thermometer pockets, bends and fittings, clearances to allow for the removal of inserted equipment where applicable;
- Outline of insulation and clearances to allow for application thereof;
- Outline of valve and similar insulation boxes and the clearances to be allowed for their removal thereof; and
- Lifting points and safe working weights of each item. Note: These may be shown on separate drawings, if necessary, to avoid confusion.

(b) Ductwork Fabrication and Installation Drawings

The A/C Contractor shall, prior to the commencement of any ductwork manufacture, submit to the Supervising Officer for technical appraisal and approval the installation drawings of the ductwork demonstrating the proposed final details of the manufacturing and erection methods of the ductwork.

Generally, the drawings shall be drawn to a scale of not less than 1:50 but subject to the Supervising Officer's approval a scale of 1:100 may be adopted where the installation is a simple one.

Ductwork drawings shall indicate the length of each ductwork section; the internal dimensions of the galvanised sheet steel or other materials to be used as specified; dimensions of bends and fittings; thickness of metal; sizes and positions of all stiffeners; angle flanges, etc. including the methods of fixing and bolting; location of all supports; outline of all insulation; position and sizes of all access doors; test points; location & fixings for all thermometers and other devices including withdrawal clearances; working pressures where applicable (e.g. for medium and high pressure systems), etc.

The details shown shall cover the provision of internal air flow equalising ductwork bends, splitters and any other air flow control devices such as dampers, control mechanisms, acoustic treatment measures, flexible joints, air diffusion devices proposed annotated with inlet or extracted airflow volumes and velocities.

(c) Air Handling Plant Installation Drawings

Air handling unit plant installation drawings shall include details of all plant to be installed therein including fan shaft and runner with withdrawal clearances; cleaning spaces for coils and eliminators; filter arrangements; detail of specialist acoustic treatment where required in any Particular Specification and Drawings or where provided as part of a standard product; details of all air sealing; details of access doors and gaskets, hinges and catches/handles with manufacturers type and numbers for proprietary items; details of drains, drain traps, cleanouts, and construction method to avoid "cold bridges" etc. as well as provisions made for hoisting of fans, motors, etc. and the necessary clearance spaces for in-situ servicing or removal.

These drawings shall also show, in outline form only, any significant adjacent building structure and the clearances from and other equipment and/or known services no matter whether these elements are provided by the A/C Contractor or others. All such known positions and/or clearances shall be dimensioned wherever possible.

(d) Pipework Installation Drawings

Prior to the commencement of any manufacture, fabrication, or installation, the A/C Contractor shall submit to the Supervising Officer for technical appraisal installation drawings for the pipework installation. Generally, the drawings shall be drawn to a scale of not less than 1:50. Subject to the Supervising Officer's approval a scale of 1:100 may be adopted where the installation is a simple one.

The drawings shall indicate the location, with dimensions given, of all pipework in relation to the building structure and other pipework and equipment. The position of all valves, strainers, check valves, etc. shall be shown together with clearances necessary for removal of strainer baskets, internal parts of all valves, motors for motorised valves, solenoids, etc.

Positions and details of all hangers and supports shall be shown and the positions dimensioned.

Positions of thermostats, thermometers, test pockets and similar devices shall be shown and dimensioned including clearances required for their removal.

Details and outline of insulation and insulation boxes shall be shown including clearances required for removal of the boxes.

(e) Control and Wiring Installation Drawings

The A/C Contractor shall prepare and submit schematic diagrams showing the control layout with each item clearly identified with all interlocking and related facilities.

These drawings shall include logic sequence and wiring/pneumatic diagrams showing full details including terminal and wire numbers, colour code, etc. for all items of electrical/electronic equipment and port designations for all pneumatic installations. Interlocking, reset or similar facilities shall be clearly shown.

Installation drawings shall also be prepared and submitted for all physical wiring and pneumatic tubing systems detailing positions, enclosures, fixings, support, protection, sizes and number of cores/tubes for all runs.

The installation drawings shall show positions in relation to the building structure and other plant, equipment and/or installations. In the context, the plant, equipment and/or installations will mean to include the A/C Contractor's own installed services and those installed by others. For those services installed by others, the A/C Contractor shall be

responsible for obtaining sufficient details of relevant information from them in order to complete the drawings.

(f) Switchgear, Starter, Control/Instrumentation/Motor Control Installation Drawings

Shop drawings/installation drawings shall show the physical construction and layout, internally and externally, of all panels/cabinets/cubicles including the physical arrangement of all major and important components, bus-bars, phase separation barriers, interconnecting wiring, pneumatic piping, labels, etc.

Wiring diagrams and schematic diagrams shall show all internal & external wiring/piping including all interlocks and connections from the panels to external equipment.

Operation and control philosophy shall also be included in the submission. The drawings shall include proposed full wording of all labels to be installed in both English and Chinese characters.

(g) Special Plant Rooms Co-ordination Work

Unless otherwise stated in the contract documents, in the case of a plant room where the A/C Contractor's equipment constitutes the major item involved (i.e. as in the case of an Air-conditioning plant room), the A/C Contractor shall allow in the Tender for taking effective responsibility for the co-ordination of other services/building details within these specific areas. Furthermore the A/C Contractor shall carry out this responsibility in co-operation with whoever has the responsibility for the overall project construction stage co-ordination.

Where necessary, the foregoing plant room co-ordination requirement shall include the preparation of plant room co-ordination drawings which other contractors involved in the plant room are to comply with. The A/C Contractor shall be responsible for the cross checking of other contractors' plant room installation drawings before work thereon proceeds.

A4.2.4 Builder's Work Drawings

Unless otherwise approved by the Supervising Officer, the A/C Contractor shall submit to the Supervising Officer in accordance with the approved "Submission Schedule", 6 copies of drawings showing details of all builder's work required e.g. the weight and the load on each support of equipment. Such drawings shall clearly indicate the details and positions of all openings, trenches, ducts, drain and cutting required and construction details for plinths and equipment bases.

A4.2.5 Manufacturer's Shop Drawings

The manufacturer's shop drawings are drawings for equipment or plant to be manufactured by a specialist manufacturing supplier in their own workshops and places away from the Site.

The drawings shall show detailed construction, principal dimensions, weights and clearances for maintenance, etc. Immediately after placing of any order or at any event within 4 weeks unless otherwise approved in writing by the Supervising Officer, the A/C Contractor shall forward to the Supervising Officer for comment, 4 copies of manufacturer's shop drawings indicating detailed construction, principal dimensions and weights, clearances for withdrawals and/or cleaning, etc. No work shall proceed on or off Site unless drawings requiring approval are so approved in writing by the Supervising Officer.

A4.2.6 Drawings for Submission to Other Authority

ACMV Systems with FSD's Statutory Requirements

4 sets of the preliminary installation drawings of the following ACMV systems shall be submitted to the Supervising Officer who will then check, endorse and return 2 sets to the A/C Contractor for onward submission to FSD for perusal. The Installations shall only be commenced upon the receipt of a set of drawings chopped/recorded by FSD and written approval from the Supervising Officer. 6 sets of all such approved drawings shall then be submitted to the Supervising Officer.

(a) Ventilation / Air-conditioning control system; and

(b) Gas extraction system for battery room.

A4.2.7 Checking Drawings of Other Trades

The A/C Contractor shall follow the design intent of the Contract Drawings in planning and carrying out the work and shall cross check with other trades in order to verify the line, level, space and sequence in which the Installations are to be installed.

If directed by the Supervising Officer, the A/C Contractor shall, without extra charge, make reasonable adjustments to the proposed installation drawing layouts as are necessary to prevent conflicts with the work of other trades or for the proper sequence of and execution of the Installations. Where such modifications are of a nature and of such unforeseen complexity that they involve unreasonably extra work not covered by the Contract, they may be covered by variation order to be issued by the Supervising Officer wherever such a requirement is justified.

A4.3 AS-BUILT DRAWINGS

A4.3.1 Submission of As–built Drawings

The A/C Contractor shall submit to the Supervising Officer as-built drawings, including the draft prints and revised draft prints for checking and the final approved drawings for record in accordance with the requirements set out in the contract documents.

A4.3.2 Size of As-built Drawings

As-built drawings shall only be of standard sizes of A0, A1 or B1 size as stipulated in BS EN ISO 5457:1999+A1:2010. Smaller size (A2 to A4) is accepted for installation drawings.

A4.3.3 Content of As-built Drawings

The A/C Contractor shall ensure all as-built drawings are accurate representation of the Installations, before submitting them to the Supervising Officer.

"As-built" drawings complete with all details such as design air and water flow rates to be used for commissioning purposes. Any amendments noted on these drawings during the commissioning and test stage shall subsequently be transferred to the original "As-built" drawings once the amendments have been accepted by the Supervising Officer.

A4.3.4 Framed Drawings

The A/C Contractor shall provide and install in the relevant major plant room glass-framed, non-fading prints of the following: -

(a) Valve and damper charts consisting of schematic diagrams showing the layouts and positions and identification of all valves and dampers with record of final settings/adjustment for regulating devices; and

(b) Plant room record drawings showing all plant items, pipework, ductwork, etc. including all electrical and control schematics and diagrams.

Glazing shall be polished plate of not less than 6 mm thickness mounted in natural finish, extruded and anodised aluminium frames with the prints mounted on acid free mounting board and the whole backed with marine grade plywood not less than 8 mm thick.

A4.4 OPERATION AND MAINTENANCE (O&M) MANUAL AND USER MANUAL

A4.4.1 General

The A/C Contractor shall provide two types of manuals to the Supervising Officer with all changes made to the installation during the course of the Contract suitably incorporated.

The O&M Manual is for use by the maintenance agent of the completed Installations. It shall contain detailed technical information covering both operation and maintenance aspects of the Installations.

The User Manual seeks to give users of the completed Installations an overview of the essential information of the Installations. The contents of the manual should be concise and succinct for ease of comprehension by people with a non-technical background.

A4.4.2 Presentation

All manuals shall be written in English, unless otherwise specified. The text of descriptive parts shall be kept concise while at the same time ensure completeness. Diagrammatic materials shall also be supported by comprehensive descriptions.

The manuals shall comprise A4 size loose-leaf, where necessary, A3 size folded loose-leaves. The loose-leaf shall be of good quality paper that is sufficiently opaque to avoid "show-through". Unless otherwise specified in the Contract, the manuals shall be bound in durable loose-leaf 4 ring binders with hard covers. The manuals shall have labels or lettering on the front cover and spine. The Supervising Officer’s approval shall be obtained on this at the draft manual stage. The electronic copy of manuals including the technical literatures shall be in PDF format readable by Acrobat Reader Freeware.

A4.4.3 Checking and Approval

The A/C Contractor shall submit to the Supervising Officer the draft of O&M Manuals and User Manual for checking and approval and the approved O&M Manuals and User Manual for record according to the requirements as specified in the contract documents.

A4.4.4 Structure and Contents of O&M Manual

The detailed requirements, structure and contents of the O&M Manual shall be as specified in elsewhere in the Contract.

A4.4.5 Structure and Contents of User Manual

The detailed requirements, structure and contents of the User Manual shall include, where applicable, the following information: -

(a) Project Information

This shall include:-

Project title, site address, contract no., contract title, contract commencement date, substantial completion date and expiry date of Maintenance Period.

(b) System Description

- Type(s) of system(s) and equipment installed, and their purposes;
- Locations of major plant rooms and riser ducts;
- Brief description of the operation and functions of the systems and equipment; and
- Listing of set points which can be adjusted by the user to suit their operation needs.

(c) Schedule of Major Plant Rooms and Installed Equipment

- Schedule of major plant rooms and riser ducts including their locations; and
- Schedule of major equipment and plants including their locations and serving areas.

(d) Safety Precautions for Operation

Any safety precautions and warnings signals that the users shall be aware of in the daily operation of the various systems and equipment in the Installations including:-

- Mandatory requirements relating to safety;
- Features or operational characteristics of the installed systems or equipment which may cause hazard and the related safety precautions;
- Protective measures and safety precautions for operation; and
- List of warning signals and the related meanings that the user shall be aware of and the actions to be taken.

(e) Operation Instructions

Instructions for the safe and efficient operation, under both normal and emergency conditions, of the installed system which shall comprise:-

- An outline of the operating mode;

- Step by step operation instructions for systems and equipment that are to be operated by the user, including at least procedures for start-up and shut-down;
- Means by which any potentially hazardous situation can be made safe; and
- Cleaning and basic maintenance procedures.

(f) List of Statutory Periodic Inspections and Tests

A schedule of periodic inspections and tests that owner and/or user of the Installations have to arrange to achieve compliance with the requirements stipulated in the relevant Laws of Hong Kong. The frequency of such inspections and tests shall be expressed in specific time intervals.

(g) Drawings

A set of selected as-built drawings which shall be able to illustrate to the user the general layout of the completed Installations.

(h) Photographs

A set of photographs with suitable captions to illustrate to the user the appearance and locations of devices which require their setting and operation.

A4.4.6 Intellectual Property Rights

The Government shall become the absolute and exclusive owner of the Operation and Maintenance Manuals and the User Manual and all intellectual property rights subsisting therein free from all encumbrances.

In the event that the beneficial ownership of any intellectual property rights subsisting in the above Manuals are vested in anyone other than the A/C Contractor, the A/C Contractor shall procure that the beneficial owner shall grant to the Employer a transferable, non-exclusive, royalty-free and irrevocable licence (carrying the right to grant sub-licences) to utilise the intellectual property rights in the manuals for the purposes contemplated in the Contract. For the avoidance of doubt such purposes shall, but not limited to, include providing free copying of the materials in the manuals by any subsequent owner or user of the Installations, and/or any party responsible for the operation and maintenance of the Installations in connection with any subsequent alteration, extension, operation and maintenance of the Installations.

PART B - GENERAL TECHNICAL REQUIREMENTS (INSTALLATION METHODOLOGY)

SECTION B1

AIR CLEANING EQUIPMENT

B1.1 GENERAL

The complete air filter set for the following types of filters shall be of heavy-duty airtight factory fabrication designed to ensure a positive seal against leakage of unfiltered air. Generally, it shall be complete with robust enclosure, holding frames and housing, all supplied by the same manufacturer, as below: -

B1.1.1 The robust enclosure shall be factory assembled in such a manner that a rigid and durable enclosure for the filter packs is ensured. The periphery of the filter pack shall be continuously bonded to the inside of the enclosing frame to eliminate air bypass and to ensure the optimum filtration efficiency.

B1.1.2 The holding frames, which are designed to accommodate standard sized filters of the specified efficiency, shall be factory assembled and manufactured by the filter manufacturer. It shall be constructed of minimum 1.6 mm galvanised steel sheet and equipped with positive gasket seals at the entire length of the holding frames. The gaskets are provided to stop the air bypass between the filter cell and the frames, between the adjacent frames, and also between the frames and the housing. To firmly hold the filter cells against sealing gaskets, fixtures shall be provided adequately. The above elements are to be fully supported against the direction of airflow and become totally rigid when installed.

B1.1.3 The housing shall be constructed of minimum 1.6 mm galvanised sheet steel and factory assembled in accordance with the recommended installation details of the filter manufacturer. It shall incorporate access doors, extruded aluminium tracks, individual holding frames and flanged joints for ductwork connections. Positive gasket seals shall be provided to stop the air leakage between the housing and the connected ductwork. For air conditioning application, the housing shall be constructed of minimum 1.6 mm double skin galvanised sheet steel with 32 mm 80 kg/m3 mineral wool insulation or factory coated/injected with suitable thermal insulation material approved by the Supervising Officer. The above material shall have the insulation property same as or better than that of the air-conditioning ductwork connected to the complete air filter set. For filters used in corrosion resistant ductwork, the associated housing, holding frames, enclosures and all metal surfaces in contact with the air stream shall be applied with the same anti-corrosion coating as the ductwork. Accessories of which the operation will be affected by the coating shall be of AISI 316 stainless steel but with the coating omitted. The housing shall have finishing painting with colour to match the air handling equipment. It

shall be with factory punched holes with gland plates for each stage of filter for field connections of manufacturers and/or automatic control devices. All holes shall be sealed after the connection work.

In any case, all components of the air filter set and its associated accessories, which are within the air stream, shall comply with requirements of the FSD.

To indicate the filter condition, differential pressure gauge shall be provided for easy inspection, operation and maintenance. Facilities for CCMS interfacing filter condition monitoring shall also be equipped. They shall be fixed in such a position, outside the casing that they will be accessible and easily read. The gauges shall be properly installed with all necessary galvanised steel support brackets and ductwork stiffeners onto the ductwork without damaging the thermal insulation. The complete mounting assembly shall be designed to ensure leakage-proof and to avoid condensation at any surface in contact with the filter section.

The A/C Contractor shall provide all required new filters for all air handling equipment at the date of the substantial completion stated in the certificate of completion issued in accordance with the Contract. For disposable type filters, the A/C Contractor shall provide at least 4 extra sets of each type of installed filters for spare and replacement. The A/C Contractor shall be responsible for the replacement of filters when necessary during the Maintenance Period. At least one set of filters shall be handed over to the Supervising Officer at the expiry of the Maintenance Period.

For cleanable filters, the A/C Contractor shall provide at least 1 extra set of each type of installed filters for spare and be responsible for the cleaning of filters when necessary during the Maintenance Period. This set of filters shall be handled over to the Supervising Officer at the end of the Maintenance Period.

B1.2 WASHABLE PANEL FILTER

The holding frames shall be equipped with fixtures for easy removal of the filter cells without the use of any special tools.

For filter cells installed inside air handling unit, separate housing is not required. However, the holding frames shall be factory mounted in the air handling unit casing and installed to provide service from the air side.

B1.3 AUTOMATIC VISCOUS FILTER

The holding frames shall be equipped with fixtures for easy removal of filter cells without the use of any special tools.

The A/C Contractor shall provide all necessary electrical cables/accessories for proper operation of the complete air filter set in accordance with the manufacturer's installation details.

B1.4 DISPOSABLE PANEL FILTER

The holding frames shall be equipped with fixtures for easy removal of the filter cells without the use of any special tools.

For filter cells installed inside air handling unit, separate housing is not required. However, the holding frames shall be factory mounted in the air handling unit casing and installed to provide service from the air side.

B1.5 DISPOSABLE PLEATED PANEL FILTER

The holding frames shall be equipped with fixtures for easy removal of the filter cells without the use of any special tools.

For filter cells installed inside air handling unit, separate housing is not required. However, the holding frames shall be factory mounted in the air handling unit casing and installed to provide service from the air side.

B1.6 RENEWABLE PANEL FILTER

The holding frames shall be equipped with fixtures for easy removal of the filter cells without the use of any special tools.

For filter cells installed inside air handling unit, separate housing is not required. However, the holding frames shall be factory mounted in the air handling unit casing and installed to provide service from the air side.

B1.7 AUTOMATIC FABRIC ROLL FILTER

The holding frames shall be equipped with fixtures for easy removal of filter cells without the use of any special tools.

The A/C Contractor shall provide all necessary electrical cables/accessories for proper operation of the complete air filter set in accordance with the manufacturer's installation details.

B1.8 BAG FILTER

The holding frames shall be equipped with at least four heavy duty spring type positive sealing latches for each filter cell to ensure a positive seal against leakage of unfiltered air.

For filter cells installed inside air handling unit, separate filter housing is not required. However, the holding frames shall be factory mounted in the air handling unit casing and installed to provide service from the air side.

B1.9 CARTRIDGE FILTER

The holding frames shall be equipped with at least four heavy duty spring type positive sealing latches for each filter cell to ensure a positive seal against leakage of unfiltered air.

For the filter cells installed inside air handling unit, separate filter housing is not required. However, the holding frames shall be factory mounted in the air handling unit casing and installed to provide service from the air side.

B1.10 HIGH EFFICIENCY PARTICULATE ARRESTANCE (HEPA) FILTER

The holding frames shall be equipped with at least four heavy duty spring type positive sealing latches for each filter cell to ensure a positive seal against leakage of unfiltered air.

For filters installed inside air handling unit, separate housing is not required. However, the holding frames shall be factory mounted in the air handling unit casing and installed to provide service from the air side.

B1.11 AUTOMATIC RECLEANABLE FILTER

The complete automatic recleanable filter set including filter cells, holding frames and housing shall be factory fabricated and assembled.

Manufacturer’s installation details shall be followed and the A/C Contractor shall provide all necessary electrical cables/accessories for proper operation of the complete Installations.

B1.12 AUTOMATIC RECLEANABLE HEPA FILTER

The complete automatic recleanable filter set including filter cells, holding frames and housing shall be factory fabricated and assembled.

Manufacturer’s installation details shall be followed and the A/C Contractor shall provide all necessary electrical cables/accessories for proper operation of the complete Installations.

B1.13 AUTOMATIC RECLEANABLE HIGH VOLTAGE ELECTROSTATIC FILTER

The complete automatic recleanable high voltage electrostatic filter set including filter cells, holding frames and housing shall be factory fabricated and assembled.

Manufacturer's installation details shall be followed and the A/C Contractor shall provide all necessary electrical cables/accessories for proper operation of the complete Installations. The A/C Contractor shall provide all necessary safety measures including automatic cut-off switch and high voltage warning label at each access panel for the electrostatic filter to prevent any possibility of electrical shock to personnel during operation, inspection and maintenance.

The operation of the electrostatic filter shall be interlocked with the fan or air handling unit in such a way that the filter is in operation whenever the fan or air handling unit is operated and the unit is cut off when the fan or air handling unit is cut off.

B1.14 GAS FILTER

The holding frames shall be equipped with fixtures for easy removal of filter cells without the use of any special tools.

Housings shall be constructed of minimum 1.6 mm thick galvanised steel with extruded aluminium filter slide tracks. Doors, on both sides, shall be hinged permanently and attached with positive locking latches. Gaskets shall be provided to prevent air leakage around doors and between the doors and the filters.

Housing shall consist of two sections, first section for housing 50mm washable type pre-filters and second section for housing filter modules.

Media shall be contained in modules which shall be constructed of ABS grade DGA-R thermoplastic with V-shaped cross section.

B1.15 ACTIVATED OXYGEN AIR PURIFIER

The air purifier shall be factory fabricated and assembled in accordance with the manufacturer's installation details. The A/C Contractor shall provide all necessary electrical cables/accessories for proper and safe operation of the complete Installations. The A/C Contractor shall provide all necessary safety measures including automatic cut-off switch and high voltage warning label at each access panel for the unit to prevent any possibility of electrical shock to personnel during operation, inspection and maintenance.

The complete assembly shall be mounted onto the wall of ductwork by the manufacturer's mounting flange provided by the manufacturer with the power generator outside the air stream and the electrode tubes within the air stream. The glass tube electrodes shall be mounted perpendicular to the direction of air flow and installed at a distance at least 150 mm away from any air distribution accessories within the ductwork. The power generator shall be installed with all necessary support brackets and ductwork stiffeners onto the ductwork and sealed without damaging the thermal insulation and without causing air leaking.

The mounting shall be designed to ensure leakage-proof and to avoid condensation at any surface in contact with the ductwork. However, easy

withdrawal of the complete unit for routine inspection and maintenance shall be allowed also.

The air purifier shall be installed in suitable location of the air stream as recommended by the manufacturer for best operating efficiency using a stainless steel mounting frame provided by the manufacturer and interlocked with the fan or air handling unit in such a way that the unit is in operation whenever the fan or air handling unit is operated and the unit is cut off when the fan or air handling unit is cut off.

The air purifier shall be wired strictly in accordance with the manufacturer's wiring diagram. It shall be wired so that the units may be unplugged and removed for regular cleaning and maintenance.

A secondary switch to automatic switch off the unit shall also be provided in case the mechanical part of the fan failure.

B1.16 ULTRA-VIOLET (UV) STERILISING LIGHT

The ultra-violet sterilising light shall be factory fabricated and assembled in accordance with the manufacturer's installation details. The A/C Contractor shall provide all necessary electrical cables/accessories for proper operation of the complete Installations. The A/C Contractor shall also provide all necessary safety measures including automatic cut-off switch, proper cover on viewing glass and ultra-violet warning label at each access panel for the unit to prevent direct exposure, which may cause eye and skin discomfort to personnel, during operation, inspection and maintenance.

The complete assembly shall be mounted onto the wall of ductwork by the manufacturer's mounting flange or inside a section of the air handling unit with the power transformer outside the air stream and the ultra-violet lamps within the air stream. The ultra-violet lamps shall be mounted perpendicular to the direction of air flow to allow maximum exposure. The power transformer shall be installed with all necessary support brackets and ductwork stiffeners onto the ductwork without damaging the thermal insulation.

The mounting shall be designed to ensure leakage-proof and to avoid condensation at any surface in contact with the ductwork. However, easy withdrawal of the complete unit for routine inspection and maintenance shall be allowed also. In accordance with the manufacturer's recommendation, baffle filters may be necessary to install for those air discharge louvres or ductwork openings near the unit to reduce the ultra-violet light intensity level in case the safety limit of the exposure level is exceeded.

The ultra-violet sterilising light shall be installed in suitable location of the air stream for best operating efficiency as recommended by the manufacturer and interlocked with the fan or air handling unit in such a way that the sterilising light is in operation whenever the fan or air handling unit is operated and the unit is cut off when the fan or air handling unit is cut off.

B1.17 WATER SCRUBBER

The complete water scrubber set shall be factory fabricated and tested. The unit may be re-assembled on Site in accordance with the manufacturer's recommended installation details subject to the approval of the Supervising Officer.The A/C Contractor shall provide all necessary electrical cables/accessories for proper operation of the complete Installations.

SECTION B2

DUCTWORK

B2.1 GENERAL

The zinc coating of the ducts shall not be damaged during fabrication, delivery and installation. Any damage to the galvanised finish shall be made good with three coats of aluminium zinc rich paint or other approved corrosion resisting paint to the satisfaction of the Supervising Officer, in addition to any other protective or finishing paint/coats required in the Particular Specification.

Fabrication and testing of all ductwork shall conform to DW/143:2013 - A Guide to Ductwork Leakage Testing & DW/144:2016 - Specification for Sheet Metal Ductwork published by B&ES and the requirements stipulated in this General Specification.

If insulation is applied to the pre-fabricated ductwork in the factory, leakage test of the ductwork shall be carried out before the application of insulation. Every precaution shall be made to ensure that the insulation and vapour barriers applied to the ductwork shall not be mechanically damaged before erection on Site.

Any damaged ductwork found shall be replaced. All inspection tests carried out in factory are part of the quality control process and shall in no way be treated as substitution of the field tests required on Site.

The ducting system shall be complete with all necessary supports, access doors, dampers, fire dampers, cleaning points and test holes.

All ducts shall be fabricated and installed so as to be rigid and free from swinging, drumming and movement.

All material of ductwork, gasket, flexible joints, acoustic linings and sealants shall not support bacteria growth or posing fire hazard.

B2.2 DESIGN AND ACCESSORIES

The ductwork shall be properly and correctly constructed with all necessary accessories to minimise waste of energy and pressure losses due to eddies, vortices, etc. and shall not create, amplify or transmit any noise or vibration. Any necessary sound reducing linings or boxes to reduce noise transmission shall be provided by the A/C Contractor in accordance with the requirements of Sections B8 and C8.

Internal roughness and obstructions to air flow (other than dampers, splitter, vanes, etc.) will not be accepted for ductwork constructed from sheet materials. Sharp edges or corners on the outside of ductwork, fittings and supports will not be accepted.

Perforated rivets shall not be used in manufacture of ductwork. Generally, the use of self tapping screws is not allowed. Where the use of other fastenings is impracticable, self-tapping screws may be used subject to the written approval of the Supervising Officer.

At each point where a duct passes through a roof or external wall, a weather "cravat" or other purpose made arrangement shall ensure a waterproof and weatherproof fixing.

All intake and discharge openings to the Building shall be fitted with 10 mm galvanised mesh bird wires and is additional to any grilles or louvers indicated for these locations.

Duct connections between individual components of an air handling unit and connections between an assembly and a ductwork system shall be made with angle flanged joints. Removable sections shall be provided for access of cleaning and maintenance. All joints shall be made perfectly airtight and proprietary duct-flange or angle duct-flange shall be used for all duct-joints and for connection to plants.

Proprietary duct-flanges shall be installed in accordance with the manufacturer's recommendations and clamped together with screw lock clamps. Angle duct-flanges shall be installed in accordance with DW144.

Unless otherwise specified, duct sizes given on the Drawings are all clear internal dimensions and allowance shall be made for both internal and external insulation on the ducts where applicable.

All ductwork shall be cleaned internally and externally before the system is set into testing, commissioning and operation. Timing of this work shall be set such that minimum inconvenience shall be caused to the work of other trades.

All ductwork installed in the protected areas or lobbies shall be properly enclosed in fire-rated enclosure in according to the requirement of the FSD and Buildings Ordinance. All fire-rated enclosure shall have fire rating meeting the requirements of the FSD and Buildings Ordinance, but shall in no case be less than 2 hours.

Take-off from main ducts shall be conical, bell mouth, or shoe type. Square take-off is not permitted.

B2.3 HANGERS AND SUPPORTS

All ductwork shall be securely supported by hangers, brackets and other appropriate forms of support as detailed in DW/144:2016 - Specification for Sheet Metal Ductwork published by B&ES.

All supports and hangers for air duct installed shall be rigid galvanised steel rod, angle bar or U-channel construction free from rust approved by the Supervising Officer.

All hangers shall be provided with screwed lengths drop rods with open turn buckles for adjustment of duct level. All fixings shall be provided with washers and lock-nuts and projecting ends of drop rods shall be cut off and protected with plastic caps.

All ductwork shall be securely supported so as to prevent vibrations or movements and arranged to allow expansion due to thermal stresses without distortion of the ductwork, rupture of insulation or damage to the supporting structure. Additional ductwork supports shall be positioned close to dampers, diffusers and all similar equipment which are not subjected to distortion, in addition to those hangers and supports generally required. Allowance shall be made in ductwork construction for instrument and controls connections and adequate local stiffening shall be incorporated to provide ridge mountings.

Noise and vibration shall not be transferred to the structure or any other element through hangers and brackets and in this respect the requirements of Sections B8 and C8 shall apply.

Approval shall be obtained from the Supervising Officer for hangers and support/installation/shop drawing designs before manufacture and installation. Furthermore, approval for the method design and calculation of fixing to the structure shall also be obtained as this may have structural implications.

All metal mounting and fixing brackets for air ductwork shall be pre-fabricated off-site.

B2.4 FLEXIBLE DUCT JOINTS

Flexible joints shall be provided on all in-line fan inlet and outlet connections, at expansion joints in the building and elsewhere on ductwork where indicated. Flexible joints shall be of the same cross-sectional area as the mating fan inlet/outlet or duct section. The centre lines of flexible joint connections shall be coaxial.

Flexible joints shall consist of, or be externally protected by, material having a fire penetration time of at least 15 minutes when tested in accordance with BS 476-20:1987and shall comply with BS 476-7:1997, Section 2, Class 1 (surface of very low flame spread).

Under no circumstances shall materials containing asbestos fibres be used. The material used for the flexible connections shall withstand the specified conditions of temperature and air pressure, and comply with the standard of air tightness.

B2.5 FLEXIBLE DUCTWORK

Where flexible ductwork is indicated, or required between rigid ductwork and items of equipment, the internal diameter of the flexible duct shall be equal to the external diameter of the rigid duct and equipment spigot. Flexible ductwork shall be kept to a minimum length and shall not be used between rigid sections of ductwork to change direction unless indicated or approved by the Supervising

Officer. The maximum length of any individual flexible duct shall not exceed 2000mm unless otherwise approved by the Supervising Officer.

Joints at flexible duct connections shall be made with a sealant which permanently retains adhesion and elasticity throughout the design working temperature range, or shall be made with clip and complete with aluminium tape as approved by the Supervising Officer. The installation details and method of application of such connections shall be in accordance with the ductwork manufacturer's recommendations and as approved by the Supervising Officer.

Flexible ductwork shall be independently supported from the underside of the concrete slab. On all circular spigots, the flexible ductwork up to and including 140 mm diameter shall be secured with a worm drive type hose clip complying with BS 5315:1991. Ductwork over 140 mm diameter shall be secured with a band clip. On rectangular connections, the flexible ductwork shall be held in place by a mating flange with a backing plate, or alternatively, proprietary material may be used, in which case the metal edge shall be held in position by backing flat. Backing flat shall not be less than 3 mm thick. No flexible ductwork shall be less than 50 mm long between rigid components.

The frictional resistance to air flow per unit length of flexible duct shall not exceed 150% of the frictional resistance per unit length of galvanised steel duct of similar diameter.

The flexible duct shall be installed in as straight a manner as possible. In situations where bending is required, the bending radius shall be sufficient to prevent tensioning of the bend and restriction of the throat likely to cause deformation and/or leakage. The radius ratio R/D for bends shall be not less than 2, where R is the centre line radius and D is the diameter of the flexible duct. In no case shall flexible ductwork be used to correct misaligned ducts.

B2.6 DUCTWORK ACOUSTIC TREATMENT

Where specialised acoustic attenuation is required either as in-line sound attenuator inserts or by internal duct lining acoustic treatment, these shall comply with the requirements of Section B8**.**

B2.7 EXTRACT HOODS AND VALANCES FOR KITCHENS

Hoods shall be of galvanised sheet steel, stainless steel, aluminium, wired glass, polyester resin-bonded glass fibre or PVC as indicated in the Particular Specification. The hoods shall be rigidly formed and shall be supported independent of the ductwork. Unless otherwise indicated, they shall be supported either from above or from a side wall. The type and size of hood shall be as indicated but the A/C Contractor shall check and (in consultation with the Supervising Officer) determine its exact position in relation to the associated item of kitchen equipment to be covered on Site.

Hoods for kitchen equipment and for the extraction of condensable vapours shall have all joints in sheets vertical and shall have a drip gutter all round with a drain

connection plugged, unless instructed by the Supervising Officer, to run a drain to a suitable point. Hoods in high fire risk situations, such as for cooking ranges in kitchen, shall overlap the equipment by minimum 500 mm.

Stainless steel hood shall be manufactured from minimum 1 mm thick 304 or higher grade stainless steel with joints continuously welded; all external welds shall be ground and polished. All stiffening and supported shall be hidden.

The stainless steel shall be free from scale and all surfaces shall be polished to type 4 commercial (satin) finish.

Unless otherwise specified, welding of the stainless steel shall be by inert-gas arc welding to ISO 9692-1:2013.

Kitchen exhaust hood should be completed with make-up air grilles or make-up ductwork complete with air grilles as approved by the Supervising Officer and constructed in such position for the best efficiency in evacuating exhausted fumes from kitchen equipment.

Lighting fitting shall be provided within the hoods, fittings shall be bulkhead design with die cast aluminium base and glass diffuser to IP rating of "IP54" or better suitable for kitchen hood design. The fittings as well as the wiring for the fittings shall be suitable for continuous use of high operating conditions over 100°C temperature and 100% RH.

For kitchen hood with water scrubber design, the requirement shall be in accordance with Clause D.5 of this General Specification.

B2.8 GREASE FILTER

Hoods and valances positioned over cooking appliances shall be fitted with grease filters as specified in Section B1.

B2.9 DUCTWORK CLEANING POINTS

The A/C Contractor shall supply and install proprietary air duct cleaning points to the ductwork systems. The cleaning points shall in general be installed at maximum distance of 4 metres between centres in fully accessible locations and shall also be fitted before and after bends, tees and other locations with difficulties in gaining access. For fan coil units, at least one air duct cleaning point shall be provided in each supply air duct, and any two points at 4 metres maximum distance apart.

The maximum distance of 4 metres may be increased if the Supervising Officer considers that the ductwork system has compatible service openings which can serve the similar purposes as the air duct cleaning points. The A/C Contractor shall submit the proposed layout of air duct cleaning points and services opening in the ductwork system for the Supervising Officer’s approval prior to the site work.

Where the cleaning sleeve penetrates the air duct, the gap shall be sealed by an expanded foam sealing ring held in position by secure flanges. Where the sleeve

penetrates the insulation, the vapour barrier shall be maintained. Where the sleeve penetrates the false ceilings, the sleeve shall be secured by matching flanges.

The cleaning sleeve shall be kept straight and shall terminate at a readily accessible position. The termination flange shall bear an instruction plate indicating an air conditioning and ventilation access point in both Chinese and English. It shall incorporate a threaded port and a screw cap which when removed shall allow the coupling of air duct inspection and cleaning probes.

Ceiling access panels requirement shall also be provided after the confirmation of service panels and air duct cleaning points.

Ductwork conveying greasy air from kitchen hoods shall be graded downward towards suitable drain points in order to facilitate drainage of water at which also is the cleaning out points.

All joints shall be air tight to prevent leakage. Air leakage for cleaning points shall comply with DW/143:2013 and all FSD requirements. The A/C Contractor shall also provide a set of proprietary type compressed air lance, disinfection application lance and sampling probe which shall be suitable for use of leakage test to the cleaning points. All operating and serving instruction manuals shall be supplied with the set of equipment.

The whole air duct installation shall be disinfected by the A/C Contractor thoroughly using an approved disinfection agent immediately before the complete ductwork installation is handed over to the Employer, as directed by the Supervising Officer. The A/C Contractor shall also supply ten bottles of one litre approved disinfection agent to the Supervising Officer before hand-over of the ductwork installation. The disinfection agent shall be easily available locally.

Interior of all ductwork shall be cleaned by rotating mechanical brush or compressed air as approved by the Supervising Officer. All contaminants shall then be removed by high efficiency vacuum pumps of sufficient degree of vacuum to ensure removal of heavier particles.

B2.10 TESTING

All installed ductwork shall be tested to the "Building Energy Code". The method of air leakage test shall follow Appendix A of DW/144:2016 and to the B&ES standard DW/143:2013 and as directed by the Supervising Officer as necessary to prove the quality of the Installations. Air leakage testing of ductwork on any section of completed Installations shall be carried out and shall be in accordance with Appendix A of DW/144:2016 and "Method of Testing" of DW/143:2013. For those items not covered in DW/144:2016 and subject to the approval of the Supervising Officer, the recommendations of the "HVAC Duct Construction Standards-Metal and Flexible":2005 and "HVAC Air Duct Leakage Test Manual":1985 issued by the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) of U.S.A. shall be applied. Air ducts shall be leakage tested as necessary and any defects rectified before applying insulation and commissioning.

SECTION B3

AIR HANDLING AND TREATMENT

B3.1 GENERAL

Fans shall be installed using galvanised steel plate, supports, bolts, nuts and washers with all "as cast" bearing surfaces for bolt heads and washers counter-faced. Anti-vibration mountings shall be in accordance with Sections B8 and C8.

Fans heavier than 50 kg shall be provided with eyebolts certified by an Authorised Person (e.g. surveyor or structural engineer) for safe working load or other purpose made lifting facilities at convenient location for fan maintenance.

Fan V-belt drives shall comply with BS 3790:2006 (or related clauses of ISO 254:2011, ISO 1081:2013, ISO 1813:2014, ISO 4183:1995, ISO 4184:1992 & ISO 5292:1995) and shall be capable of transmitting at least the rated output with one belt removed. Minimum two belts per drive shall be used for motor rated higher than 4 kW unless otherwise specified. Pulleys shall be exactly aligned. The A/C Contractor shall ensure that any holding down bolts grouted in by builders are positioned to the correct alignment. Provision shall be made for positive adjustment of the tension in V-belt drives.

Fan guards shall be provided for all open unprotected intakes to centrifugal fans; for unprotected intakes to and exhausts from axial flow fans; for open unprotected and easily accessible intakes to and exhausts from propeller fans; for V-belt drives; for drive couplings and elsewhere as indicated. For full specification on motor drive guards refer to relevant clauses of Section C7.

Flexible joint shall be provided for air duct connecting to the inlet and outlet of fans.

Air flow direction, fan designation and fan number shall be clearly marked on the fan casing.

Galvanised steel or superior materials shall be used for all supports and fixing accessories and suitable paint shall also be applied in accordance with Part G.

B3.2 AIR HANDLING UNITS (AHUs)

Air handling unit shall be mounted on a hot dipped galvanised I beam or U-channel mounting frame which is either fixed on concrete plinths by builder or ceiling mounted by suspension galvanized steel hangers. Sufficient space shall be allowed for installation of drain trap and fall of condensate drain.

For ceiling mounted air handling unit, the mounting frame and hanging rods shall be designed to account for the operation loading of the air handling unit and the associated ducting and piping. Hanging rods shall be threaded and completed with locking nuts for level adjustment. All AHU steel supports and supporting accessories shall be hot dipped galvanised.

Neoprene pad shall be installed continuously between the air handling unit mounting frame and concrete plinth as vibration absorption media.

The routing of piping, ducting, electrical, control wiring and accessories shall be so arranged that all access panels of the air handling unit shall be free from obstruction.

Air handling unit or individual module heavier than 50 kg shall be provided with eyebolts or other purpose made lifting facilities nearby.

All gauges and meters other than insertion type shall not be mounted on the casing of the air handling unit on Site to avoid breaking the thermal insulation. All such provision required for connection must be purposely designed and made in the factory.

Chequer plate cover shall be provided for protecting services along the access route to the air handling unit.

B3.3 AXIAL FLOW FANS

Suitable galvanised steel mounting plates or bracket provided from the same manufacturer shall be used for fixing the fan. The fans should be mounted on anti-vibration mountings.

B3.4 CEILING FANS

Unless otherwise stated, ceiling fans shall be mounted no lower than 2400 mm and no higher than 2600 mm from finished floor levels. Down rod lengths shall be sized to meet these requirements.

In case the installed ceiling fan will be lower than 2400 mm, 400 mm sweep rotary ceiling fans in accordance with Clause C3.12 shall be used instead.

Where ceiling heights are too high for the practical installation of ceiling fans because the rods would be too long and unstable, 400 mm or larger sweep rotary wall fixed fans in accordance with Clause C3.12 shall be used.

B3.5 CENTRIFUGAL FANS

For floor mounted arrangement, the fan shall be mounted on G.I. support with anti-vibration mountings and sit on concrete plinth provided by builder.

For ceiling mounted arrangement, the fan shall sit on anti-vibration mountings fixed on steel mounting frame supplied and installed by the A/C Contractor. Threaded suspension rods with lock nuts shall be used for level adjustment.

Anti-vibration mounting shall be selected to cater for different point load of the fan at four corners.

B3.6 FAN COIL UNITS

B3.6.1 Threaded suspension rods with lock nut and washer shall be used for ceiling mounted fan coil units for level adjustment.

B3.6.2 Flexible joints shall be installed for air duct, water pipe, conduit and other services connection to the unit to isolate vibration generated by the unit.

B3.6.3 Sufficient access panels shall be provided at the supply air duct and the return air plenum for servicing the blower and duct heater. Demountable return air grille of minimum dimensions 600 mm × 600 mm shall be considered as an access panel subject to the approval of the Supervising Officer.

B3.6.4 Power supply will be provided by electrical contractor and terminated at fused connector unit with pilot light and isolation switch adjacent to each fan coil unit, all cabling from the power source (e.g. connector unit) to the control box of the fan coil unit and fan coil room remote control and accessories at convenient position including the termination shall be carried out by the A/C Contractor. G.I. metal boxes for housing the fused connector unit and all necessary conduit works inside ventilated ceiling or otherwise indicated shall be supplied and installed by the A/C Contractor.

B3.6.5 The location of the local control box shall be within 600 mm from the terminal box of the fan coil unit and the duct heater.

B3.6.6 All units shall be selected to suit the limited space within the false ceiling, with due consideration to access for maintenance and servicing.

B3.6.7 All blowers and motors of fan coil units shall be demountable from the ceiling void for maintenance purpose without causing damage to the associated ductwork and insulation.

B3.6.8 A second or additional larger stainless steel insulated drain pan shall be provided for those air conditioning units, evaporators of direct expansion system and alike installed in switch rooms, lift machine rooms, UPS rooms, control rooms and other essential areas sensible to water damage. A water overflow alarm indication shall be equipped at conspicuous place outside the room or connected to CCMS.

Air conditioning units, evaporators of direct expansion system and alike and its associated piping and ducting should not be mounted above essential electrical and control equipment such as switchboard, lift machine, control panel, UPS, etc.

B3.6.9 For unoccupied rooms and other areas sensible to water damage as specified, an overflow detection device shall be installed inside the drain pan or at the connection to the overflow drain pipe which fitted at the overflow level of the drain pan. Upon water accumulating in the

drain pan due to malfunction of the condensate drain system, the device shall be activated to shut down the corresponding fan coil unit and trigger an overflow alarm at conspicuous place outside the room, and/or in the CCMS.

B3.7 CASSETTE TYPE FAN COIL UNITS

Refer Clause C3.7.

B3.8 MIXED FLOW FANS

Mixed flow fans shall be mounted on a G.I. steel support. Threaded steel rod with lock nuts shall be used for ceiling mounted purposes. Neoprene pad shall be provided for vibration isolation.

B3.9 MECHANICAL ROOF EXTRACT UNITS

Mechanical roof extract unit shall be mounted on a vermin proof hard wood sill and concrete curb provided by Building Contractor with dimensions according to requirements of the manufacturer. All gaps between the mounting frame and structural base shall be sealed up properly.

B3.10 PROPELLER FANS

Where propeller fans are mounted in a casing, the casing shall be longer than the length of the fan and motor. The casing shall be of galvanised steel or aluminium sheet or stainless steel as specified, and shall have flanged ends and an inspection door. A terminal box shall be mounted externally on the casing.

B3.11 PROTECTIVELY COATED FANS AND FANS FOR CORROSIVE OR HAZARDOUS APPLICATIONS

All steel mounting brackets, bolts, washers and nuts shall be hot dip galvanised and painted with protective coatings to meet the appropriated corrosive environment.

B3.12 ROTARY FANS

Refer Clause C3.12.

B3.13 IN-LINE CENTRIFUGAL FANS

In-line centrifugal fans shall be mounted on G.I. steel support. Threaded steel rod with lock nuts shall be used for ceiling mounted purposes. Neoprene pad shall be provided for vibration isolation.

B3.14 EC PLUG FANS

Same as Clause B3.5

B3.15 JET FANS

Refer to Clause C3.15.

B3.16 CONDUCTING FANS

Refer to Clause C3.16.

B3.17 TERMINAL AIR CONTROL DEVICES

Terminal air control devices shall be mounted on a steel support. Threaded steel rod with lock nuts shall be used for ceiling mounted purposes. Neoprene pad shall be provided for vibration isolation.

Fixture shall be installed on the steel support to govern the lateral movement of the unit.

The power supply to the unit shall refer to Clauses B3.6.4, B3.6.5 and B3.6.6.

Flexible duct connecting the inlet/outlet of the unit shall be fixed by omega clip or similar approved devices.

B3.18 GRILLES AND DIFFUSERS

Grilles and diffusers shall be fixed on air duct by self-tapping stainless steel screw or purposely made spring or locking devices. Fixing the grille or diffuser by self-taping screw on the face panel exposed to view shall be avoided.

For linear diffuser or special made air fittings, lifting brackets or fixing devices shall be provided to facilitate site installation.

B3.19 DOMESTIC EXHAUST FANS

The installation of domestic exhaust fans shall follow the installation instruction of the manufacturer or refer to contract drawings. All domestic fans shall be protected with safety guard.

SECTION B4

AUTOMATIC CONTROL

B4.1 AUTOMATIC CONTROL SYSTEM (ACS)

The Automatic Control System (ACS) is the Master Control of a building that controls and monitors the proper, effective and efficient operation of the Air-conditioning and other Building Services System(s) in building(s). An ACS can be a complicated Central Control & Monitoring System (CCMS) or as simple as an electronic controller with built-in real time clock for scheduling controls. The appropriate ACS shall be so designed to meet the requirements and operation needs of the building operation & management team and the operation requirements of the end users in building(s). As different equipment and systems may have different operation schedules, the ACS shall have adequate capacity for scheduling all the operation needs.

The ACS described below shall be applied to buildings which do not require sophisticated CCMS (if so specified, the designed ACS shall have provisions for the proper interfacing and direct connection to the network of the future CCMS) for the normal operation and control of the air conditioning, refrigeration and ventilation systems, and other building services and electrical & mechanical (E&M) systems installed in the buildings if so specified. The main function of an ACS is for on/off controls, optimisation, monitoring of operation status and alarms generation of the connected systems in building(s). Comprehensive system controls and monitoring functions of each individual system shall be carried out by the system controller of each individual air conditioning, building services or E&M system. The ACS shall be so designed to achieve a reliable control in performing the control and monitoring functions set in the design criteria and shall be of electronic or direct digital control type as specified. Unless otherwise specified, the ACS controller shall be located inside the A/C Supervisory Control Panel.

B4.1.1 Electronic Controller with Micro-processor and REAL Time Clock Control

With the application of micro-processor and real time clock, all building services systems specified shall be turned on and off in accordance with the time schedules pre-set in the built-in program including any holiday and special schedules so required by the users. A monitoring and alarm system shall be incorporated in the controller in giving audio and visual status and alarm of faults for each building services system in the building.

For easy programming, user friendly input/output (I/O) devices shall be provided for the setting and re-setting of the operation schedules. To prevent malfunctioning of the real time clock and losing of memory, back-up battery with power healthy indicator and alarm shall be provided.

B4.1.2 Direct Digital Controller (DDC)

(a) Each controller shall operate as a standalone unit capable of performing its specified control responsibilities independently of other controllers in the network.

(b) Portable operator's terminals shall be provided for local viewing and operation.

(c) Power Fail Protection – All system set point, control algorithm and other programmable parameter should be stored such that power failure of any duration does not necessitate reprogramming the DDC controller.

B4.1.3 Control of Chiller Plant

(a) General

(i) Controllers

Built-in micro-processor based electronic controller or DDC for each chiller plus a micro-processor based electronic controller or DDC for chiller plant Sequential/Step/Interfacing controls. (for chillers and chilled water pumps controls and interfacing with ACS and other system controllers)

(ii) Start – Stop Control

Make provision for the following control functions unless otherwise specified in the Particular Specification or Drawings:-

- Manual on/off (maintenance/manual mode);
- On/off by the Automatic Control System as scheduled; and
- On/off by special demand overriding the pre-set schedule for dehumidification and/or cooling during night purging or other special duty cycles as specified.

(iii) Faults and Abnormal Operation Controls and Monitoring by the Chiller Controller

- High condenser pressure;
- Low refrigerant pressure/temperature;
- High motor temperature;
- Motor overload;
- Low oil pressure;

- Low oil sump temperature;
- High oil sump temperature;
- Chilled water flow interlocked;
- Condenser water flow interlock (water cooled only);
- Back-up for the low chilled water temperature controller (if required by the chiller manufacturer); and
- Plus other items as specified or recommended by the chiller manufacturer.

(iv) Fault Surveillance

Fault surveillance and safety controls of chiller shall be carried out by the built-in electronic controller or DDC of the chiller. Interfacing shall be provided for communication between the built-in chiller controller and the chiller plant controller. Interfacing system shall also be provided for the chiller plant controller in receiving operation instructions from the ACS and sending out chiller status and alarm signals to the ACS and the A/C Supervisory Control Panel.

(v) Energy Conservation

If specified in the Particular Specification or Drawings, sufficient control provision shall be allowed in the chiller controllers for the proper operation of the following energy systems:-

- Heat recovery condenser for the supply of heat source as specified;
- Cycling of condenser fans by head pressure control for energy saving;
- Variable Speed Drive for chiller. The application of electronic speed controller in maintaining higher chiller energy efficiency at partial load operation; and
- Reset of supply chilled water temperature to optimise the chiller energy efficiency.

(b) Single Chiller

(i) Capacity Control

Make provision for the following control functions plus other special requirements specified in the Particular Specification or Drawings:-

- Chiller output capacity modulated to maintain the pre-set supply or return chilled water temperature (after mixing with the by-pass); and
- The chiller controller shall modulate its refrigeration capacity to meet the cooling load demand in the chilled water circulation system.

(c) Multiple Chillers in Parallel

(i) Capacity Control

Make provision for the following control functions plus other special requirements specified in the Particular Specification or Drawings:-

(1) Built-in controller of each chiller modulates output capacity to maintain a constant supply chilled water temperature pre-set at the outlet of each operating chiller; and

(2) The Chiller Plant Controller shall control the sequencing of chillers and cut-in or cut-out a chiller in accordance with the return chilled water (with by-passed chilled water well mixed) temperatures pre-set in the controller. The sequencing logic shall be as follows :-

- Chiller that has run longest since last start is first to stop;
- Chiller that is idle for the longest time is first to start; and
- Chiller(s) in manual or maintenance mode shall be by-passed from the automatic sequencing control operation.

(d) Make provision of monitoring and Alarm Signals to ACS and the A/C Supervisory Control Panel

Other special requirement as specified in the Particular Specification or Drawings.

B4.1.4 Control of Chilled Water Pumping System (by chiller plant controller)

Unless otherwise specified in the Particular Specification or the Drawings, chilled water control system shall perform the following: -

(a) Circulation Pumps with Differential Pressure By-Pass

(i) For a single chiller system, the duty chilled water pump shall be operated as long as the system is in operation mode. During partial load condition, excessive chilled

water supply shall be by-passed by the differential pressure by-pass valve and hence lower the system return chilled water temperature. Dropping of the return chilled water temperature shall then call for refrigeration capacity control in the chiller. There is possibility that the cooling load demand is so low that the chiller will be cut off and at idle condition for a period of time. However it is important to keep the chilled water pump to run continuously for sensing the correct chilled water temperature. The pump shall only be cut-off when the chiller plant is turned off by the ACS;

(ii) For a multiple chiller system, the number of chillers put into operation and chiller refrigeration capacity controls shall be in accordance with the system return chilled water temperature, which is affected by the amount of chilled water by-passed by the differential pressure by-pass valve. Each chilled water pump shall be operated in accordance with its associated or delegated chiller. The delegated chilled water pump shall be cut-in earlier than the chiller in order to maintain the chilled water flow required for the chiller operation. The same logic of leaving at least one chilled water pump to operate for monitoring the chilled water temperature shall be applied; and

(iii) Manual on/off for pumps (maintenance/manual mode).

(b) Primary and Secondary Pumps (Decoupled) System

In a typical decoupled pumping system, the primary pumps are of constant flow and the secondary system can be of all variable flow pumps or a combination of constant and variable flow pumps. Exact configuration shall refer to the Particular Specification or the Drawings.

(i) Primary chilled water pump

Primary chilled water pump shall be of constant flow type, which shall be operated with time leading its associated or delegated chiller and cut-out when the associated chiller is turned off. When a reverse flow is detected in the by-pass, an additional chiller shall be cut in and when the by-pass flow is greater than the designed full capacity flow rate of a chiller, an operating chiller shall be cut off. The associated primary chilled water pumps shall then be operated in the same arrangement. The logic of keeping at least one pump operated in the primary circuit (when the system is in operation mode) is still valid.

(ii) Secondary chilled water pumps

Secondary chilled water pumps shall be operated to meet the flow demand at the load side. Discharge head pressure or differential pressure control (across supply and return mains of the secondary loop) shall be used to monitor the flow demand. The secondary pumps (no matter constant or variable flow) shall be operated in such a configuration that a constant chilled water supply pressure (i.e. in proportion to the amount of chilled water supplied) is maintained and hence meets the chilled water flow demand.

For a system with constant and variable flow pumps, the constant flow pump(s) shall only be operated as long as the demand flow is greater than the full capacity of that constant flow pump. The variable speed pump shall always be operated first to handle any partial load demand for energy saving.

(iii) Manual on/off for all pumps (maintenance/manual mode)

(c) Variable Primary Flow System

In a typical variable primary flow system, variable flow pumps shall be used in conjunction with chillers that adaptable to variable flow. The number and capacity of pumps normally match with the capacity of chillers but not necessarily. Exact configuration shall refer to the Particular Specification or the Drawings.

(i) Chilled water pumps shall be operated to maintain a pre-set differential pressure at a specific point in the system. Whenever the control valves of air terminal units open with an increase in cooling demand, the pressure tends to decrease. The variable speed drive of the pumps in operation shall be increased in such a configuration that a constant chilled water pressure difference between supply and return is maintained;

(ii) When the chilled water demand flow reduces with the system load to a low load condition that the minimum evaporator flow limit of the operating chiller, the modulating valve in the bypass pipe shall be opened to deliver the water necessary to maintain the minimum flow of the chiller; and

(iii) Manual on/off for pumps (maintenance/manual mode).

(iv) Other alternative control methods shall be considered subject to the approval of the Supervising Officer.

(d) Make provision of monitoring and Alarm Signals to ACS and the A/C Supervisory Control Panel

Other special requirement as specified in the Particular Specification or Drawings.

B4.1.5 Control of Cooling Towers and Condenser Water System (by condenser plant controller)

Micro-processor based electronic controller or DDC for Condenser Water Plant Sequential/Step/Condenser Water Temperature By-Pass/ Cooling Tower Fans Cycling/Interfacing controls. (for condenser water plant controls and interfacing with the chiller plant controller and ACS)

(a) Start-stop Control

Condenser water pumps shall be interlocked with their associated water-cooled chillers and shall be started in advance and turned off after their associated chillers.

(i) Manual on/off (maintenance and manual mode) Condenser water pumps on/off are interlocked with the chiller plant, which is started /stopped by the ACS as scheduled.

(ii) Cooling towers and their associated control valves shall be opened for the reticulation of condenser water.

(iii) Once the condenser water plant is turned on, its ancillary equipment such as water treatment plant, condenser water filtration and cleansing devices shall be energised accordingly.

(iv) For cooling tower system installed with multiple cooling towers and/or standby cooling tower(s), sequence control shall be provided to allow each cooling tower to be operated at least one hour per week.

(b) Capacity Control

(i) For energy saving, cycling of cooling tower fans shall be used to maintain the supply condenser water temperature entering the chillers at the designed value.

(ii) If the supply condenser water temperature drops below the pre-set value even with all the cooling tower fans cut off, the temperature by-pass valve shall be modulated to by-pass condenser water leaving the chillers from entering the cooling tower but to mix with the condenser water supply.

(iii) For a system with variable flow pumps, the speed of pumps shall be adjusted by the temperature of condensing water leaving the chillers or maintaining a designed temperature difference between condensing water supply and return to chillers. The water flow shall be reduced with decreasing cooling demand and hence the heat rejection capacity, while the minimum condensing flow limit shall be satisfied at all time.

(iv) Other alternative control methods shall be considered subject to the approval of the Supervising Officer.

(c) Faults and Abnormal Operation Controls and Monitoring by the Condenser Water Plant Controller

(i) High condenser water temperature.

(ii) Extra high condenser water temperature. (chillers to be cut off one by one if so specified)

(iii) Low water level of cooling towers.

(iv) Faults of cooling tower fans.

(v) Faults of condenser water pump. (associated chiller to cut off)

(vi) Faults of water treatment plant(s).

(vii) Faults of condenser water filtration and cleansing equipment.

(viii) Plus other items as specified or recommended by the condenser water plant manufacturer.

(d) Make Provision of Monitoring and Alarm Signals to ACS and the A/C Supervisory Control Panel

Other special requirement as specified in the Particular Specification or Drawings.

B4.1.6 Control of Primary Air Handling Unit (PAU)

Micro-processor based electronic controller or DDC as specified shall be used for the control of the PAU, its associated equipment and the interfacing and communication with the ACS and its associated zone AHUs, FCUs, etc. The following functions shall be provided unless otherwise specified: -

(a) Start-stop Control

(i) Automatic fire tripping as specified or required by the FSD;

(ii) Manual on/off control (maintenance/manual mode);

(iii) On/off control by the ACS as scheduled;

(iv) On/off controls by special demand overriding the pre-set schedule for dehumidification and/or cooling during night purging or other special duty cycles as specified;

If so specified in the Particular Specification or the Drawings, the demand control function in sub-clause (v) below shall be adopted; and

(v) Demand on/off control. The operation of any AHU/ FCU served by the unit shall energise the PAU. Unit will only be cut-out when all associated AHUs/FCUs are turned off or the whole system is turned off by the ACS as scheduled.

(b) Capacity Control

(i) For constant air flow design

Constant flow, full capacity at all the time during operation.

(ii) For variable air flow design

- Air flow modulated by variable speed drive in order to reduce the indoor CO2 level within the specified range (applicable for single zone system only); and

- Air flow modulated by variable speed drive to maintain the pre-set static pressure at the main supply air duct. Amount of fresh air supply to each zone shall be controlled by motorised damper, which is modulated to reduce the indoor CO2 level at that particular zone to be within the range specified (applicable for multi-zone system).

(c) Temperature and Relative Humidity Control

(i) Temperature Control

- Cooling (outdoor air temperature higher than the pre-set value)

If the supply air temperature rises above the pre-set upper temperature, chilled water flow through the cooling coil of the PAU shall be increased by a

modulating valve and vice versa when the supply air temperature drops below the pre-set lower temperature. The controller shall respond to modulate the control valve in maintaining the pre-set supply air temperature.

- Heating (outdoor air temperature lower than the pre-set value)

  The supply air temperature is maintained within the range specified by modulating the control valve and hence regulating the amount of hot water (for space heating) from entering the heating coil of the PAU or for electric heating by staging of electric heaters to maintain the supply air temperature specified.

(ii) Humidity Control

- Dehumidification (when the outdoor air enthalpy/moisture content is higher than the pre-set cut-in value)

  Despite of the PAU is in cooling mode or heating mode, the humidistat shall modulate the chilled water control valve to open for dehumidification until the humidity condition of the outdoor air drops below the pre-set cut-out value. If the supply air temperature drops below the lower limit due to the dehumidification process, the hot water coil or electric heaters shall be actuated for re-heating.

  If so specified in the Particular Specification or the Drawings, the dehumidification process shall be carried out by a separate dehumidification system installed at the fresh air intake section.

- Humidification (outdoor air relative humidity lower than the pre-set value)

  Humidification process is not taken place in the PAU. If the room humidity condition at the space inside the building is lower than the value specified, humidification by means of steam or water spray humidifier shall be operated at the relevant AHUs. For fan coil system, individual room/zone humidifier or system shall be used as specified.

(d) Filters and Air Cleaners

Controller of PAU shall also control the proper operation of its ancillary equipment such as automatic air filter, air cleaner, air

steriliser, etc. Unless otherwise specified, the following alarm signals shall be sent to the A/C Supervisory Control Panel:-

(i) Filter clog alarms;

(ii) Filter detached from filter chamber;

(iii) Time for replacement of absorption filters; and

(iv) Status and fault alarms of air cleaner & steriliser.

(e) Make provision of monitoring and Alarm Signals to ACS and the A/C Supervisory Control Panel

Other special requirement as specified in the Particular Specification or Drawings.

B4.1.7 Control of Air Handling Unit (AHU)

Micro-processor based electronic controller or DDC as specified shall be used for the control of the AHU and its associated equipment and the interfacing and communication with the ACS and its associated zone terminal, VAV units, etc. The following functions shall be provided unless otherwise specified: -

(a) Start-Stop Control

(i) Same as Clause B4.1.6 (a).

If so specified in the Particular Specification or the Drawings, the demand control function in sub-clause (ii) below shall be adapted; and

(ii) Demand on/off control. The operation of any VAV unit served by the unit shall energise the AHU. Unit shall only be cut-out when all associated VAV units are turned off or the whole system is turned off by the ACS as scheduled.

(b) Capacity Control

(i) For Constant Air Volume System

Single zone constant volume; full flow capacity to a single zone at all the time during operation (applicable for single zone system only); and

Multi zone constant volume, the amount of air supplied to each zone is still constant. However zone reheater shall be provided at each zone for temperature control (applicable for multi zone system).

(ii) For Variable Air Volume System

Airflow modulated by variable speed drive to maintain the pre-set static pressure at the main supply air duct. Amount of air supplied to each zone shall be controlled by motorised damper of each VAV unit. The VAV damper shall be modulated to open or close in order to maintain the room temperature/supply air flow rate to be within the range specified.

(c) Temperature and Relative Humidity Control

(i) Temperature Control for Constant Air Volume Systems

- Cooling

If the room air temperature rises above the pre-set upper temperature, chilled water flow through the cooling coil of the AHU shall be increased by opening the modulating valve and vice versa when the room air temperature drops below the pre-set lower temperature. By modulating the control valve, chilled water flowing through the cooling coil of the AHU shall be regulated to meet the cooling demand load.

- Heating

The room air temperature shall be maintained within the range specified by the control valve and hence the amount of heating hot water from entering the heating coil of the AHU or by staging of electric heaters to maintain the room air temperature specified.

(ii) Temperature Control for Variable Air Volume Systems

Unless otherwise specified, the supply air temperature at the discharge of a variable air volume AHU shall be maintained at a pre-set value by controlling the flow of chilled/hot water entering the cooling/heating coil. Space/room temperatures shall be controlled by the VAV units as described in Clause B4.1.8 (b) of this General Specification.

(iii) Humidity Control

- Dehumidification (indoor air relative humidity higher the pre-set value)

Despite of the AHU is in cooling mode or heating mode, the humidistat shall modulate the chilled

water control valve to open for dehumidification until the relative humidity of the room air drops below the pre-set cut-out value. If the room air temperature drops below the lower limit, the hot water coil or electric heaters shall be actuated for re-heating.

If so specified in the Particular Specification or the Drawings, the dehumidification process shall be carried out by a separate dehumidification system installed at the air handling system.

- Humidification (indoor air relative humidity lower than the pre-set value)

  If the room relative humidity at the space inside the building is lower than the value specified, humidification by means of steam or humidifier shall be provided at the relevant AHUs as specified.

(iv) Temperature Display

LCD or 7-bit segment (self-illuminated) digital display of the room temperature thermostat within readable size from three metres apart at the appropriate locations inside the air-conditioned areas shall be provided. Temperature display shall be setting up in steps not coarser than 0.5K. Numbers of the display units shall be in accordance with the air-conditioning layout design and to be specified in the Particular Specification.

(d) Fresh Air Supply Control

CO2 sensor at return air of AHU shall be used to modulate the fresh air intake damper. Sufficient amount of fresh air shall be sucked in to reduce CO2 level at all zones to be within the range specified. If so specified, a minimum amount of outdoor air supply shall be maintained for the proper pressurisation of the air-conditioned areas.

(e) Filters and Air Cleaners/Sterilisers

Same as Clause B4.1.6 (d).

(f) Make provision of monitoring and Alarm Signals to ACS and the A/C Supervisory Control Panel

Other special requirement as specified in the Particular Specification or Drawings.

B4.1.8 Control of Zone Air Distribution Units

(a) Fan Coil Unit (FCU)

Unless otherwise specified, controller for FCU shall be of micro-processor based electronic type or DDC type as specified. Backup battery shall be provided for all programmable controller and controller with real time clock. Unless otherwise specified, the control functions listed below shall be performed by the controller:-

(i) Start-stop control

- Automatic fire tripping as specified or required by the FSD. Automatic reset is required once the fire signal is clear;
- Manual on/off control by the three-speed controller;
- c/w space temperature sensor; and
- Automatic on/off control by ACS as scheduled plus manual override control located at management office or other location as specified (for public areas, corridor, etc.).

If so specified in the Particular Specification or the Drawings, the following control function shall be adopted.

Automatic on/off control by Occupancy Detector (dual mode) plus manual override control by three-speed controller c/w space temperature sensor.

(ii) Temperature Control

- Cooling

  Motorised on/off control valve shall be turned on and off to maintain the room temperatures pre-set in the controller. Chilled water shall only flow through the cooling coil of the FCU when the FCU is turned on and the control valve is opened.

- Heating

  When the controller is set to the heating mode, the electric heater shall be turned on and off to maintain the room temperatures set in the controller. If hot water heating is used, a motorised on/off control valve shall be turned on and off to maintain the room temperatures set.

- Temperature Display

  LCD or 7-bit segment (self-illuminated) digital display of the room temperature thermostat within readable size from three metres apart inside the air-conditioned areas shall be provided. Temperature display shall be setting up in steps not coarser than 0.5K.

(iii) Fresh Air Supply Control

For a variable volume primary air supply system, a zone CO_2 sensor shall be used to control a modulating damper, which will increase or decrease the amount of fresh air supply from the PAU to a FCU or a group of FCUs in the same control zone. The motorised damper shall be modulated to reduce CO_2 level to be within the range pre-set. If so specified in the Particular Specification, a minimum amount of fresh air supply shall be maintained when individual FCU or any zone FCU is switched off. A separate electronic controller or DDC instead of the FCU controllers shall be used for the control of this fresh air modulating system.

(iv) Monitoring & Alarm Control

Unless otherwise specified, the following controls shall be incorporated in the controller of each FCU and signals and alarms shall be sent to the zone or main supervisory control panel as specified:-

- Filter clog alarms;
- Overheat of electric heater; and
- Room temperature outside upper and lower limits pre-set.

(b) Variable Air Volume (VAV) Unit

Controller for VAV unit shall be of micro-processor based electronic type or DDC type as specified. Backup battery shall be provided for programmable controller and controller with real time clock. Unless otherwise specified, the control functions listed below shall be performed by the controller:-

(i) Start-Stop Control

- Automatic fire tripping as specified or required by the FSD. Automatic reset is required once fire signal is clear;
- Manual on/off control by user; and

- Automatic on/off control by ACS as scheduled plus manual override control located at management office or other location as specified (for public areas, corridor, etc.).

If so specified in the Particular Specification or the Drawings, the following control function shall be adopted.

Automatic on/off control by Occupancy Detector (dual mode) plus manual override control.

(ii) Temperature Control

- Cooling

  Unless otherwise specified, pressure independent type VAV units shall be adopted.

- Pressure Independent Type

  The room temperature sensor shall send signal to the controller, which works together with the supply air flow measuring device and shall actuate the motorised modulating control damper to supply the designed amount of cooled air required in maintaining the room temperature pre-set. With the installation of the air flow measuring device, adjustment of the supply air quantity shall not be affected by the fluctuation of the supply air pressure at the distribution air duct and be well within the design limits. There shall also be a minimum open position in the control damper to maintain the minimum air movement and fresh air to the room. If the room temperature continues to drop when the damper is already at its minimum open position, reheat or supply temperature reset is required as specified.

- Heating / Reheating (for VAV units with heating and reheating)

  The electric heater shall be turned on and off to maintain the room temperatures and humidity set in the controller. If hot water heating is used, motorised control valve shall be turned on and off to maintain the room temperatures set.

- Temperature Display

  LCD or 7-bit segment (self-illuminated) digital display of the room temperature within readable

size from three metres apart inside the air-conditioned areas shall be provided. Temperature display shall be as described in B4.1.7(c)(iv) and the numbers of the display unit required are to be specified in the Particular Specification.

(iii) Fresh Air Supply Control

Fresh air supply control is generally carried out in the AHU. If so specified, zone CO_2 sensor shall be installed to send a signal to the room VAV unit(s) for higher supply air quantity (i.e. more fresh air in proportion). Excessive cooling effect shall be offset by reheating or reset of supply air temperature in the AHU.

(iv) Monitoring, Alarm and Other Controls

Unless otherwise specified, the following controls shall be incorporated in the controller of each VAV unit and signals and alarms shall be sent to the zone or main supervisory panel as specified:-

- Flow sensor clog alarm (flow detected beyond limits);
- Overheat of electric heater;
- Room temperature outside upper and lower limits set; and
- Part load signal to the AHU for supply air temperature reset.

B4.1.9 Ventilation System Control

(a) Toilet Exhaust System

(i) Start/stop

- Automatic fire tripping as specified or required by the FSD. Automatic reset is required once fire signal is clear.
- Manual on/off (for manual operation and maintenance) plus
- On/off by ACS as scheduled; or
- On/off interlocked with lighting of the room if specified.

(ii) Capacity Control

Unless otherwise specified, constant exhaust air flow rate.

(b) Printer Room Exhaust System

Same as Clause B4.1.9 (a).

(c) Plant Room Ventilation System

(i) Start/stop

- Manual on/off (for manual operation and maintenance) plus
- On/off by ACS as scheduled; or
- On/off by thermostat or other local sensing devices as specified.

(ii) Capacity Control

Unless otherwise specified, constant exhaust air flow rate.

(d) Car Park Ventilation System

(i) Start/stop

- Automatic fire tripping as specified or required by the FSD.
- Manual on/off (for manual operation and maintenance) plus
- On/off by ACS as scheduled; or
- On/off or modulated by zone CO and/or NO_2 sensors as specified.

(ii) Capacity Control

- Constant air flow rate;
- Variable air flow by staging of multi-fans; or
- Variable airflow by variable speed fans.

Unless otherwise specified, all demand ventilation systems using CO/NO_2 sensors shall be equipped with variable speed fans for energy saving.

(e) Make Provision for the Monitoring and Alarm Signals to ACS and the A/C Supervisory Control Panel

Other special requirement as specified in Clause C5.54 of this specification or the Particular Specification or Drawings.

B4.2 GENERAL REQUIREMENTS

B4.2.1 Control Equipment Features

Basic adjustments for original setting (such as control characteristic, wind and sun effect settings, set-back, boost, etc.) shall be concealed and tamper proof and housed within lockable panels. Temperature setting scales shall be clearly marked in °C.

Unregulated power supplies shall be filtered. Shielded cable shall be used when it is necessary to install DC signal leads in the same control wiring conduit.

Suitable support and easy access facilities shall be equipped for all sensors, monitoring and measuring equipment. Suitable protection guard against damage shall be provided for equipment exposed to public contact.

B4.2.2 Sensing Elements in Liquids

(a) Elements sensing liquid temperature in pipework shall be: -

(i) Provided with means for withdrawal for calibration, servicing, etc., without the need for draining the system;

(ii) Positioned so that the active part of the element is wholly within the liquid;

(iii) Positioned so that the element is not less than 10 pipe diameters downstream from a point of mixing, unless otherwise recommended by the manufacturer;

(iv) Positioned so that sufficient length of flexible conduit can be allowed to permit complete withdrawal of the element; and

(v) Positioned downstream from the valve, after the pumps, for the control of mixed flow temperature using mixing valves.

(b) Elements sensing liquid flow in pipework shall be positioned so that: -

(i) The element is mounted in a section of pipe where there is a straight run of at least five pipe diameters on each side of the flow switch;

(ii) The element is mounted so that the terminals or wire leads are easily accessible for wiring; and

(iii) The element must not be subjected to water hammering. If a fast-closing valve is located downstream of the element, a suitable water hammer arrester must be used.

B4.2.3 Sensing Elements in Air or Gases

(a) Elements sensing the temperature of air in room or other such space shall be: -

(i) Positioned so that the element is not subjected to thermal radiation and shall be away from door, windows, and heat sources, etc.;

(ii) Positioned so that all conduit openings are sealed to avoid false temperature measurement; and

(iii) Positioned in a representative position.

(b) Elements sensing the temperature of air in a duct shall be positioned so that: -

(i) The element is not subjected to thermal radiation;

(ii) The active part of the element is wholly immersed in the controlled air stream;

(iii) The element in supply air duct is fitted a few metres downstream from the heating coil;

(iv) The element in extract air duct is fitted before the extract fan to avoid thermal radiation influence;

(v) Temperature stratification is accounted for, (i.e. positioning for low temperature limit sensing, positioning for high temperature limit sensing, positioning for average temperature sensing);

(vi) If of the capacity averaging type, it is installed on a suitable framework and is suitably arranged for servicing; and

(vii) If used for determining the dew point, the air adjacent to the element is known to be saturated within acceptable limits.

(c) Elements sensing the temperature of a solid surface shall be positioned and fixed so as to give good thermal contact.

(d) Elements sensing the temperature of air external to a building shall be positioned: -

(i) Generally as indicated and away from the influence of direct solar radiation and local heat gains;

(ii) Far away from the warm air outlets such as windows or extract; and

(iii) Where special requirements are indicated (e.g. the determination of solar gain, or wind influence), the control sensor manufacturer's recommendations for positioning the sensors shall be followed.

(e) Humidity sensing element shall be positioned: -

(i) In a representative of the space in which the humidity is being measured;

(ii) Such that the air velocity is within the range required by the sensing element; and

(iii) To ensure that the air reaching the element is free from airborne contaminants.

(f) Element sensing both temperature and humidity shall be: -

(i) Positioned so that the element is not subjected to thermal radiation and shall be away from door, windows, and heat sources, etc.;

(ii) Positioned so that all conduit openings are sealed to avoid false temperature measurement; and

(iii) Positioned in a representative position.

(g) Elements sensing differential pressure of air in a duct shall be positioned so that: -

(i) Sensor stem is fully immersed in the controlled air stream;

(ii) Differential air switch shall be positioned where it will not be exposed to corrosive or flammable atmosphere or vibration;

(iii) The pressure switch shall be mounted on a vertical surface and has two air pressure tappings which are connected with tubing to the sensing points in the duct;

(iv) The mounting method of the pressure transmitter shall be subjected to the manufacturer's recommendations; and

(v) All sensors shall be arranged to give convenient access for servicing the sensor.

(h) Elements sensing carbon dioxide of air in a room shall be positioned so that: -

(i) Areas with low air exchange or close to supply air outlets; windows, doors, etc. shall be avoided;

(ii) The sensors shall be mounted at a minimum of 2 m above finished floor level;

(iii) All sensors for any individual installation shall be of same appearance; and

(iv) For sensors exposed to view, the precise location shall be approved by the Supervising Officer.

(i) Elements sensing carbon dioxide of air in a duct shall be positioned so that: -

(i) Sensor is mounted with rigid support in the return duct in a position far away from external heat sources;

(ii) Sensor stem shall be fully immersed in the controlled air stream; and

(iii) All sensors shall be arranged to give convenient access for servicing the sensor.

(j) Elements sensing carbon monoxide and nitrogen dioxide for carpark shall be positioned so that: -

(i) The Practice Notes on Control of Air Pollution in Car Parks issued by the Environmental Protection Department shall be complied;

(ii) The exact quantities of sensors shall be based on the regulation but not less than 500m2 per one detector; and

(iii) For sensors exposed to view, the precise locations shall be approved by the Supervising Officer.

(k) Air velocity sensors shall be: -

(i) Sensor tube made of stainless steel material carrying a scale to indicate the immersion length; and

(ii) The location and immersion length shall be in accordance with the manufacturer's recommendation.

(l) Sensing elements shall in all cases be installed in accordance with the manufacturer's recommendations and instructions.

(m) All room or space mounted sensing elements to temperature or humidity for any individual installation shall be of the same appearance.

(n) For sensors exposed to view, the precise location shall be approved by the Supervising Officer.

(o) All sensors shall be arranged to give convenient access for servicing.

B4.3 AIR COOLING CONTROL

B4.3.1 Control valves used for heating or cooling circuits shall be provided with an isolating valve on each port. The isolating valve on the by-pass port being of the double regulating type to enable regulation such that the pressure drop through the by-pass can be set to equal to that through the cooling coils.

B4.3.2 The control valves shall be quiet in operation.

B4.3.3 All valves shall operate in sequence with another valve when required by the sequence of operations.

B4.3.4 All control valves shall be suitable for the system flow conditions and close against the differential pressures involved.

B4.4 AIR HEATING CONTROL

B4.4.1 Control valves used for heating or cooling circuits shall be provided with an isolating valve on each port. The isolating valve on the by-pass port shall be of the double regulating type to enable regulation such that the pressure drop through the by-pass can be set to equal to that through the heating coils.

B4.4.2 Electric air heaters shall be energised in three phase-balanced stages not exceeding 6 kW per three-phase stage. Single-phase stages shall not be more than 2 kW each. There shall be a time lag of not less than five seconds between successive stages on demand for heating.

B4.4.3 Arrangements shall generally be such that in the event of electrical supply failure, or after normal shut down, the control system will recycle to the "OFF" position. Unless otherwise specified, the control sequence shall start automatically.

A vane or differential pressure switch wired in series with the high limit temperature cut-outs shall also be provided to switch off the heater in

the event of a fan or other failure. Any cut out on these items shall require to be manually reset.

B4.4.4 The control valves shall be quiet in operation.

B4.4.5 All valves shall operate in sequence with another valve when required by the sequence of operations.

B4.4.6 All control valves shall be suitable for the system flow conditions and close against the differential pressures involved.

B4.5 ELECTRICAL/ELECTRONIC (LOCALISED) CONTROL SYSTEM

B4.5.1 The systems shall be operated at single-phase mains voltage or at extra low voltage such as 12 or 24 V as indicated in the Particular Specification.

B4.5.2 Where a particular manufacturer's system is offered and accepted, the Installations shall be installed to comply with that manufacturer's recommended technical details and methods of installation.

SECTION B5

CENTRAL CONTROL AND MONITORING SYSTEM (CCMS)

B5.1 GENERAL REQUIREMENTS

B5.1.1 Complete Building Automation System

The system shall perform the general functions for ACMV installation and shall incorporate the facilities for developing other building automation systems, such as automatic fire alarm, automatic security and access control in future without replacement of existing equipment. Energy Management is an integral part of the CCMS; other management functions that include self-diagnostics, maintenance and facilities shall also be made available for future connection. Unless otherwise specified in the Particular Specification, a central uninterrupted power supply (UPS) with suitable capacity not less than 60 minutes shall be equipped for the CCMS.

B5.1.2 Compliance with Various Codes/ Standards

The Installations shall comply with the standards as described below where applicable: -

(a) International Organization for Standardization ISO/IEC 9075-9:2016 -Information Technology - Database Languages - SQL – Part 9: Management of External Data (SQL/MED), ISO/IEC 9075-10:2016 – Information Technology – Database Languages – SQL – Part 10: Object Language Bindings (SQL/OLB), ISO/IEC 9075-13:2016 – Information Technology – Database Languages – SQL – Part 13:SQL Routines and Types Using the Java TM Programming Language (SQL/JRT);

(b) International Telecommunication Union Recommendation V.90 – A digital modem and analogue modem pair for use on the Public Switched Telephone Network (PSTN) at data signalling rates of up to 56000 bit/s downstream and up to 33600 bit/s upstream and Recommendation X.25 – Interface between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit;

(c) ASHRAE Standard 135-2016 - A Data Communication Protocol for Building Automation and Control Networks (BACnet);

(d) ANSI /CEA-709.1-B - Control Network Protocol Specification (known as Lon talk);

(e) TIA/EIA 232-F, Interface Between Data Terminal Equipment and Data Circuit Terminating Equipment Employing Serial Binary Data Exchange;

(f) TIA/EIA 485-A, Electrical Characteristics of Generators and Receivers for use in Balanced Digital Multipoint Systems;

(g) TIA/EIA 568-.1-D, Commercial Building Telecommunications Cabling Standard;

(h) Transmission Control Protocol/Internet Protocol of Defence Advanced Research Project Agency (TCP/IP);

(i) International Organization for Standardization ISO/IEC 1989:2014- Information Technology – Programming Languages – COBOL; and

(j) International Organization for Standardization ISO/IEC 8802-3:2017 – Standard for Ethernet

B5.1.3 Expandability

The Installations shall be expandable at all levels as described in the following sections using the same software interface that replacement of either the workstation software or field controllers are not required.

B5.1.4 Submittals

(a) Working drawings shall be prepared in AutoCAD software of A0 or A1 size, unless otherwise specified.

(b) Working drawing submissions shall include a block diagram depicting locations of all controllers and workstations with associated network wiring.

(c) Working drawing submissions shall also include schematic diagrams for ACMV installations indicating all connected points with reference controllers. Details and typical installation should be shown.

(d) Manufacturer's data on all hardware and software products shall be indicated clearly. Other equipment such as valve, damper and airflow stations shall be shown with size, configuration, capacity and location of fixing.

(e) Software submittals shall be detailed with description of sequences of operation, program listings, point lists and the design of graphics, reports, alarms and configuration to be furnished with the workstation software.

(f) Operation and maintenance manual together with CAD CD Rewritable Storage Media shall be submitted to the Supervising Officer in accordance with the Contract requirement.

B5.1.5 System Clean up

Upon completion, the A/C Contractor shall check and clean all equipment pertinent to installation. Such cleaning shall extend to the exposed surfaces of tubing, hangers and other exposed metal of grease, plaster and other areas around the equipment.

B5.1.6 System Start-up & Commissioning

Upon complete installation prior to put into operation, the A/C Contractor shall ensure the work as described below is being carried out and the results are satisfactory: -

(a) All equipment shall be calibrated and the transmission media operation shall be verified before the system is put into operation. The work shall include testing for both hardware and software functionality of each point in the system as well as the sequence of operation of ACMV sub-systems under the CCMS control;

(b) The A/C Contractor shall carry out the commissioning that includes field testing, calibrating and adjusting and set in operating conditions for all major installations such as chilled water, hot water and all air handling systems under the direction of the manufacturer or its authorised representatives; and

(c) Operation parameters and control settings shall not be modified without notification to the Supervising Officer.

B5.1.7 Operation and Maintenance Manual

Operation and maintenance manual together with CAD CD Rewritable shall be submitted to the Supervising Officer in accordance with the Contract requirement: -

(a) It shall contain all details necessary for operation, maintenance, replacement, installation and parts procurement for the system;

(b) It shall include specific part numbers and software versions and dates together with a complete list of spare parts;

(c) It shall include relevant as-built drawings, test certificates and commissioning records;

(d) It shall include a copy of all application software both in written form and on diskette;

(e) It shall include step-by-step system recovery procedures for system re-start up after fatal breakdown. Such procedures shall

be properly demonstrated to the Supervising Officer's Representatives during the T&C. Any special tools required for system re-start shall be supplied together with the System; and

(f) It shall include all necessary passwords to initiate functioning of the complete CCMS to initial start-up and to work after any modification or reprogramming.

B5.1.8 Training

Adequate training shall be provided to the operators for the day-to-day operation and future maintenance. Unless otherwise specified, the training should include both on-site and classroom courses with training handouts/manuals to the designated personnel, details as follows: -

(a) On Site Training

It shall consist of a minimum of 30 working days of hands-on instruction geared at the operation and maintenance of the systems. The activities shall include:-

(i) System overview;

(ii) System software and operation;

(iii) Operation sequences including start-up, shutdown, adjusting and balancing;

(iv) Equipment maintenance; and

(v) Data logging and Alarm reporting.

(b) Classroom Training

It shall contain a comprehensive understanding of the hardware and software course materials covering workstation operation and controller programming. The number of attendance and period should be agreed with the Supervising Officer and should not be less than two weeks, unless otherwise specified in the Particular Specification.

B5.1.9 Warranty

(a) During the Maintenance Period, the A/C Contractor shall provide all services, materials and equipment necessary for proper operation of the system.

(b) The A/C Contractor shall be responsible for all necessary revisions to the software as required to provide a complete and operable system being consistent with the sequence of

operations. All updates to the manufacturer's software shall bear no extra costs.

B5.2 SYSTEM ARCHITECTURE

B5.2.1 General

It shall be either a single network or a hierarchical system architecture that may be a multi-user computer system to allow remote access as specified in the Particular Specification.

B5.2.2 Level 1 Network

It should be the highest level that is developed for management on a wide area fast speed network based on open protocol.

B5.2.3 Level 2 Network

It should be a high performance peer-to-peer operation level network that shall be able to connect to remote sites. This level shall apply for a single network system.

B5.2.4 Level 3 Network

It should be local area network with DDC controller for communication that shall be able to extend its performance and capacity by using remote sub-system controllers. The sub-system controller shall be microprocessor-based stand-alone controller capable of operation of ACMV installations independently.

B5.2.5 Local Area Network (LAN)

The system shall be able to segment through software into multiple local area networks distributed over a wide area network with a standalone DDC controller and communicate with other controllers on the network via a network controller unit.

B5.2.6 Standard Network Support

The workstations, controllers and file server, etc. shall be able to use standard network components to utilise the existing network and/or structural cabling system.

B5.2.7 Remote Communication

It shall be able to manage remote system via standard component of software that is being incorporated.

B5.2.8 System Expansion

The system shall be able to expand memory and enhance programming language and to upgrade all existing controllers and remote control units without interrupting its operation. The system shall be able to expand 20% of the system hardware and software points without adverse effect on the system performance.

B5.2.9 Support for Open System Protocols

The network shall be capable of integration of the open system protocols such as BACnet, Lon Talk, etc.

B5.3 ELECTRICAL WIRING

The works shall be carried out in compliance with the requirements of the Electrical General Specification (See Clause A2.1) and Section B7 of this Specification and should comply with application guidelines of TIA/EIA 568.1-D / TIA/EIA 485-A / TIA/EIA 232-F whenever applicable.

The A/C Contractor shall provide all wiring work and electrical devices and material necessary to complete the Controls and Instrumentation System. Complete metal cable trays or enclosures shall be provided for conductors throughout all systems specified. Equipment and devices, which are not constructed with housings for mounting and enclosing all live parts, shall be installed in metal cabinets. All equipment, enclosures, cable trays, etc., shall be appropriate for the atmosphere and hazards encountered within their associated areas.

"Low" and "line" voltage wiring shall be done in strict accordance with the authority referred to this Section as mentioned above. Conduit shall be concealed in building construction in all finished spaces. Conduit runs exposed shall be run in a parallel manner to building surfaces. Conduit shall be supported in approved manner. Rigid conduit shall be used in all concrete pours. All connections from instruments shall terminate on terminal strips, properly tagged for ease of identification, located in control centres. No splices or junctions of wirings will be permitted in the field.

The A/C Contractor shall provide all interlock wiring required to make system operate in accordance with the drawings and specifications. All wiring diagrams, etc., required shall be provided and co-ordinated. Wiring shall begin on terminals of control device and terminate on terminals of controlled device.

The term "wiring" shall include wire, conduit, wiring device, conduit boxes/accessories and miscellaneous materials and labour required for mounting and wiring electrical control devices and services.

B5.4 HARDWARE INSTALLATION

The Installations shall comply with Statutory Requirements as specified in Section A2.

B5.4.1 Wiring and Tubing

Unless otherwise specified, wiring shall be dedicated runs with separate circuit breaker and each run shall include a separate neutral and ground wire.

A proper earth system shall be provided and should be separated from other services for dedicated run.

Wires shall be properly fixed at intervals.

Wires shall be kept away from hot water pipe, steam and condensing piping, etc.

Wires shall not run across telephone equipment.

Unless otherwise specified, all conduits shall be of galvanised steel.

Surface conduits shall be installed in plant room or other area as approved by the Supervising Officer.

Flexible conduits shall be adapted for connection to the equipment and/or sensors, etc.

Control air tubing shall be in concealed run unless otherwise approved by the Supervising Officer.

All control tubing run in surface to controls, control panels or run in equipment rooms, plant rooms, apparatus rooms, mechanical shafts and return air plenums, etc. shall be enclosed in metal raceway.

All control air tubing shall be thoroughly cleaned before putting the system into operation.

B5.4.2 Field Devices

The Installations shall comply with Clause B4.2 whenever applicable.

Thermal conduction compound shall be applied to ensure good heat transfer to the well-mounted sensor.

Sensors installed on pipeline shall be removable without shutting down the system.

The high-pressure port of the duct type static pressure sensors shall be connected to a metal static pressure probe that shall be inserted into the duct pointing upstream. While the low pressure port shall be left open

to the plenum area at the point that the high-pressure port is being tapped into the air duct.

Building static sensors shall be installed with the high-pressure port to be inserted into the space via a metal tube and the low-pressure port to outside.

Actuators shall be installed firm and be mounted to give a positive movement throughout 100 percent of the stroke.

The relays shall be installed such that transient suppression shall be across all coils.

B5.4.3 Enclosures

All field interface devices shall be mounted in a panel that shall be provided with enclosures to protect from dusts and moisture.

The panel shall be adequate for installation of power supply for sensors, interfacing relays, contactors, safety circuits and transducers, etc.

Sufficient heat dissipation device shall be provided to prevent over-heat of equipment.

The panel shall be steel enclosure with hinged door, keyed lock and earthed.

All outside mounted enclosures shall be weatherproof type.

B5.4.4 Identification

All control wires and pneumatic tubing shall be identified with labelling tape or sleeves using word, letters, or numbers that will be cross-reference with the as-built drawings.

All field enclosures shall be identified with nameplates.

All junction boxes shall be marked to identify for "CCMS".

All field devices mounted inside the panel shall be labelled.

All field devices outside the panel shall be identified with nameplate.

B5.4.5 Location

The panel for enclosing interface devices shall be installed immediately adjacent to the controller panels being interfaced.

Room humidity or temperature sensors shall be mounted away from the machines that would generate heat, direct sunlight and diffuser air streams.

Outside air sensors shall be mounted on suitable location on the north building face directly in the outside air.

B5.5 SOFTWARE INSTALLATION

B5.5.1 General

All system software under the Contract including operating software and the third parties software shall be installed initialised, started-up and debugged.

B5.5.2 Database Configuration

The Installations shall comply with the schedule in Clause C5.55 and other schedules as specified in the Particular Specification.

B5.5.3 Colour Graphic Slides

The graphic displays shall be installed in accordance with the floor layout plans and the schematic diagrams, etc. Also, the display shall consist of associated points identified in the point list and shall allow for set point changes as specified.

The full list of graphic slides, legend and fonts shall be approved by the Supervising Officer.

B5.5.4 Reports

The Installations shall configure a certain report to be issued as specified. The A/C Contractor shall provide adequate paper for periodic reports.

B5.5.5 Documentation

It shall cover all software being installed that shall include description of point lists and alarm list, printouts of all reports and graphics, application program listing, etc.

SECTION B6

CENTRAL REFRIGERATION MACHINE, DIRECT EXPANSION EVAPORATORS AND HEAT REJECTION PLANT

B6.1 GENERAL

In this section, refrigeration machine may refer to chiller or heat pump.

Refrigerants are classified in three flammability safety classification according to ANSI/ASHRAE Standard 34-2016: Designation and Safety Classification of Refrigerants. For refrigeration and air-conditioning system in government building projects, only non-flammable Class 1 refrigerants such as R-134a, R-407C and R-410A, etc. should be adopted.

Use of highly flammable hydrocarbon refrigerants under Class 3 should be prohibited and under no circumstances should they be adopted in government building projects.

Use of refrigerants under Class 2 (such as ammonia (R-717)) should only be considered under special consideration on individual project basis and subject to the conditions that such application fully complies with relevant safety procedures and standards such as ANSI/ASHRAE 15-2016 and ANSI/ASHRAE 34-2016 : Safety Standard for Refrigeration Systems, Designation and Safety Classification of Refrigerants and the statutory requirements from local authorities.

All necessary refrigerant and lubricating oil shall be supplied by the A/C Contractor during testing and commissioning and plant operation stages until the plant is accepted at the expiry of the Maintenance Period.

Each unit shall have an electronic/microcomputer control panel factory installed and tested. Full automatic control function shall be provided as detailed in Sections B4, B5, C4 and C5.

Eye wash, shower facilities and drain shall be provided by the Building Contractor and located at the exit(s) of the A/C plant room where the central refrigeration plant is installed.

Refrigerant leakage warning alarm in accordance with ANSI/ASHRAE 15-2016 and ANSI/ASHRAE 34-2016 or BS EN 378-3:2016 shall be installed if the refrigeration plant is installed in indoor environment.

The plant shall be so selected and installed with sufficient space allowed for effective heat dissipation to surrounding air, and for easy maintenance and servicing.

Appropriate corrosion resistant materials and assembly methods shall be used including isolation of dissimilar metals against galvanic interaction, etc.

Mounting and fixing details including details and dimensions of equipment bases, fixing bolts, supporting steelwork, flexible connections, vibration isolators and

any special builder's work requirements, etc. shall be provided by the A/C Contractor in good time to meet the building programme.

Any damage to finishes of the equipment which may have occurred during transit, storage, installation or other causes shall be made good in the manner recommended by the manufacturer and to the satisfaction of the Supervising Officer. Same type of paint shall be used for making good the damages.

Apart from the fixed maintenance platform provided by the Building Contractor as indicated on the Drawings, removable rigid working and service platform shall be equipped for the easy inspection and maintenance of the refrigeration plant and associated equipment. The platform shall be assembled from galvanised steel structure or fibreglass reinforced polyester with stainless steel fixing bolts, nuts and washers, and accessories approved by the Supervising Officer.

All mounting and fixing supports shall be of galvanised steel and exposed metal surface after cutting shall be treated against corrosion and painted in accordance with Part G.

B6.2 LAYOUT AND ISOLATION OF PLANT COMPONENTS

The plant layout shall be so arranged with physical division and valves such that any plant component may be isolated for servicing without completely draining the refrigerant or water circuits of the whole plant and shall follow the ANSI/ASHRAE 15-2016 and ANSI/ASHRAE 34-2016 or BS EN 378-2:2016 to BS EN 378-3:2016. All equipment shall be located within safety marking perimeter. Clear floor safety marking in durable brilliant colour approved by the Supervising Officer shall be provided.

Motor control centre and central monitoring and supervisory console shall be installed inside a control room which is free from water pipes with double glazing window for plant viewing provided by the Building Contractor.

B6.3 DELIVERY OF EQUIPMENT

All equipment delivered to Site shall be properly protected as detailed in Section A3.

The A/C Contractor shall take into account the site constraints when planning the delivery route of the equipment. The delivery route together with information on the imposed loading of the equipment and/or any temporary structural openings required shall be submitted to the Supervising Officer for agreement prior to the transportation of the equipment to Site. Any temporary hoisting or handling facilities and installations to facilitate the delivery of the equipment shall be provided and removed after use by the A/C Contractor.

B6.4 REFRIGERATION PIPEWORK AND FITTINGS

Joints in copper pipe shall be flanged, flared (up to 20 mm OD only), or brazed with or without capillary fittings. Brazing shall be carried out to the requirements

of the B&ES Code of Practice - Brazing and Bronze Welding of Copper Pipe and Sheet.

Joints in steel pipe shall be flanged or welded. Mitre or segmented bends will not be accepted.

Screwed joints will not be accepted in refrigerant pipes except on the equipment accessories. In such cases, the thread shall either be of taper form and used in conjunction with PTFE tape or an anaerobic sealant, or of parallel form associated with machined joint faces and a suitable joint.

Plastic pipe with compression fittings will be accepted for feed piping to control cabinet door mounted pressure gauges and similar fittings. The grades of pipe used shall withstand the test pressure applied and the effects of refrigerant and oil. Plastic pipe will not be accepted for any other refrigerant pipework.

Compression fittings will not be accepted on refrigerant pipework.

Refrigerant pipework shall not be arranged for running compressors in parallel (i.e. with common suction and/or discharge pipes). The use of multi-compressors each having an independent refrigerant circuit in a common evaporator will be permitted provided pressure tests between adjacent refrigerant circuits in the evaporator are carried out during manufacturing.

The pipework shall be so designed that oil in the refrigerant leaving the compressor (and passing any oil separator fitted) shall be carried through the system and back to the compressor at the lowest stage of capacity unloading.

Pipework shall be firmly supported and secured to minimise vibration. Vibration eliminators shall be fitted to the compressor suction and discharge pipes to minimise transmission of vibration or noise. Where indicated, a gas pulsation damper shall be fitted at the refrigerant discharge pipe, in the plant room, as close as possible to the refrigeration compressor.

After completion, the refrigerant pipe work shall be pressure tested as detailed in T&C Procedure No.1 clause 4.1.3.

All parts and components containing refrigerant shall be clean and dry before they are connected to the system. No mill scale shall be permitted in pipes and all pipes shall be capped on Site until welded in. Prior to charging refrigerant to the refrigeration system, field pressure tests shall be carried out in accordance with Part H. Any leak found shall be repaired before the system can be considered tight.

Hangers, clips and other hanging or clamping studs shall be galvanised and they shall not be welded to tubes and pressure vessels containing refrigerant. Pipework and other parts shall be erected and clamped so that vibration and noise are kept to minimum.
Both insulated and uninsulated components, pipes and vessels shall be cleaned and painted with anti-corrosion primer. Finished coatings shall be applied to uninsulated metals. Insulated vessels shall be supported on high density insulation material at the support cradles.

The air-conditioning installation works in connection with the handling (including installing, commissioning and testing) of hydrofluorocarbon (HFC) and blend type refrigerants shall be undertaken by a minimum percentage of workers who shall have a valid certificate of completing satisfactorily the relevant refrigerant handling training courses organised by the recognised association as specified in the contract. Upon request, details and particulars of these workers shall be submitted to the Supervising Officer for approval.

All installed pipework for blended refrigerant shall not be pressurised with refrigerant and air. Blowing of the refrigerant pipework shall not be done by means of the blended refrigerant mixed with air. The A/C Contractor shall pay particular attention and precaution when handling the blended refrigerant pipework installation. For charging of refrigerant to the system, the recommendations from the supplier and the procedures stipulated in the Testing and Commissioning Procedure for Air-conditioning, Refrigeration, Ventilation and Central Monitoring & Control Systems Installation in Government Buildings Hong Kong shall be followed. The work shall also be carried out by trained and qualified persons approved by the Supervising Officer.

B6.5 AIR-COOLED PACKAGED REFRIGERATION MACHINE

B6.5.1 Installation Requirements

(a) When lifting the unit to position, clevis connectors shall be installed through the lifting plates provided on the unit. Required lifting beam dimensions shall comply with the manufacturer's recommendations. To prevent unit damage, the lifting beam shall be positioned so that cables will not be in contact with the unit or otherwise appropriate protection shall be applied on the unit casing.

(b) If the unit is installed on spring isolators, it shall be located on the isolators and the isolators shall be securely fixed to the roof curb structure. The A/C Contractor shall, according to the manufacturer's advice, advise the requirements on strength of the roof curb structure. Selection of the spring isolators shall be submitted to the Supervising Officer for approval prior to execution of work.

(c) The unit shall be installed so that air can circulate through the condenser coils without any hindrance, and the air discharged from the condenser fans is not recycled. If the unit has to be placed near a wall or an obstacle that may prevent satisfactory air circulation, sufficient distance as recommended by the manufacturer shall be maintained between the unit and the obstacle. The location to install the unit shall be submitted to the Supervising Officer for approval prior to execution of work.

(d) Adequate clearance opposite to the evaporator connections as recommended by the manufacturer shall be allowed so that

cleaning of the tubes and maintenance of the evaporator can be carried out. Sufficient space shall be allowed at each end of the unit for opening the fan access panel and the starter door.

(e) All components such as control panels, indicating lights and gauges shall be housed in a weatherproof, watertight, and anti-corrosion metal cabinet with lockable door. The components shall be neatly and tidily arranged within the cabinet with proper labelling in both English and Chinese. A clear and precise circuit diagram, service and safety instructions for the refrigeration machine separately enclosed in waterproof enclosures shall be provided in a conspicuous position within the cabinet.

(f) The A/C Contractor shall provide a rigid sun/rain shelter in front of the control panel, starter and equipment cabinet of each refrigeration machine unit. The shelter shall be constructed of minimum 2 mm thick galvanised sheet steel and reinforcement framework or FRP materials. Rim inclining downward along the edges of the shelter or similar provision shall be provided to prevent water from flowing to the underside of the shelter and dripping onto the control panels or equipment cabinets. All metal work shall be treated with suitable anti-corrosion paintings. The shelter shall be made of adequate sizes to cover the above-mentioned panels and cabinets and extend at least 1 m in depth from the refrigeration machine to provide a protective cover for the panels and cabinets, and for the servicing personnel, to the satisfaction of the Supervising Officer.

B6.5.2 Water Piping Connection

(a) All water piping to the unit shall be thoroughly flushed before making the final piping connections to the unit.

(b) To avoid possible equipment damage, untreated or improperly treated system water shall not be used.

(c) Sufficient vents shall be provided at high points in the piping to bleed air from all water circuits. Necessary pressure gauges shall be installed to monitor the entering and leaving water pressures. Shutoff valves shall be provided between the pressure tapping point and the pressure gauge to enable the gauge to be replaced and the zero point to be checked while the plant is running.

(d) Thermometers shall be installed in the water circuits to monitor entering and leaving water temperatures. A balancing valve shall be installed in the leaving water line for water flow balancing.

(e) Shutoff valves shall be installed in both the entering and leaving water lines to the evaporator so that the evaporator can be isolated for maintenance when required.

(f) A pipe strainer shall be installed in the entering water line to prevent water-born debris from entering the system.

(g) Vibration eliminator shall be installed in the entering and leaving water lines to the unit.

(h) A shutoff valve shall be installed in the drain line of the evaporator.

(i) A water pressure relief valve shall be installed in the evaporator water system.

B6.5.3 Installation and Connection of Temperature Sensors

(a) To enable the sensor to read a well mixed water temperature, the sensor finger shall be positioned at a substantial distance from the evaporator and avoid placement near elbows.

(b) Thermo-contact paste shall be put on each sensor finger before inserting the sensor to ensure better thermal conductivity. The bottom of the sensor shall be in touch with the sensor finger.

(c) The electrical cables connecting the temperature sensors shall be installed in G.I. conduit.

B6.5.4 Installation of Flow Sensing Devices

(a) Flow switch or differential pressure switch with pump interlocks shall be installed to sense system water flow. The flow switch shall be installed in series with the pump interlocks to protect the refrigeration machine.

(b) The flow switch shall be mounted upright, with a minimum of 5 pipe diameters straight, horizontal run on the water circuit. The flow switch shall not be installed close to elbows, orifices or valves.

B6.5.5 Installation of Energy Metering Devices

(a) Electricity meters and thermal energy meters shall be installed to continuous measure, record and monitor the electricity consumption, energy input and output, cooling/heating power, coefficient of performance, and energy performance for each refrigeration machine. Independent electricity meters and thermal energy meters in accordance with ASHRAE Guideline 14-2014 and ASHRAE Guideline 22-2012 shall be provided by the A/C Contractor to measure the energy performance of the whole refrigeration system.

(b) Ambient temperature sensors shall be installed to continuous measure, record and monitor the outside air temperature, outside air dry-bulb, and relative humidity for the whole refrigeration system.

(c) The electricity meters in accordance with ANSI C12.1-2014, and ANSI C12.20-2015 or IEC 62053-22:2003+A1:2016, IEC62058-11:2012, IEC62058-21:2012 and IEC 62058-31:2012 shall be installed with 10 years certified life.

(d) Thermal energy meters in accordance with ANSI C12.20-2015 and IEC 62053-21:2003+A1:2016, IEC62058-11:2012, and IEC62058-21:2012 shall be installed with 10 years certified life.

(e) Type test report of the electricity meters and thermal energy meters shall be submitted to the Supervising Officer for approval prior to execution of work.

(f) The electricity meters and thermal energy meters shall be connected to Central Control Monitoring System, if such system is provided, to optimise the operation of the refrigeration system. The measurement and data collection details shall comply with Code of Practice for Energy Efficiency of Building Services Installation (2018 Edition).

B6.6 WATER-COOLED PACKAGED REFRIGERATION MACHINE

B6.6.1 Installation Requirements

(a) Same as Clause B6.5.1 (a).

(b) Elastomeric isolation pads shall be installed on the foundation for the unit to isolate the vibration of the unit. The A/C Contractor shall advise the Supervising Officer the strength and mass of the foundation to support the unit operating weight.

(c) Sufficient space shall be allowed around the unit for unrestricted free access of the Installations and maintenance personnel to all service points. Adequate clearance as recommended by the manufacturer shall be allowed so that cleaning of the tubes of the evaporator and condenser and maintenance of the various components can be carried out effectively. Sufficient vertical clearance above the unit shall also be allowed. No services such as ductworks and water pipes shall be located over the compressor motor.

B6.6.2 Water Piping Connection

(a) Same as Clause B6.5.2 (a).

(b) Same as Clause B6.5.2 (b).

(c) Sufficient vents shall be provided at high points in the piping to bleed air from the water circuits. Necessary pressure gauges shall be installed to monitor the entering and leaving chilled or hot/condensing water pressures. Shutoff valves shall be provided to the gauges to isolate them from the system when required.

(d) Thermometers shall be installed in the lines to monitor entering and leaving chilled and condensing water temperatures. A water balancing valve shall be installed in the leaving chilled or hot/condensing water lines for water flow balancing.

(e) Shutoff valves shall be installed in both the entering and leaving chilled or hot/condensing water lines so that the evaporator and condenser can be isolated for maintenance and servicing when required.

(f) A pipe strainer shall be installed in the entering chilled or hot/condensing water lines to prevent water-born debris from entering the system.

(g) Vibration eliminator shall be installed in the entering and leaving chilled or hot/condensing water lines to the unit.

(h) A shutoff valve shall be installed in the drain line of the evaporator and condenser.

(i) A water pressure relief valve shall be installed in the evaporator and condenser water system.

B6.6.3 Installation and Connection of Temperature Sensors

(a) Same as Clause B6.5.3 (a).

(b) Same as Clause B6.5.3 (b).

(c) Same as Clause B6.5.3 (c).

B6.6.4 Installation of Flow Sensing Devices

(a) Flow switches or differential pressure switches with pump interlocks shall be installed to sense system water flow. The flow switches shall be installed in series with the pump interlocks for either chilled or hot/condensing water circuits to protect the machine.

(b) Same as Clause B6.5.4 (b).

B6.6.5 Installation of Energy Metering Devices

Same as Clause B6.5.5

B6.7 AIR-COOLED CONDENSER

Air cooled condensers mounted outside buildings shall have weatherproof fan motors. The units shall discharge air vertically upwards. If specified to discharge horizontally, they shall be protected by an integral wind deflector or purpose-made baffle. The structure and casing of units shall be constructed of material which is either corrosion resistant or treated against corrosion after manufacture in the factory.

The unit shall be installed on vibration isolation devices as specified in Sections B8 and C8. The A/C Contractor shall, according to the manufacturer's recommendation, advise the requirements on strength of the roof curb structure for supporting the unit. Selection of the vibration isolators shall be submitted to the Supervising Officer for approval prior to execution of work.

The unit shall be installed so that air can circulate through the condenser coils without any hindrance, and the air discharged from the condenser fans is not recycled. If the unit has to be placed near a wall or an obstacle that may prevent satisfying air circulation, sufficient distance as recommended by the manufacturer shall be maintained between the unit and the obstacle.

B6.8 AIR-COOLED EVAPORATOR

The cooling unit shall be dehydrated, charged with an inert gas, pressure tested and sealed after manufacture.

B6.9 COOLING TOWER

The fiber-reinforced plastic (FRP) warm water distribution or hot water basin shall be covered by removable FRP covers that keep out sunlight and give a finished appearance to the tower. The cold water basin shall be supported by a structural beam assembly provided by the cooling tower manufacturer. Builder's work supports by the Building Contractor, exact tower orientation and architectural aesthetic consideration shall be submitted in sufficient time according to the building programme to the Supervising Officer for approval.
The make-up water pipe inlet shall be fitted with a strainer and flow meters capable of being used to record the maximum rate of make-up water in m3/hr, and the make-up water consumption in m3. Isolation valves, unions, and by-pass valve shall be provided to facilitate meter removal for maintenance and servicing.

A bleed pipe with stop valve and flow regulating device shall be provided on each cooling tower to the nearest builder's drain.

Control and chemical or ozone treatment plants shall be located near to the cooling towers and they shall be installed inside a covered plant room/space with proper ventilation.

B6.10 HEAT RECOVERY CHILLER

Refer to Clause C6.23.

B6.11 TOTAL ENERGY HEAT PUMP

Refer to Clause C6.26.

B6.12 VIBRATION ISOLATION

All plants offered shall have minimum vibration and noise levels during operation, with particular attention to the sound pressure level requirements from different sources while all plants operating in full capacity shall comply with the requirements of the Environmental Protection Department or other statutory noise control requirements issued prior to tendering, whichever is more stringent. The A/C Contractor shall be responsible for provision of adequate vibration isolation and/or sound attenuation measures for the refrigeration plant to meet the requirements as detailed in Sections B8 and C8 and to the satisfaction and acceptance of the Supervising Officer.

B6.13 ELECTRICAL WORK

The A/C Contractor shall supply and install suitable power cables, cable trays, G.I. supports, starters/motor drives, isolators, control, safety earth bonding and all necessary accessories to connect power from the isolator to each electricity-driven equipment. The A/C Contractor shall allow for adequate cable size for power/control/earthing systems and protection devices to meet the current demand, voltage drop and fault tripping requirements of the equipment offered.

B6.14 SAFETY ANCILLARIES FOR AMMONIA REFRIGERATION MACHINE

B6.14.1 Pressure Relief Device

A pressure-relief valve connected via discharge pipe in accordance with relevant Sections of ANSI/ASHRAE15-2013(Packaged with ANSHI/ASHRAE 34-2013) or ANSI/IIAR Standard 2-2014 shall be provided at both high side and low side pressure vessels of the ammonia refrigerating system which automatically relieves pressure of pre-determined excessive pressure due to emergency conditions. A solenoid valve shall be provided in addition to the pressure-relief valve which is opened by means of a manual emergency switch. The solenoid valve shall be installed in a parallel by-pass circuit of the pressure relief valve on the pressure vessels. The required capacity of the pressure relief valves shall be determined in accordance with 2017 ASME Boiler and Pressure Vessel Codeand the maximum length and size of the discharge pipe shall be determined in accordance with

relevant sections as stipulated in ANSI/ASHRAE 15-2016 and ANSI/ASHRAE 34-2016.

An emergency discharge system including discharge pipeline size, length, pipe route and material, valve size, common header, pipe support, control valve box and termination diffuser, etc. shall be designed and constructed by the A/C Contractor according to ANSI/ASHRAE 15-2016 and ANSI/ASHRAE 34-2016 or ANSI/IIAR 2-2014- relevant sections. All emergency discharge pipelines shall be connected above the liquid refrigerant level on the high pressure side and the low pressure side of the system. The lines shall be pitched so as to drain the system. These lines shall extend into an emergency refrigerant control box readily accessible outside the ammonia refrigeration machine plant room. The box shall be locked and labelled with "Emergency Refrigerant Control Box - Ammonia R-717". A readily accessible stop valve labelled with "High Pressure Refrigerant Discharge Valve" and a suitable pressure gauge shall be installed on the discharge pipes within the emergency refrigerant control box. The emergency discharge lines shall be connected to a common riser for discharge to the atmosphere. At the upper extremity of the common riser, it shall be fitted with a diffuser for mixing the refrigerant with air. The discharge termination shall be within 600mm of one side of the discharge outlet of the emergency ventilation fan at roof level to ensure good mixing of ammonia/air by forced ventilation. The emergency ventilation system shall in this case operate within 1 second after the actuation of any one of the pressure relief devices or the manual discharge system.

The safety refrigerant relief discharge point shall be sited at a location away from any pedestrian access as approved by the Supervising Officer. A clear warning label shall be displayed next to the discharge point.

B6.14.2 Emergency Apparatus

The A/C Contractor shall provide two sets of the FSD approved type respirators and protective clothing and one First Aid Kit and one portable ammonia detector ranged 10-1500 ppm inside a waterproof stainless steel cabinet for use in emergency service. The equipment shall be stored near to the entrance of the ammonia refrigeration machine plant room or as indicated on the Drawings. The respirator shall be full face gas mask, front head sparing or back mounted type, with industrial size ammonia canister. The protective clothing shall include gloves, shoe covers, and aprons impervious to ammonia. The First Aid Kit shall contain the Saturated Solution of Sodium Thiosulsulfate, or Sterilised Water, Sterile Compresses or Dressings, 0.5% Ponto Caine Solution (with eye dropper), and Rubber Bulb Syringe.

B6.14.3 Warning Plate

The A/C Contractor shall also provide the FSD approved type warning plates with the words "DANGER-AMMONIA ASPHYXIATING GAS" to be prominently displayed on each exit doors and gas pressure relief/discharge point of the ammonia refrigeration machine plant room in 120 mm high in both English and Chinese characters.

B6.14.4 Ventilation

The emergency, independent mechanical ventilation of the ammonia refrigeration machine plant room is provided by means of exhaust ductwork constructed of stainless steel AISI 316, extraction fans and its associated cables as shown on the Drawings. The capacity of the extractors for emergency ventilation shall comply with the ventilation requirement stipulated in relevant sections of ANSI/IIAR 2-2014 and/or as shown on the Drawings, whichever is greater. The emergency ventilation system shall be actuated automatically by an ammonia vapour detector when the concentration of ammonia exceeds 0.03% (300 ppm) when leakage occurred or when the pressure relieve valves are actuated or when the manual discharge system is actuated. Manual means for actuating the emergency ventilation system by means of emergency control switch shall be provided and located as shown on the Drawings.

B6.14.5 Ammonia Vapour Leakage Detection System

A/C plant room where ammonia refrigeration machine is installed shall be provided with an ammonia vapour leakage detection system to monitor and indicate at least two concentration levels to warn the people in the surrounding and automatically actuates the emergency measures. The ammonia leakage detectors shall be based on semiconductor techniques and has a stable zero point, long life time up to 8 years and good resistance to fouling by gases containing high concentration of ammonia. The detectors shall have an adjustable relay output of 4-20 mA analogue signal with a range of 0-1500 ppm for remote logic processing in the digital controllers. Fixed ammonia leakage detectors shall be installed. The low level alarm at 0.03% (300 ppm) by volume shall be actuated to warn the responsible personnel in the refrigeration machine plant room and start the emergency ventilation system automatically. The high level alarm at 0.1% (1000 ppm) by volume shall be actuated to shut down automatically the refrigeration system. Manual emergency switches shall also be provided immediately outside the A/C plant room. The ammonia vapour leakage detection system shall be powered by battery supply system with battery charger. The power supply for all electrical consuming equipment shall be maintained for at least 6 hours for pre-alarm condition and 2 hours for full alarm condition. The ammonia detection panel shall be made of 1.2 mm thick stainless steel sheet and located as shown on the Drawings. The indication lamps and manual emergency buttons of the ammonia detection panel shall also be repeated in the Main Fire Alarm Annunciation Panel inside the Fire Services Control Centre by means of dry contacts and relays. In

addition, means shall be provided by the A/C Contractor to interface the ammonia detection panel with the CCMS if such system is provided.

B6.14.6 Operation of Condenser Fans and Associated Safety Protection

For air-cooled ammonia refrigeration machines, the condenser fans shall have two operation modes. During normal application, the fans shall run at low speed to achieve low noise level adequate for the ventilation requirement. On detection of ammonia leakage, the fans shall be speeded up to provide larger ventilation rate to dilute and blow away the ammonia to the atmosphere. Water sprinkler installed in the machine refrigerant compartment shall also be activated to dilute and drain away the ammonia safely.

B6.15 SOLAR HEATING SYSTEM

B6.15.1 General

The installation details should be in accordance with the instruction prepared by the manufacturer.

The plant shall be so selected and installed with sufficient space allowed for maintenance and servicing. All mountings and fixing supports shall be hot dip galvanised steel. Exposed metals shall be treated to prevent corrosion and painted in accordance with Part G (Painting, Finishing and Protective Treatment).

B6.15.2 The solar collectors shall be mounted at a tilt angle to the horizontal and faced south to achieve maximum solar gain for the application.

B6.15.3 The A/C Contractor shall design, supply and install hot dip galvanised steel maintenance platform, catwalk and cat ladder for future maintenance access of the solar collector system. The A/C Contractor shall design the fixing method and provide calculation for the solar collector system for approval by the Supervising Officer. The mounting brackets and supports for the solar collector system shall be designed by a registered structural engineer to withstand the most severe wind load conditions in Hong Kong.

B6.15.4 The Feed and Expansion tank shall be mounted at the highest point of the solar heating system. All water pipework shall be completed with flexible closed cell elastomeric insulation of sufficient thickness and with coating for UV protection.

B6.15.5 Operation and Maintenance

6.15.5.1 General

The operation and maintenance details should be in accordance with the instruction recommended by the manufacturer.

Fixed maintenance platform, including working and access service platform, shall be made of hot dip galvanised steel, and shall be designed and equipped for easy inspection and maintenance of the solar heating system and associated equipment as recommended by the solar collector manufacturer.

6.15.5.2 Sufficient maintenance space shall be allowed for access, servicing, and cleaning of the solar collector panels.

SECTION B7

ELECTRIC MOTORS AND ELECTRICAL EQUIPMENT

B7.1 LOW VOLTAGE-GENERAL

Unless otherwise specified, the A/C Contractor shall provide and install all low voltage electrical equipment necessary for the complete Installations under the Contract and shall carry out all necessary wiring from the points of power supply provided by others as indicated on the Drawings.

The A/C Contractor shall be responsible for the accuracy of all installation and shop drawings and wiring diagram and for the correct internal wiring of all pre-wired equipment supplied under the Contract.

All electrical equipment, wiring and installation work, and materials shall comply with the provisions of the relevant parts of the Electrical General Specification.

Motor arranged for automatic restart shall have a label of durable material permanently fixed to it and in a prominent position clearly inscribed as per the Electrical General Specification Clause B9.1.6.

B7.2 LOW VOLTAGE-ELECTRIC MOTORS

The low voltage electric motors shall comply with Clause B9.1 of the Electrical General Specification.

B7.3 LOW VOLTAGE-VARIABLE SPEED DRIVES

The drives shall be either wall mounted or floor mounted in a well ventilated location and in accordance with the manufacturer's standard installation recommendations.

The drives shall be located away from any nearby water pipework to avoid possible damage by water leaking or water pipe bursting. In case that such location could not be identified, the A/C Contractor shall provide all necessary protective means to avoid the damage.

The distance between the drives and the controlled motors shall be within the range as recommended by the manufacturer. The A/C Contractor shall submit calculations including his selected interconnecting cable sizes to the Supervising Officer to substantiate that the overall performance shall meet the design requirements.

For essential air conditioning services subject to the approval of the Supervising Officer and requiring to meet special building functions and client's operational requirements, all major and essential electric motor drives in the air conditioning systems shall be configured in such a way that there is a minimum chance of serious interruption and/or breakdown of the entire plant operation due to a single

point of failure for major and essential electric motor drives in the systems. The A/C Contractor shall provide sufficient redundancy and/or backup provisions such as installation of alternate motor starters as appropriate according to the Electrical General Specification Clause C5.26.4 where necessary for maintenance by-pass of variable speed drives in the motor control equipment and ancillaries.

B7.4 LOW VOLTAGE-MOTOR SWITCHGEAR, STARTER AND CONTROL PANELS

The low voltage motor switchgear, starter and control panels shall comply with Clause B9.2 of the Electrical General Specification.

B7.5 LOW VOLTAGE-AUTOMATIC POWER FACTOR CORRECTION CAPACITORS

The capacitor bank shall be wall or floor mounting cubicle-type, built up from static primary capacitor unit. The capacitor bank together with its associated equipment shall not be installed inside the switchboard, where practicable. However, if it is not practical due to physical constraint or other justified reasons, the equipment shall be installed in a separate compartment segregated from the rest of the switchboard.

B7.6 HIGH VOLTAGE– ELECTRIC EQUIPMENT

The high voltage electric equipment shall comply with the relevant sections of the Electrical General Specification.

Equipment	Electrical General Specification
High Voltage - General	Clause B9.3
High Voltage - Electric motors	Clause B9.4
High Voltage - Motor control switchboards	Clause B9.5
High Voltage - Auto-transformers	Clause B9.6
High Voltage - Power factor correction capacitors	Clause B9.7
High Voltage - Power cables	Clause B9.8

SECTION B8

NOISE AND VIBRATION CONTROL

B8.1 GENERAL

The A/C Contractor shall install sufficient noise and vibration control measures on the plant/equipment, the interconnected piping, ductwork and conduit so that when the installed plant/equipment are put into operation, the resulting noise and vibration levels at locations within the building and at adjacent or nearby buildings shall not exceed the acceptable limits.

Unless otherwise specified in the Particular Specification, the total noise level in occupied areas within the building, whether it be airborne, structure-borne or ductwork-borne, shall not exceed the following limits when all the plant/equipment installed by the A/C Contractor are put into operation: -

Table B8.1 Noise Control Criteria

Broadcasting and recording studios	NC 25
Concert and opera halls	NC 25
Theatres, assembly halls and churches	NC 30
Cinemas	NC 35
Hospital wards and operating theatres	NC 35
Homes, bedrooms	NC 35
Private offices, libraries, courtrooms and schoolrooms	NC 35
General offices	NC 40
Mechanised offices	NC 45
Restaurants, bars, cafeterias and canteens	NC 45
Department stores and shops	NC 45
Swimming baths and sports arenas	NC 50
Kitchens	NC 50
Factories (light engineering)	NC 65
Factories (heavy engineering)	NC 75

The specified noise criteria shall apply based on fundamental principles, such as those in ASHRAE Fundamentals SI Handbook 2017 to all areas as measured at a level of 1.2 to 1.8 m above the floor and the measuring points shall avoid exact geometric center of the room and any location within 1m of a wall, floor, or ceiling of the rooms.

The Corrected Noise Level at potential Noise Sensitive Receiver in the adjacent or nearby building, if so identified in the Contract, shall not exceed the Acceptable Noise Level stipulated in the Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites issued by the Environmental Protection Department when the plant/equipment installed by the A/C Contractor are put into operation.

B8.2 EQUIPMENT BASES

B8.2.1 General

Floor mounted equipment shall be installed on 100 mm high concrete housekeeping pads provided by the Building Contractor covering the whole floor area requirements of the equipment bases plus a minimum of 150 mm further on each side or on inverted beams at roof. Vibration isolators are then mounted on this concrete pad or inverted beams.

Unless otherwise specified in the Particular Specification, plant/equipment to be isolated shall either be supported by structural steel bases or concrete inertia bases.

B8.2.2 Welded Structural Steel Bases

Detailed design calculation of the base and its anti-vibration isolator arrangements plus shop drawings for each base shall be provided for approval by the Supervising Officer before manufacture.

B8.2.3 Concrete Inertia Bases

Detailed design calculation of the base and its anti-vibration arrangements plus shop drawings for each base shall be provided for approval of the Supervising Officer before manufacture.

B8.3 VIBRATION ISOLATORS

The following types of vibration isolation mountings or suspensions are not exhaustive but serve to cover the main types that shall be applied as appropriate unless otherwise stated in the Particular Specification.

B8.3.1 Type 'A' - Free Standing Spring Mounts

Springs shall be designed and installed so that the ends of the springs remain parallel. They shall be corrosion-protected.

Submittals for approval shall include spring diameters, "compressed" spring height, "solid" spring height, rated capacities and rated deflections.

B8.3.2 Type 'B' - Restrained Spring Mounts

A minimum of 10 mm clearance shall be maintained around restraining bolts and between the housing and the spring so as not to interfere with the spring action. Limit stops shall be out of contact during normal operations.

B8.3.3 Type 'C' - Double Deflection Neoprene Mounts

These mountings shall have a minimum static deflection of 8.5 mm. Bolt holes shall be provided for applications where bolting down is required. They shall be carefully positioned such that all supporting mounts would be properly loaded and the weight load on each mount would be evenly distributed over the entire surface.

B8.3.4 Type 'D' - Neoprene Pads

Where necessary, pads may be bolted through with bolts isolated from the machine by neoprene grommets. Alternatively, "waffled" neoprene pads can be used without holding down bolts where the vibration is minimal and the weight of machine is such that the resultant friction is adequate and the machine is unlikely ever to move. They shall be carefully positioned such that all supporting pads will be properly loaded and the weight load on each pad will be evenly distributed over the entire surface.

B8.3.5 Type 'E' - Spring Hangers

Springs shall have a minimum additional travel to solid equal to 50% of the rated deflection.

Submittals for approval shall include scale drawing of the hanger showing its 30º to 35º swing capability.

Application - See Clause B8.5.2 for pipework vibration isolation and Clause B8.6 for ductwork vibration isolation.

B8.3.6 Type 'F' - Spring and Double Deflection Neoprene Hangers

Submittals for approval shall include scale drawing of the hanger showing its 30º to 35º swing capability.

Application - See Clause B8.5.2 for pipework vibration isolation and Clause B8.6 for ductwork vibration isolation.

B8.3.7 Type 'G' - Pre-Compressed Spring Hangers

Submittals for approval shall include scale drawing of the hanger showing its 30º to 35º swing capability.

Application - See Clause B8.5.2 for pipework vibration isolation and Clause B8.6 for ductwork vibration isolation.

B8.3.8 Type 'H' - All Directional Anchor Units

Submittals for approval shall include rated capacities and rated deflections.

Application – The units may use to provide high frequency noise and vibration isolation for those locations where movement must be controlled.

B8.3.9 Type 'I' - Pipe Anchors and Guides

Submittals for approval shall include rated capacities and rated deflections.

B8.3.10 Type 'J' - Split Wall/Floor Seals

The seals shall be tightened around the pipes to eliminate clearance between the inner sponge faces and the piping.

Concrete may be packed around the seals to make it integral with the floors, walls or ceilings if the seals are not already in place around the pipes prior to the construction of the building members.

Seals shall project a minimum of 25 mm past either face of the walls.

Application – The seals may be used to prevent noises generated within equipment rooms or plant rooms from leaking through the spaces around piping which pass through walls, ceilings or floors of these rooms.

B8.3.11 Type 'K' - Horizontal Thrust Restrains

The assembly shall be furnished with one threaded rod and two angle brackets for attachment to both the equipment and ductwork or the equipment and the structure. Horizontal restraints shall be attached at the centre line of thrust and symmetrically on either side of the unit.

B8.3.12 Type 'L' - Built in Inertia Block Plant Support

Where specified, the A/C Contractor as the case may be, shall provide plant foundations and housekeeping pads in form of large concrete blocks recessed into the main floor slab.

B8.4 PLANT/EQUIPMENT VIBRATION ISOLATION

B8.4.1 General

All rotating or reciprocating equipment shall be mounted on vibration isolation mountings or suspended from vibration isolation hangers.

The A/C Contractor shall ensure that there is no rigid connection in whatever form between the isolated equipment and the building

structure which will otherwise short-circuit the vibration isolation system and degrade its performance. This includes the necessary co-ordination with other trades by the A/C Contractor.

All isolators shall operate in the linear portion of their load versus deflection curve. The load versus deflection curves shall be furnished by the manufacturer, and must be linear over a deflection range of not less than 50% above the design deflection.

All vibration isolators shall have their known undeflected heights or calibration markings so that, after adjustment when carrying their loads, the deflection under load can be verified, thus determining that the load is within the proper range of the device and that correct degree of vibration isolation is achieved according to the design.

The static deflection of the isolator at each support point shall not differ from the design objective for the equipment as a whole by more than ±10%.

The ratio of lateral to vertical stiffness for spring shall be neither less than 0.9 nor greater than 1.5.

The A/C Contractor shall verify that the isolation requirements are complete, the equipment offered is correct and suitable in meeting the design requirements on the vibration levels.

The installation of all vibration isolators, hangers and associated equipment bases shall be carried out strictly in accordance with Drawings, the approved manufacturer's written instructions, and where indicated under the direct supervision of the manufacturer's representative.

B8.4.2 Method of Installation

The equipment structural steel or concrete inertia base shall be placed in position and supported temporarily by blocks or shims. The machinery shall then be installed on the base and when that is complete, the isolators are to be installed without raising the machine and frame assembly.

After the entire Installations is complete and under full operational load, the isolators shall be adjusted such that the load, are transferred from the blocks to the isolators. When all isolators are properly adjusted, the blocks or shims will become slightly free and can then be removed.

The springs of vibration isolators shall in general have a loaded working height equal to 1.0 to 1.5 times the outside diameter of the spring and shall be capable of being compressed to approximate 50% of their unloaded height.

Where any vibration isolation system permits equipment motion in all directions, provide where necessary additional resilient restraints shall

be provided where necessary to flexibly limit the lateral movement of the equipment to 6 mm at start and stop.

Prior to start-up, remove all foreign matter underneath the equipment base and verify that the vibration isolation system is not short-circuited.

Electrical circuit connections to isolated equipment shall be looped to allow free motion of isolated equipment.

B8.5 PIPEWORK VIBRATION ISOLATION

B8.5.1 General

Unless otherwise indicated, all piping located in mechanical equipment room and having connection to vibrating equipment shall be isolated from the building structure by means of noise and vibration isolation hangers for a distance of at least 15 m or 100 times the pipe diameter from the vibrating equipment, whichever is the greater. At least three of the first hangers from the equipment should provide the same deflection as the equipment isolators, with a maximum limitation of 50 mm deflection. The first three hangers adjacent to the equipment shall also be of "positioning" or "pre-compressed" type, to prevent load transfer to the equipment flanges when the piping system is filled. This "floated" pipe run shall include, where situation permits, bends in two mutually perpendicular directions in order to give three degrees of freedom of movement, with approximately equal distance between successive elbows or bends.

All piping over 50 mm in diameter and for any piping suspended below or near noise-sensitive areas shall be suspended by vibration isolated hangers. Hangers adjacent to noise-sensitive areas shall be Type ‘F’.

For floor-supported piping in equipment rooms or adjacent to isolated equipment, the vibration isolators shall be selected appropriately. The first two adjacent floor supports shall be Type ‘B’, with a blocking feature that prevents load transfer to equipment flanges as the piping is filled or drained.

Where specified in the Particular Specification, all horizontal and vertical pipework throughout the building which has connection to vibrating equipment shall also be isolated from the building structure by means of noise and vibration isolation guides and supports.

All piping to be isolated shall freely pass through walls and floors without rigid connections. Penetration points shall be sleeved or otherwise formed to allow passage of piping, and a clearance of 10 to 15 mm around the outside of the piping shall be maintained. This clearance space shall be tightly packed with glass fibre or rock wool and caulked airtight after installation of piping. Alternatively, factory fabricated Type 'J' split wall/floor seals may be used.

The inlet and outlet connections of all vibrating equipment shall be fitted with either flexible connectors or flexible hoses as appropriate.

B8.5.2 Horizontal Pipe Isolation

Where horizontal pipe isolation is required, the first three pipe hangers in the main line near the mechanical equipment shall be of Type 'G' and the hangers for the horizontal run in all other locations shall be of Type 'E' or Type 'F', the latter being used for more sensitive situations where a higher degree of noise and vibration attenuation is required.

Type 'G' hangers shall have the same static deflection as that of the mountings under the connected equipment. Type 'E' and Type 'F' hangers shall have a minimum deflection of 20 mm.

B8.5.3 Pipe Riser Isolation

Where pipe riser isolation is required, the pipe risers to be isolated shall be suspended from Type 'G' hangers or supported by Type 'B' mountings and anchored with Type 'I' pipe anchors or guided by Type 'I' pipe guides. Steel spring deflection shall be a minimum of 20 mm except in those expansion locations where additional deflection is required to limit deflection or load changes to within plus or minus 25% of the initial stress.

B8.5.4 Flexible Connectors

Flexible connectors shall be fitted to the inlet and outlet connections of all pumps, water chillers, refrigeration machine, water towers and other centrifugal or reciprocating vibrating equipment.

Flexible connectors shall be full line size of the equipment connection and fitted as close to the source of vibration as is practicable. Straight connectors shall, where practicable, be installed in a position that is parallel to the equipment shaft as equipment vibration tends to be most severe in a direction radial to the shaft.

All flexible connectors shall be provided with end restraint to counteract the pressure thrust.

Manufacturers' recommendations on restraints, pressure, and temperature limits shall be strictly followed during the installation.

B8.5.5 Flexible Metallic Hose

For higher operating temperatures and pressures, vibrational movement generated by pumps, chillers, refrigeration machine, water towers, air handling units and other centrifugal or reciprocating vibrating equipment shall be accommodated by braided flexible metallic hoses. Allowable stress levels shall be within the units as prescribed in PD 5500: 2018+A1:2018.

The lengths of the flexible metallic hoses shall be in accordance with manufacturer's recommendation.

Since the braid is stretched taut by the pressure in the axial direction, hoses cannot accept axial motion. Therefore, the hoses shall be installed on the equipment side of the shut off valves and be installed parallel to the shaft for best performance so that the vibration movement is perpendicular to the axis of the hose. A Type 'I' pipe anchor capable of withstanding the deflection forces generated by the flexible hose shall be installed immediately after the hose in order to force the hose to flex transversely, otherwise the hose will serve little purpose.

Two hoses at right angles to each other shall be provided when major vibrational motions to be isolated exist in two planes.

B8.6 DUCTWORK VIBRATION ISOLATION

Flexible connections shall be provided between the vibrating equipment and the ductwork. Thrust restraints shall be used to maintain a slack position of the flexible ductwork connections.

Unless otherwise specified, all discharge ductwork which runs for a distance of 15m from the connected vibrating equipment with a discharge pressure of 1kPa or above shall be isolated from the building structure by means of Type 'E' hangers provided with top and bottom eye bolts for flat iron hanger strap and ductwork strap respectively. Spring deflections shall be minimum 20 mm.

Except where the ductwork passing through compartment walls requires a fire damper, all ductwork to be isolated shall freely pass through walls and floors without rigid connections. Penetration points shall be sleeved or otherwise formed to allow passage of ductwork, and a clearance of 20 to 32 mm around the outside surfaces of the ductwork shall be maintained. This clearance space shall be tightly packed with glass fibre, caulked airtight and sealed with approval sealant after installation of ductwork.

In case where fire damper is required, ductwork to be isolated shall be fitted with a flexible joint on the side of the fire damper where the vibration is originated.

B8.7 DUCTWORK ACOUSTIC INSULATION

Acoustic linings shall not be applied to the interior of the ductwork unless otherwise specified.

Transverse joints of the ductwork liner board shall be neatly butted and there shall be no gap in between the board shall be cut to assure tight, overlapped corner joints. Board shall be adhered to the sheet metal ductwork with 100% coverage of adhesive conforming to ASTM C916-85(2007), and all exposed edges and joints shall also be coated with adhesive. Board shall be additionally secured with mechanical fasteners which shall start with 75 mm of the upstream transverse

edges and 75 mm from the longitudinal joints and be spaced at a maximum of 150 mm centres around the perimeter of the ductwork and 100 mm from corner joints. Elsewhere the fasteners shall be spaced at a maximum of 150 mm centres in the direction across width of ductwork and 400 mm centres in the direction along length of ductwork and not more than 75 mm from longitudinal joints and 100 mm from corner joints. Entering and leaving edges of the ductwork liner boards shall be provided with continuous sheet metal edge protectors.

Ductwork internal linings shall not be installed within 1 m of the fire damper.

Dimensions of lined ductwork are to be clear inside dimensions after lining has been installed.

B8.8 ACOUSTIC DUCTLAG

Acoustic duct lag shall be applied, only where indicated, to the exterior of the work to prevent noise break-in or breakout through the duct wall.

The acoustic duct lag shall be installed in such a way that the material is completely decoupled from the vibrating duct wall. The A/C Contractor shall submit installation details to the Supervising Officer for approval prior to installation.

B8.9 DUCTWORK SILENCERS

Ductwork silencers shall be supplied and installed as indicated in the Particular Specification or Drawings.

Mani folded silencers shall be installed with continuous metallic nosing crimped in place. Nosing pieces and tails shall be provided as per manufacturer's design.

Before ordering ductwork silencers, the A/C Contractor shall submit for the Supervising Officer's approval the proposed manufacturer's certified test data for pressure drop and insertion loss ratings.

The silencers shall be located at least three ductwork equivalent diameters from fans, coils, elbows, branch take offs, or other ductwork elements.

B8.10 ACOUSTIC DOORS

The A/C Contractor shall supply and install proprietary made acoustic doors to plant rooms only where specified in the Particular Specification or Drawings.

B8.11 ACOUSTIC LOUVRES

The A/C Contractor shall supply and install acoustic louvres to the external walls of plant rooms only where specified in the Particular Specification or Drawings.

B8.12 ACOUSTIC ENCLOSURES

B8.12.1 General

Where specified for in the Particular Specification or Drawings, double-wall, insulated, and air-pressure-tight acoustic enclosures for housing noisy plant or machinery shall be provided as specified and installed in strict accordance with the installation details and instructions from the specialist manufacturer in order to achieve the published standards of construction and performance.

B8.12.2 Access Doors and Louvres

When required as shown on the Drawings, access doors and louvres forming part of the complete acoustic enclosures shall be of acoustic type and be so fixed and installed without degrading the acoustical performance.

B8.12.3 Openings and Sealing

All openings with dimensions greater than 150 mm shall be factory/workshop cut and framed.

The clearance space between the acoustic enclosure and any ductwork, pipes, or conduits passing through the enclosure shall be tightly packed with glass fibre or rock wool and sealed with approved sealant. Both ends of the opening shall then be covered up by 1.2 mm thick sheet steel and sealed airtight by high pressure ductwork sealer.

B8.13 PLANT ROOM ACOUSTIC LININGS

Where specified in the Particular Specification or Drawings, the A/C Contractor shall supply and install acoustic linings to walls and / or ceilings of the plant rooms in order to reduce the reverberant noise levels of the plant rooms.

The wall liner board shall be secured by 1.5 mm thick galvanised steel 'z' or channel sections of 50 mm deep which shall be firmly fixed to the wall surfaces at 600 mm intervals. The wall liner boards shall be protected by 0.8 mm thick galvanised perforated metal plates which shall be secured by self-tapping screws to the galvanised steel sections. The perforated metal plates shall be removable to enable future maintenance.

B8.14 FLOATING FLOORS

In cases where machines are adequately mounted to reduce vibration transfer but emit transmittable noise into the air space of the plant room which is above a noise-sensitive area, it may be necessary to mount all the plant in the room on a floating floor.

Unless the situation is one of incorrect plant selection by the A/C Contractor, the detailed design and construction for the floating floor will be provided to the A/C Contractor. In such cases the A/C Contractor shall avoid any action that may subsequently undermine the acoustic performance of the air space formed under the floating floor.

In such situations, it is likely that the walls and ceiling will also be required to be acoustically treated by the specialist or Building Contractor. Again, the A/C Contractor shall avoid any action that will undermine the acoustic programme of the acoustic absorption membrane.

B8.15 SPECIALIST MANUFACTURER'S INSPECTION

On completion of the installation of all noise and vibration control devices, the (local or overseas) representative of the acoustic and vibration equipment/materials manufacturer shall inspect the completed system and report in writing to the A/C Contractor concerning any installation errors, improperly selected isolation devices, and/or other faults that could adversely affect the overall performance of the system.

The A/C Contractor shall then submit a report to the Supervising Officer in which the report shall include all findings of the manufacturer's representative and confirmation of the satisfaction completion of all isolation work together with any remedial actions proposal.

Where remedial action has to be taken by the A/C Contractor, further inspections shall be carried out until all faults are rectified.

The A/C Contractor shall allow the cost of visiting the Site by the (local or overseas) representative of the noise and vibration equipment/materials manufacturer for this purpose.

B8.16 INDEPENDENT INSPECTIONS

In addition to the inspection of the A/C Contractor's works by the specialist manufacturer's representative, independent parallel inspections and tests may be carried out by others under direct instructions of the Supervising Officer. Any deficiencies revealed by these inspections and tests shall be rectified by the A/C Contractor at no additional cost to the Employer.

SECTION B9

PIPEWORK, VALVES, COCKS AND STRAINERS

B9.1 GENERAL

This section covers pipework for: -

B9.1.1 Chilled or hot water circulation, vent & drain.

B9.1.2 Condensate drainage.

B9.1.3 Condenser cooling - fresh water circulation.

B9.1.4 Condenser cooling - sea or brackish water circulation.

B9.1.5 Make-up cold water supplies.

Note: Pipework fitting and accessories for refrigerant systems shall read in conjunction with Section B6 of this General Specification.

Pipework and valves for pneumatic control systems will be fully specified in the Particular Specification. When mild steel or malleable iron support and fixing accessories are called for, they shall be hot dip galvanised.

B9.2 AUTOMATIC AIR VENTS

Automatic air vents shall be provided at all high points in the pipework. They shall be installed in the highest points of the sections where they are intended for venting.

Air bottles shall be made from 50 mm size tube, each approximately 230 mm long, fitted with a cap and 8 mm size air cock; they shall be fitted to equal tees or have 50 mm size connections if the main is 50 mm or above. Where an air bottle is fixed out of reach, an 8 mm extension tube shall be run from the cap to within 1.5 m of the floor and terminated with an 8 mm size needle-seated key-operated air cock.

B9.3 BELLOW EXPANSION JOINTS/ANCHORS AND GUIDES

B9.3.1 General

Movements of the pipework due to changes in temperature shall be accommodated by the natural flexibility of the pipework run or by bellow expansion joints, in either case allowable stress levels should not be exceeded.

Where expansion joints are utilised, they shall be manufactured in accordance with the design philosophy for thin walled bellow membranes as laid down by the Expansion Joint Manufacturers Association (EJMA).

B9.3.2 Axial Movement Pattern

Axial movement bellow expansion joints on all services shall comprise thin wall multi-plied omega formed convoluted bellows of stainless steel material to BS EN 10029:2010, BS EN 10051:2010 and BS EN ISO 9445-1:2010, BS EN ISO 9445-2:2010of appropriate type. Bellows should be argon arc welded to carbon steel end fittings utilising a stainless steel seal ring to reinforce the bellow cuff end.

The bellow expansion joint shall be provided with a close fitting stainless steel internal liner to reduce turbulent flow.

End termination to be carbon steel threaded male to ISO 7-1:1994/cor1:2007 or carbon steel flanges to ISO 7005-1:2011 Standard to suit the line pressures.

For copper or non-ferrous pipework systems expansion joints shall be manufactured in stainless steel throughout. The bellow expansion joints shall be installed with pre-cold setting to their required length to suit the temperature condition at the time of installation. The joints shall be rated suitable for the required amount of designed axial movement and shall be capable of performing the required cycles within the working life of the pipework. Mild steel outer protection sleeves shall be fitted to the bellows only when the units are open to the environment and exposed to risk of damage or when it is necessary to carry lagging over the joint.

Units should be installed in strict accordance with the manufacturers' recommendations. Manufacturers of expansion joints should be approved to ISO 9001: 2015.

B9.3.3 Angular or Lateral Movement Pattern

These bellow expansion joints shall generally comply with the requirement as specified in this General Specification. Hinge and shackle or centre joining tube, tie bars and spherical nut arrangement shall be carbon steel to ISO 9692-1:2013 fully designed to contain the pressure thrust. End termination to be flanged to ISO 7005-1:2011 Standard to suit the line pressures.

The joints shall be designed to meet the required angular movement or the required movement in all directions perpendicular to the axis of the bellows.

B9.3.4 Provision for Anchors and Guides

Anchors and guides shall be installed according to the recommendations of the expansion joint manufacturer and the details shall be submitted to the Supervising Officer for approval before manufacture commences.

(a) Anchors

Allowances shall be made for anchors capable of withstanding the maximum stresses created within the pipework system, and have adequate safety margin. These shall be positioned as indicated on the layout drawings or as necessary shop drawing/details introduced by the A/C Contractor.

On steel pipework, the pipe shall be welded to the anchors via heavy steel straps. On copper pipework, the pipe shall be brazed to the anchors via heavy copper straps.

(b) Guides - Axial Movement Pattern

The pipework shall be guided along its length and the guides shall be capable of withstanding not less than 15% of the maximum stresses created within the pipework system and have an adequate safety margin.

Guides shall be adjustable in both directions in the lateral plane, so that pipework can be accurately aligned with the expansion joint.

Each guide shall not be less than 2 pipe diameters long and shall have a minimum manufacturing clearance of the pipe diameter.

The distance from the expansion joint to the first guide must not be greater than 4 pipe diameters, and the distance between the first guide and the second guide must not be more than 14 pipe diameters. Guides thereafter should be spaced in accordance with normal pressure performance requirements as a minimum standard.

(c) Guides - Angular or Lateral Movement Pattern

Directional guiding shall apply, such as side plates, local to the expansion joint, the remainder of the pipework should be supported in the nominal way, by roller or frictional supports, or pipework hangers.

A combination of axial, angular or lateral movement guides shall not be permitted.

B9.4 CHANGES IN PIPE SIZE

Changes in pipe size can be facilitated at tees by reduction on branch or outlet.

Reduction on bend elbows or by bushes is not permitted without prior permission of the Supervising Officer.

Reduction by means of straight through reducing sockets is permitted.

Care must be taken in carrying out reductions to ensure that air is not entrapped at high points. In such case, it shall be necessary to install eccentric reducing sockets with the "flat" at the top for horizontal pipework and concentric reducer for vertical pipe riser.

B9.5 CONNECTIONS IN PIPEWORK

For non-welded pipework, connections shall be by means of screwed fittings, mechanical couplings, flanges or unions. The use of "long screws" shall not be permitted, unless otherwise approved by the Supervising Officer.

Unless otherwise specified, flanges complete with appropriate gaskets, nuts, bolts and washers shall be used to connect up all plant and equipment such that it can easily be removed for servicing or replacement.

B9.6 FLOW MEASURING

Methods for measuring flow rates in chilled or hot water and/or other liquid circuits shall be in accordance with Section C10 of this General Specification.

B9.7 FLUSHING DOWN AND DRAINAGE

15 mm diameter key-operated drain cocks with hose unions shall be fitted to the lowest accessible points of the system pipework and also on individual items of plant to ensure complete drainage.

20mm or above drain cocks shall be required for rapid flushing down in connection with water treatment and dead legs or stagnant water corners of chilled water or condensing water circulation pipework.

B9.8 JOINTS AND FITTINGS FOR STEEL PIPEWORK

B9.8.1 Joints on all permanently concealed pipework and all pipework over 100 mm size shall be welded unless otherwise agreed by the Supervising Officer. The other pipework may be of screwed or welded joints. Mechanical coupling joints may be used for joints under the conditions as stated in Clause B9.8.5. When the A/C Contractor chooses to use screwed joints at least one of the two engaging components shall be taper-threaded to ISO 7-1: 1994/Cor1:2007 or BS EN 10226-1:2004 and the joints between them shall be made with approved jointing material, selected to suit the appropriate type of services. For pipework without anti-rust threaded joints, it shall be patched up with galvanised painting or anti-corrosion paint before making such joints.

B9.8.2 At dismantling points or where the pipework is connected to an appliance, ground-in spherical seated unions shall be used for pipework up to 50 mm size and flanges shall be used for pipework at 65 mm size and above. The flanges shall be to ISO 7005-1:2011 of appropriate type or another acceptable national/international standard, such as BS, EN or BSEN. Flanged joints shall be made with flat ring gaskets suitable for the pressure and temperature and extending to the inside of the bolt circles.

B9.8.3 Screwed fittings, other than sockets, shall be malleable cast iron, banded or beaded pattern. Standard but welding fittings shall be used on welded pipework. Use of mixed joints shall be prohibited.

B9.8.4 Flanges for mild steel pipework shall be forged steel and machined over the raised or flat faces. Headers shall be of flanged mild steel tube with flanged outlets welded on and spare outlets shall be blanked off with bolted flanges.

B9.8.5 Where specified, and/or subject to the Supervising Officer's written agreement, mechanical pipe couplings may be employed for pipe connection (except for connections to units incorporating reciprocating compressors or where the water temperature exceeds 93ºC, unless the couplings are suitable for these conditions and acceptable to the Supervising Officer.)

Mechanical pipe couplings shall be self-centred, engaged and locked in place onto the grooved or shouldered pipe and pipe fitting ends. The pipe connection shall result in a positive watertight couple, where flexible types shall provide reasonable allowance for angular pipe deflection, contraction and expansion, and where rigid types shall provide no joint movement, angular pipe deflection, contraction or expansion. The coupling housing clamps shall consist of two or more malleable or ductile iron castings or rolled steel segment holdings with a composition water sealing gasket of suitable working temperatures, so designed that the internal water pressure will increase the water tightness of the seal. The coupling assembly shall be securely held together by two or more oval-neck heat treated carbon steel track head bolts and nuts. All pipe fittings connected to mechanical pipe couplings shall have groove and shouldered ends and shall be malleable or ductile iron castings. Flanged or threaded end valves may be used with grooved adapters.

Before couplings are assembled, pipe ends and outsides of gaskets shall be lightly coated with grease or graphite paste to facilitate installation.

Pipe grooving shall be in accordance with the pipe coupling manufacturer's specifications. Pipes may be cut-grooved or roll-grooved as recommended by the manufacturer. The cut-grooving shall be roll-grooved without the removal of any metal.

The entire coupling installation shall be in accordance with manufacturers' recommendations.

B9.8.6 Couplings or flange adapters for plain ended pipework shall be cast iron or steel, slip-on type as approved by the Supervising Officer: -

Coupling shall consist of: -

(a) Sleeve (without centre register);

(b) End flanges;

(c) Sealing rings; and

(d) Bolts and nuts.

Flange adapter shall consist of: -

(a) End flanges/sleeves;

(b) Sealing rings; and

(c) Studs and nuts.

To provide hard and durable protection against impact, abrasion, chemicals and low temperature, all couplings and flange adapters shall be coated with Rilsan Nylon 11 by either a dip process giving a coating thickness of 250 - 375 microns or an electrostatic spray process giving a coating thickness of 150 - 250 microns.

B9.9 JOINTS AND FITTINGS FOR COPPER TUBES

Fittings for copper pipework shall be as follows: -

B9.9.1 Size up to and including 65 mm shall be of the capillary or compression type to ISO 2016:1981 or BS EN 1254-1 to BS EN 1254-4 for water distribution purpose and ASME B16.22 for refrigeration copper fittings for refrigerant distribution purpose. Size of the 76 mm and 108mm shall be the flanged to ISO 7005-1:2011, ISO 7005-2:1988 and ISO 7005-3:1988. Size for pipework above 108 mm shall be flanged or welded.

B9.9.2 Pipework shall be arranged with adequate connection points to allow easy dismantling. Connection points in copper pipework size up to and including 65 mm size shall be unions or screwed and for pipework of size 76mm and above shall be flanged.

B9.10 PIPEWORK GENERAL DETAILS

B9.10.1 Pipework shall follow the contours of walls and shall be suitably graded not less than 1 in 500 to ensure proper venting and draining. Generally, the clearance between pipework (or the lagging) and the wall and any other fixtures shall be not less than 25 mm. Pipework shall not run near to or above electrical appliances, cables, trunkings and conduits.

B9.10.2 Where two or more pipe runs follow the same route, all pipes shall run parallel with one another and to the building structure without prejudice to the necessary allowances for venting, drainage or other reasonable restrictions. Any pipework which requires subsequent insulation shall be adequately spaced to allow for individual finish.

B9.10.3 Purpose-made sets or springs may be used where it is necessary to deviate from a straight run in ungalvanised pipework.

B9.10.4 Sets or springs in tubes of 50 mm size and above shall be heat-treated and the tubes shall remain circular after setting. In galvanised pipework, no deviations shall be formed from standard fittings.

B9.10.5 Tubes shall be reamed after cutting and shall be free from burrs, rust, scale and other defects and shall be thoroughly cleaned before erection. Pipe ends left open during the progress of work shall be temporarily closed with purpose-made metal or plastic plugs or caps, or blank metal flanges and protect from corrosion.

B9.10.6 Joints shall not be made in the thickness of any wall, floor or ceiling and pipework shall not be embedded in the structure of floors unless otherwise instructed by the Supervising Officer. Where pipework passes through walls, floors or ceilings, sleeves shall be provided. Pipework passing through floors shall, where specified, be provided with approved type floor and ceiling plates and fastened securely to the sleeve. Sleeves shall be of the same metal as the pipe, unless otherwise accepted by the Supervising Officer. The space between pipework and sleeve shall be sealed with an approved fire resisting material having FRP of not less than that of the wall and floor and in compliance with relevant regulations and code of practices.

B9.10.7 All entry and exit holes to or from a building for a pipework services shall be sealed and plugged. The sealant shall be a mastic compound or silicone rubber. Where the pipework enters the building through a large hole or duct, a mild steel blanking plate not less than 6 mm thick shall be built into the wall of the hole or duct. The service pipes shall pass through clearance sockets welded to the plate. The space between pipe exterior and socket interior shall be sealed and plugged with rockwool or equivalent material having an FRP of not less than that of the wall and in compliance with the relevant regulations and code of practices, all to the approval of the Supervising Officer.

B9.10.8 All fittings shall, as far as practicable, be the same size as the tubes and pipes connected to them. Bushed outlets will only be accepted if the required outlet size of a fitting is not of standard manufacture. Eccentric bushings and square tees shall be used where concentric bushings and pitcher tees may cause air to be trapped in the system.

B9.10.9 Elbows shall be used, where practicable, in preference to bends. However, square elbows will not be permitted. Unless otherwise specified, long radius elbows shall be used in order to minimise hydraulic resistance.

B9.10.10 In the event of the bends being formed in the lengths of pipe, a hydraulic bender shall be used to have "shoes" of the correct size for the relevant pipe. Flattening or distortion of the bore will not be accepted.

B9.10.11 For forming bends in small bore, copper pipe up to size 25 mm pipe bending springs may be used but again there must be no distortion of the pipe involved.

B9.10.12 In the case of all bends formed in the pipe, these shall constitute long radius bends.

B9.10.13 All centrifugally cast ductile iron buried mains shall be coated externally with zinc. Metallic zinc shall be used with a zinc content of not less than 99.9% by mass. The zinc shall be applied at the manufacturer's works to the oxide skin of the pipe surface which shall be dry, free from dust, non-adhering particles, oil or grease. The zinc coating shall cover the external surface of the pipe to a mean density of 130 g/m^2. Spiral appearance is permissible only if there is no bare patch.

B9.10.14 On pipework up to and including 50 mm nominal bore, minor type fittings shall be provided to make up to valves, expansion pieces, loops and items of plant.

B9.10.15 Short radius elbows shall only be used at the discretion of the Supervising Officer where long radius elbows will not fit or are not manufactured.

B9.10.16 Where pipes are ordered galvanised, the zinc content shall be not less than 98.5% by weight of zinc and at a temperature suitable to produce a complete uniformly adherent coating of zinc.

B9.10.17 Pipes which are to be screwed shall be galvanised before servicing. Pipes which are to be fitted with welded flanges shall be flanged before galvanising. Galvanised treatment on all welding joints shall be required after welding.

B9.11 PIPEWORK LAYOUT

The Drawings indicate the size and general layout of the required pipework. The exact position may not be indicated on the Drawings as for the purpose of clarity, they are generally shown as separately spaced out from one another as if they were at the same plan level. The A/C Contractor shall accurately set out the various pipelines in the Installations in compliance with the provisions of Clauses A3.16 and A4.3 of this General Specification.

B9.12 PIPEWORK SUPPORTS, EXPANSION JOINTS AND ANCHOR POINTS

B9.12.1 Where the Employer's Guide Drawings& Details for pipework supports and brackets, expansion joints and anchor points are issued with the Contract or have previously been issued to approved contractors for general application on the Employer's projects, these standard details shall be followed "in-principle" but adjusted as to the detail in order to suit the particular circumstances. Such adjustments shall be indicated on the A/C Contractor's own Installation/Shop Drawing and loading calculation Submissions and be approved by the Supervising Officer before work commences.

B9.12.2 Pipework shall be supported so as to permit free movement due to expansion and contraction. Pipework supports shall be installed as near as practicably possible to joints and changes in direction. Each support shall take its due proportion of the load. The spacing of the supports shall not exceed the centres given in Tables B9.17-(1), B9.17-(2) and B9.17-(3) under Clause B9.17. Where there are two or more pipes, the spacing shall be based on the centres required by the smallest bore pipework.

B9.12.3 Vertical rising pipework shall be supported at the base or, as indicated, to withstand the total weight of the riser. Branches from risers shall not be used as a means of support for the riser. If such base has to be rested on an intermediate floor slab, the A/C Contractor must draw particular attention to the Supervising Officer for structural reinforcement to the floor slab and also allow for additional treatment to the base as required by the Supervising Officer.

B9.12.4 Where pipework up to 50 mm size is fixed to solid wall, brackets may be of the screw-on or long shank built-in type in case the walls are plastered, only the long shank built-in type shall be used. For fixing to woodwork and lightweight partitions or walls, brackets shall be of the screw-on pattern of adjustable two-piece type. Brackets for mild steel and plastic pipework shall be mild steel or malleable iron; brackets for copper pipework shall be brass or gunmetal. The upper half of the pipe clip shall be detachable without disturbing the fixing.

B9.12.5 Brackets screwed to walls shall be secured by expanding plugs. Other purpose designed fixing devices or softwood plugs will not be permitted.

B9.12.6 Pipework of 65 mm size and larger, subjected to expansion and contraction and hung from supports shall be suspended on swivel hangers unless otherwise agreed by the Supervising Officer.

B9.12.7 Unless otherwise specified, hangers for horizontal pipework at high level shall be supported from galvanised mild steel angle or channel sections or approved proprietary devices supplied by the A/C Contractor, suitable for building-in or otherwise securing to the structure by the Building Contractor. Adjustable mild steel hangers shall be used. Pipe rings shall be of malleable cast iron or fabricated

steel, made in halves and secured by bolts or screws. Alternatively, malleable iron hinged pipe rings may be used. Calliper type hooks will not be permitted.

B9.12.8 Where pipework is fitted in service duct or trenches or where it is of 65 mm size or greater and supported from walls, the design of the pipe supports, guides and anchors shall be in accordance with the Drawings. Otherwise, the A/C Contractor shall submit details and proposal to the Supervising Officer for approval. Where roller supports are required, they shall be of an approved type. The performed insulation shall be kept free of the rolling surface. Load-bearing insulation at supports, where required, shall be fitted by the A/C Contractor at the time of erecting the pipework.

B9.12.9 For copper pipework, the anchors shall be provided by wide copper straps secured to the pipework in such a manner that the pipe is not damaged.

B9.12.10 The A/C Contractor shall supply, and fix in position ready for building-in, all cleats, brackets and steelwork required for anchor points. Anchor steelwork secured to the bottoms of ducts or trenches shall be coated with hot-poured bitumen to inhibit future corrosion.

B9.12.11 Supports for plastics pipework may be of any approved pattern that prevents free axial movement of pipe at all temperatures and have radial edges to prevent cutting into the pipe. The entire bearing surface must be sufficiently wide to prevent indentation.

Heavy "in-line" equipment must be supported independently. Valves and meters must also be supported independently, where necessary.

Supports for pipes carrying water at a maximum temperature of 15^{o}C and covered with lightweight insulation shall be spaced in accordance with Table B9.17-(3) under Clause B9.17. Alternatively, the pipework may be continuously supported, provided that the thermal insulation covering the pipework is sufficiently rigid to ensure that no compression or deformation of the insulation occurs.

B9.12.12 Provision for movement due to expansion and contraction shall be generally as indicated and/or shall be by changes in direction of the pipework, by loops or by other approved expansion devices.

B9.12.13 Supports and guides shall be arranged to ensure that all movement is taken up by the change in direction of the pipework or by the loop or device.

B9.12.14 The spacing of supports for steel, copper and plastic pipework shall be in accordance with Tables B9.17-(1), B9.17-(2) and B9.17-(3) under Clause B9.17.

B9.12.15 Cold bridge should be prevented between the insulated pipework and the associated hangers and pipework supports.

B9.12.16 All metal mounting and fixing brackets for water pipework shall be pre-fabricated off-site.

B9.13 PIPEWORK VIBRATION DE-COUPLERS

Pipework connections to the suction and delivery outlets of pumps and other vibrating machines shall be isolated from such sources of vibration by means of anti-vibration couplings as detailed in Sections B8 & C8 of this General Specification.

The vibration de-couplers shall be capable of attenuating the vibration of the plant such that the bulk of the vibrations are prevented from being transferred to the pipework.

Wherever vibration de-couplers are installed, the adjacent pipework shall be adequately supported by guide type brackets.

B9.14 PLASTIC PIPEWORK

Fittings for plastics pipework shall be as follows: -

B9.14.1 Fittings shall be of the same material as the pipework to which they are joined. They shall be made or approved by the pipe manufacturers and suitable for the solvent welding process. Where screw threads are required (e.g. at connections to metal valves, strainers, etc.), a factory made threaded adapter shall be used. Adapters shall be made from heavy weight tube with an appropriate thread at one end; the other end shall form part of a socket and spigot solvent welded to the plastic pipe. As a general rule UPVC pipe should only be made threaded and screwed into metal "Female" threaded fittings.

B9.14.2 Joints between pipe and pipe fittings shall be made by the solvent welding process. No cleaning fluid or solvent cement other than that supplied or recommended by the pipe manufacturer shall be used.

B9.14.3 Where it is required to form a spring in the pipe run, the pipe shall be softened by immersion in (or by pouring on) heated brine, glycerine oil or water as recommended by the pipe manufacturer. The use of a naked flame on the pipe surface will not be accepted.

B9.14.4 Unless otherwise specified, connections to items of plant such as pumps or air cooler batteries shall be made by means of flanged joints. The plastic pipe shall terminate with a socket flange of the full face or stub type welded on by the solvent process and having a loose metal backing ring; the ring and the flange shall be drilled to match the mating flange. The joint shall be made with a neoprene or similar gasket.

B9.14.5 Where UPVC is used for condenser cooling circuits and for the inlet and outlet to pumps, it must be effectively isolated from the vibration of the machine. This shall be achieved by the insertion of flanged synthetic rubber vibration de-couplers installed between UPVC pipework and plant on all connections.

B9.15 SPECIALISED HYDRAULIC SYSTEM BALANCING VALVES

B9.15.1 In addition to those specified, the A/C Contractor shall allow providing necessary hydraulic valves at all points on the system where circulation flow balancing must be carried out in order that the system balancing can be done.

B9.15.2 These valves shall be of manufacture approved by the Supervising Officer and be designed to: -

(a) Allow measurement of pressure differences across the valve;

(b) Allow measurement of flow through the valve;

(c) Allow for proportional balancing of the system;

(d) Provide shut off;

(e) Provide for venting (where required); and

(f) Provide for draining (where required).

B9.15.3 Construction

10 - 50 mm	Gunmetal	Working pressure up to 2 MPa (to BS EN 1982:2017)
65 - 300 mm	Cast Iron	Working pressure up to 1.6 MPa (to BS EN 1561:2011 and ISO 185:2005)

The valve will be constructed with angled seat and valve handle complete with two plug type pressures tapping on each side of the valve seat.

Drain or vent plug valve

Valves 10 - 50 mm with screwed ISO 7-1:1994/Cor1:2007 and 7-2:2000 connections.

Valves 65 - 300 mm with flanged ISO 7005-1:2011, ISO 7005-2:1988 and ISO 7005-3:1988 connections.

B9.15.4 Commissioning and Testing Equipment

One set (or more if specified) of electronic measuring equipment for use with hydraulic balancing valves shall be provided by the A/C

Contractor for initial balancing and commissioning of the system where hydraulic balancing valves are installed.

At completion of the work, one new set of test equipment shall be handed over to the Supervising Officer for subsequent monitoring and adjustment by the Employer's operation and maintenance staff.

See also Part H of this General Specification.

B9.16 'T' AND 'Y' FITTINGS

Except at vent and drain points, all tees and 'Y' fittings shall be of the swept type. The sweep radius being at least equal to that of the medium bend but where specified as a long sweep it shall then be equal in radius to the long bend.

B9.17 SUPPORTS FOR PIPEWORK

Table B9.17 - (1) Supports for Steel Pipework

Supports with suitable load spreader for the pipework shall be provided.

	Intervals for Horizontal runs		Intervals for Vertical runs
Size of tube	Bare	Lagged	Bare and Lagged
mm	m	m	m
15	1.8	1.8	2.4
20	2.4	2.4	3.0
25	2.4	2.4	3.0
32	2.7	2.4	3.0
40	3.0	2.4	3.7
50	3.0	2.4	3.7
65	3.7	3.0	4.6
80	3.7	3.0	4.6
100	4.0	3.0	4.6
125	4.5	3.7	5.5
150	5.5	4.5	5.5
200	8.5	6.0	8.5
250	9.0	6.5	9.0
300	10.0	10.0	10.0

Table B9.17 - (2) Supports for Copper Pipework

Size of tube	Intervals for horizontal runs		Intervals for vertical runs
	Bare	Lagged	Bare and lagged
mm	m	m	m
15	1.2	1.2	1.8
22	1.2	1.2	1.8
28	1.8	1.5	2.4
35	2.4	1.8	3.0
42	2.4	1.8	3.0
54	2.7	1.8	3.0
65	3.0	2.4	3.7
76	3.0	2.4	3.7
108	3.0	2.4	3.7
133	3.7	3.0	3.7
159	4.5	3.7	3.7

Table B9.17 - (3) Supports for Plastics Pipework

Nominal Bore of Pipe	Intervals for horizontal runs	Intervals for Vertical Runs
mm	m	m
15	0.75	1.5
22 to 28	1	1.8
28 to 35	1	2
42	1.2	2.4
53 to 65	1.4	2.8
76	1.8	3.5
108 and over	2	4

B9.18 WELDING AND BRAZING

The procedure and the competence of the operative shall be in accordance with the recommendations contained in the following B&ES publications: -

B9.18.1 "Welding of Mild Steel Pipework"

B9.18.2 "Code of Practice - Brazing and Bronze Welding of Copper Pipework and Sheet"

Welding operations which are beyond the scope of (a) and (b) shall comply in particular with: -

B9.18.3 ISO 9692-1:2013 and ISO 15609-1:2004 -relevant subsections for metal-arc welding (steel pipe)

B9.18.4 ISO 9692-1:2013 and ISO 15609-2:2001 -relevant subsections for gas welding (steel pipe)

B9.18.5 ISO 5187:1985 - Brazing (copper pipe)

Where the visual inspection and tests reveal those welding joints which are reasonably believed to be unacceptable, the Supervising Officer shall be entitled to have such welding examined by radiography or other approved inspection method and independently assessed. The A/C Contractor shall be responsible for the cost of the tests and subsequently remedy the work to the satisfaction of the Supervising Officer if tests prove the welding joints to be non-compliance with the specification.

B9.19 LABELLING AND CIRCUIT CONTROL DIAGRAM OF VALVES

All plant room valves and circuit control valves shall be provided with approved plastic labels in compliance with Clauses A3.13.1 or A3.13.2.

A circuit control diagram showing the location of each isolating, regulating and control valve shall be provided and fixed in a glazed hardwood frame in a position indicated by the Supervising Officer or as specified in Clause A4.4.4.

SECTION B10

SYSTEM MONITORING INSTRUMENT

B10.1 GENERAL

Clauses related to electrical control shall be read in conjunction with Sections B4, B5 and B7.

All instruments, gauges and devices with indication scales shall be mounted in such a position that they can be accessed and read easily.

B10.2 SYSTEM STATIC PRESSURE GAUGES FOR AIR DISTRIBUTION SYSTEMS

System static pressure gauges shall be provided as per following table B10.12 – (1). Two gauges shall be provided for each fan and arranged to indicate system static pressure on the intake and discharge sides.

The gauges shall be connected into the system at points where the static pressures are steady. On completion of commissioning, the suction and delivery static pressures indicated by the gauges shall be indelibly marked adjacent to them to serve as system reference points.

B10.3 THERMOMETERS - AIR IMMERSION

Two 12 mm diameter test holes shall be provided for the insertion of thermometers (for measuring both dry and wet bulb temperatures at the same time) in each of the following locations of each air handling unit (fan coil units excluded): -

B10.3.1 Outdoor air connection

B10.3.2 Return air connection

B10.3.3 Supply air connection

B10.3.4 Mixed air connection

B10.3.5 Before and after each air cooling coil/heater bank

B10.3.6 Before and after each humidifying device

Sealing plugs shall be provided and fitted to all test holes. Test holes shall be positioned so that thermometers are not affected by thermal radiation.

Permanent thermometers shall be inserted in test holes for systems as in table B10.12 – (1).

For systems with flow rate less than 5 m^3/s, four nos. of thermometers or in quantity equivalent to 10% of the total numbers of the test holes, whichever is greater, shall be provided with each individual packed in protective casings and to facilitate identification of correct location, and handed to the Supervising Officer. Each thermometer shall be complete with a pierced plug to fit the test hole and each wet bulb thermometer shall be provided with a fabric sleeve.

B10.4 THERMOMETERS - LIQUID IMMERSION

Thermometer pockets shall be provided adjacent to the flow and return connections to/from each heating coil and cooling coil as per following table B10.12 – (1). The location and depth of thermometer pockets shall be determined to assure correct reading of liquid temperature. Each pocket shall be filled with sufficient approved heat conducting medium.

Cylindrical brass case, mercury-in-glass thermometers of straight or angle type shall be provided and permanently installed in pockets.

B10.5 PRESSURE GAUGES FOR WATER SYSTEMS

Pressure gauges shall be provided as per following table B10.12 - (1). Pressure gauges shall be fitted with lever handle cocks and shall have siphon pipes, pigtail with 2 complete turns minimum or pulsating damper, fitted between them and the system pipework.

B10.6 SELF SEALING TEST POINTS

Self-sealing test plugs suitable for temperature and pressure measurement can be provided to substitute the thermometer pockets and pressure gauges for systems with capacities or flow rates less than the values mentioned in Clauses B10.2, B10.4 and B10.5.

The test plugs shall be fitted with captive caps for sealing them when not in use and shall have internal self-sealing devices. The plugs and probes shall be of materials suitable for the respective application and shall be submitted to the Supervising Officer for approval prior to ordering or installation.

Valve pressure tapping shall be provided for water systems.

Four thermometers and four pressure gauges for each range of temperatures and pressures, suitable for use with the test plugs, shall be packed in a protective casing and handed to the Supervising Officer together with adequate supply of all necessary insertion lubricant.

B10.7 VOLTAGE AND CURRENT READINGS

As detailed in Section B7 and following table B10.12 – (1) of this General Specification or specified in the Contract, the A/C Contractor shall provide

instruments to monitor the supply voltage, and/or current to individual or groups of refrigeration plant.

B10.8 POWER FACTOR MONITORING

Where indicated elsewhere in this General Specification or in the Contract, the A/C Contractor shall provide instruments to monitor the power factor of the equipment provided and installed under the Contract as individual items or groups of plant.

B10.9 POWER CONSUMPTION METERING

Power Consumption (kWh) metering devices shall be installed for the following plants and equipment as per following table B10.12 – (1).

B10.10 LIQUID FLOW RATE METERING

Appropriate type of flowmeters shall be installed for the following plants and equipment as per following table B10.12 – (1).

B10.11 OTHER TYPES OF METERING DEVICES

B10.11.1 Pitot Static Tube

The device shall provide differential pressure reading through: -

(a) The high pressure velocity head sensor, with interpolating tube to continuously average velocity pressure, facing the flow; and

(b) A low pressure sensor which detects the static pressure.

The resultant differential pressure can be transmitted through the instrument head to a differential pressure flow responder meter.

The sensor shall not be inserted near any bends or other fittings likely to affect the water flow by turbulence or differential velocities across the pipe. The distance from any such fitting upstream of the measuring point shall not be less than 10 diameters of the pipe.

Where indicated, flow measurement as displayed on the responder meter shall be capable of transmitting to central control and monitoring system or simpler control system through electronic relay amplifier.

B10.11.2 Water Consumption Meters

WSD approved impeller type water meter complete with inlet/outlet isolating valve unions and a strainer shall be provided to measure the makeup water consumption rate.

B10.11.3 Hour Run Meters

The meter system shall be of reputable and proven manufacturer's make. Where required, it shall be suitable for working with central control and monitoring system.

B10.11.4 Energy Meters

Where specified in the Contract, energy meters for chilled (or hot) water system shall be provided. The energy meter shall consist of temperature sensors for both flow and return water circuits, electrostatic or ultrasonic flowmeter, flow transmitter/converter unit and a calculator unit.

B10.12 PROVISION OF METERING FACILITIES

Referring to the following table B10.12 - (1), the types of metering functions and extent of metering provisions are listed as follows and shall be provided by A/C Contractor:

Table B10.12 - (1) Provision of Metering Facilities

Type of Load	Type of Metering Function	Extent of Provision
1. Refrigeration		
(i) Chillers/ Heat Pump/ Unitary Air-conditioner/ Condensing Units/ Chilled or Heated Water Plant	a. Current (three phases and neutral)	To be provided except for small split units below 7kW.
	b. kWh (Energy Input)	)
	c. kWh (Cooling/ Heating Energy Output)	) To be provided if the cooling/) heating capacity exceeds) 200kW, in addition to item a.) The power metering should) incorporate an accumulative
	d. kW (Power Input)	) function for the measured data) over time and analytical
	e. kW (Cooling/ Heating Energy Output)	) function to convert the power) over successive time intervals) into energy terms for adding) up to give the cumulative
	f. Coefficient of Performance	) energy value)
	g. Hour Run	To be provided if the cooling capacity of chiller/ condensing unit/ heat pump exceeds 70kW

	h. Chilled Water Flow Rate	To be provided for chilled water circuit with a cooling capacity of 200kW or above. Test points shall be provided if the cooling capacity is less than 200kW. (See Note 1)
	i. Chilled/ Hot Water Supply & Return Temperature	Thermometers shall be provided for cooling/ heating capacity exceeding 30kW. For systems with cooling/ heating capacity not exceeding 30kW, test points shall be provided.
	j. Sea Water Flow Rate k. Sea Water Intake & Discharge Temperature	) To be provided for sea water mains.
(ii) Cooling Tower	a. Current (three phases & neutral) b. kW c. kWh	) To be provided for all fans and pumps.
	d. Condensing Water Flow Rate e. Condensing Water Supply & Return Temperature	) To be provided when the total motor power of cooling tower exceeds 40kW. If the total motor power is less than 40kW, test points shall be provided, in addition to items a, b and c.
	f. Water Volume Flow for Make-up Water and Bleed-off Water	To be provided for all cooling towers.
2. Chilled/ Sea/ Condensing Water Distribution		
(i) Chilled Water/ Water Pumps (including sea water and condensing water pumps)	a. kWh and Current (three phases and neutral) b. kW (Power Input)	) To be provided for all chilled water, sea water and condensing water pumps.

	c. Water Flow Rate d. Water Supply and Return Temperature	) To be provided for chilled/ hot) water circuit when water flow) exceeds 9 L/s. Test points shall) be provided if the water flow is) less than 9 L/s,) in addition to items a and b (equivalent to a cooling capacity of about 200kW)
	e. Pressure	To be provided at suction and discharge sides when the water flow exceeds 1.3 L/s. Test points shall be provided if the water flow is less than 1.3 L/s, in addition to items a and b. (equivalent to a cooling capacity of about 30kW)
(ii) Chilled Water Distribution Pipework	Differential Pressure	Commissioning valve to be provided at least at each main circuit branch-off to facilitate water balancing.
3. Air Distribution AHU/ PAU/ Fans	a. kWh and kW (energy and power input)	To be provided if motor power exceeds 5kW.
	b. Pressure	To be provided at fan intake and discharge side when fan power exceeds 3kW.
	c. Supply Air & Return Air Temperature	Thermometers shall be provided for systems with air volume flow rate of greater than $5m^3/s$. Test holes shall be provided for systems with air volume flow rate of less than $5m^3/s$.
4. Central Hot Water System	a. Water Supply & Return Temperature	Thermometers shall be provided for hot water system with capacity exceeding 40kW. For systems with capacity not exceeding 40kW, test points shall be provided.
	b. Water Flow Rate	To be provided when hot water flow exceeds 9L/s. Test points shall be provided if the water flow is less than 9L/s. (See Note 1)

Notes:

1. For measuring energy/ water consumption, A/C Contractor should provide sufficient metering facilities for data monitoring, measuring, logging and manipulations for different reporting entities, with consideration on factors like system identity, different division/ group of users and size of accommodations, etc. For joint user buildings, separate metering facilities shall be provided to suit the organisational boundaries or operational boundaries of the reporting entities. Particular attention shall also be paid on the sharing mechanism among the users on quantification and reporting the energy consumption associated with the communal and/ or central services or facilities.

SECTION B11

THERMAL INSULATION

B11.1 GENERAL

The thermal insulation works shall be undertaken by a minimum required percentage of workers who shall have a valid certificate of completing satisfactorily the thermal insulation training courses organised by the recognised association as specified in the contract. Upon request, details and particulars of these workers shall be submitted to the Supervising Officer for approval.

In general, all ductwork and equipment shall be insulated if the air conveyed within the ductwork and the air external to it have a temperature difference which may cause an unwanted condensation or heat loss either on the duct surface or within the ductwork or result in unwanted thermal exchange between the external and inside air of the ductwork.

Thermal insulation shall be applied to chilled or hot water pipework distribution systems and to components within distribution systems such as valves, storage vessels, strainer and accessories.

All insulation shall fit tightly to surfaces to be covered, and all slabs and sections shall be built up close, butting edges being mitred, chamfered or shaped as necessary. Any minor interstices left in insulation shall be filled and sealed with granules embedded in suitable and approved adhesive compound.

Insulated pipes and ducts shall be supported on the outside of the insulation, with load spreading galvanised iron or corrosion treated steel metal plates of suitable size and thickness between the insulation and supports to prevent the insulation being crushed. A higher density load bearing quality insulation or hard wood block should be used at support points as recommended by the insulation manufacturer and as directed by the Supervising Officer.

At the point of support, specially prepared blocks of hardwood or Styrofoam material must be positioned to ensure the integrity of the vapour barrier and cladding where applicable by bonding the supports to the insulation.

Pre-insulated pipes shall be supported on the outside of the cladding/ outer jacket and no high density load bearing or hardwood block should be used between the service pipe and cladding.

All materials delivered to Site shall be new, and where appropriate, colour coded and labelled at the factory to identify different grades, sizes and types. The insulation shall be protected from damage or deterioration before, during and after fixing. Damaged or compressed insulation should be replaced.

Immediately before applying insulation, clean all surfaces until these are free of rust, scale and grease, and are thoroughly dry. Under no circumstances should the insulation be applied to wet surfaces.

Any surface to be insulated, which shows any sign of rusting or damage, shall, prior to insulating, be thoroughly scrapped and wire brushed as necessary to remove all rust, scale, etc. Surfaces shall then be cleaned with appropriate solvent to remove all oil, grease and dirt prior to the application of two coats of grey epoxy primer paint and insulation. Only clean and dry insulation shall be applied in any case, and it shall be free from damage before application.

All materials including the thermal insulation itself, together with adhesives, paint, bands, sheeting, etc. shall be supplied with a reasonable margin for cutting, wastage and making good damage and loss. All materials shall be stored in a suitable manner so as to prevent them from damage or deterioration before fixing.

All insulation shall be applied so as to give a smooth, homogeneous and linear surface. All rigid sections shall be concentric, and accurately matched for thickness. Steps and undulations in the surfaces are not acceptable. Any sections or slabs having damaged ends will be rejected.

Continuous insulation shall be provided through all sleeves and insulation joints shall be staggered with respect to joints on the associated pipework or ductwork systems.

Insulation damaged for whatever reasons will be rejected.

Where thermal insulation is applied to the outside of piped and ducted services, equipment and plant used to convey, store or generate fluids or gases at temperatures lower than the design ambient dew point temperature indicated, a water vapour barrier shall be provided unless it can be demonstrated that the insulation material itself provide adequate barrier throughout its thickness to the approval of the Supervising Officer. The separate type vapour barrier where employed shall not be pierced or otherwise damaged by supports or by the application of external cladding.

Where relevant, moisture and vapour barriers, whether applied to the ductwork, hangers or projections, shall be continuous and completely provided throughout the surface of the insulation, and the insulation complete with the barrier shall be properly and firmly bound on the duct or pipe surface by appropriate fixing provisions. Such fixing provisions shall in no way impair the insulation or the vapour barrier. The A/C Contractor shall be responsible for any damages on the insulation or barrier due to improper installation and shall make good or replace the damaged insulation as appropriate and any subsequent wetting of the insulation due to improper installation or material shall be replaced by the A/C Contractor at his own cost.

Flexible connections on air conditioning ductwork shall be insulated with flexible blanket made from non-flammable material. The insulated blanket is to be wrapped with vapour barrier that conforming to Clause C11.4. The blanket shall be wrapped around the flexible connection, overlapped and secured in place by metal bands at both ends to the rigid ducts.

B11.2 TYPES OF THERMAL INSULATION MATERIALS

B11.2.1 Phenolic Foam Insulation

For pipe insulation and pipe support, the phenolic foam joint shall be of unique Z-shape slip along the longitudinal joint sealed with adhesive and shall be provided with shiplap joints (male and female joint) at both circumference ends. The shiplap joints shall be a minimum width and depth of 10mm respectively in contact with each other for thermal lock purpose and sealed with adhesive.

Rigid cut sections shall be used with factory applied Class 'O' facing for pipework. "Butt-joints" of slabs shall be sealed with minimum 75 mm wide matching Class 'O' self-adhesive tape as recommended by the insulation manufacturer. Overlap of factory applied Class 'O' facing for cut pipe sections shall be sealed with manufacturers recommended adhesive tape. All tapes shall be conformed to Clause C11.4.

Factory-preformed insulated fittings formed to suit standard radius elbows, long bends and tees shall be used wherever available, otherwise, the Supervising Officer’s permission shall be sought to neatly cut and mitre the insulation to fit around fittings. In the latter, great care must be taken to ensure that all mitred joints are a close fit and the aluminium foil adhesive tape is neatly applied as a finish coating.

Flanges and other protrusions shall be insulated by factory-fabricated oversized sections ordered to suit the diameter of the flange or adjacent pipe insulation whichever is the greatest. The oversized section shall overlap on to the adjacent pipe insulation by a minimum of 75 mm width on each side.

Pipe supports shall fit around the outside of the insulation. The insulation at the support points shall be made of heavy density load bearing phenolic foam in preformed sections of same thickness as the adjacent pipe insulation. This shall be complete with the same external finish to Class 'O' as used on the adjacent standard pipe insulation.

Reference shall be made to the insulation manufacturer recommended support details to ensure the load bearing and dimensions of high density foam and associated galvanised metal plate supports are correctly inserted to spread the point loads involved.

B11.2.2 Fibreglass Insulation

All fibreglass insulation shall be completely sealed by effective vapour barrier and self-adhesive foil tape as required by Clause C11.4.

All fibreglass insulation shall be completely sealed at all joints. All holes, tears, punctures, etc. made in the vapour barrier shall be completely sealed with the same specified foil tape. If damage in a

definite insulation area exceeds 5% of the insulation surface or duct or pipe, the A/C Contractor shall be responsible for replacement with new one.

When pins are required to be used to support the fibreglass blanket, all the pins must be fire resistant and sealed by same specified foil tape after installation.

The material shall be adhered to the ducts with moisture and fire resistant adhesive of an approved type. Where preformed fibreglass sheets are to be adhered to flat surfaces such as ductwork the method of fixing shall be approved by the Supervising Officer before the commencement of work.

B11.2.3 Flexible Closed Cell Elastomeric Insulation

The flexible closed cell elastomeric insulation sheet shall be supplied in rolls in dimensions recommended by the manufacturer for application over ductwork so that the top, adjacent and bottom sheets lapped with adjacent sheets edges and corners. Adhesives shall be applied evenly to the entire contact surfaces if the elastomeric insulation sheet is not a self-adhesive sheet with adjacent sides lapped to maintain a uniform thickness at corners.

When shifting large bore flexible closed cell elastomeric tube which has become elliptical during storage, the slit shall be made in the flattened surface.

If the Flexible Closed Cell Elastomeric Insulation is exposed to weather, inside plant room or services duct, protection finish coating recommended by the insulation manufacturer shall be applied.

All coatings must be supplied by the original insulation manufacturer and application shall strictly follow the manufacturer’s installation manual to obtain the required result.

B11.2.4 Polystyrene Insulation

Unless otherwise instructed by the Supervising Officer, polystyrene insulation shall be covered with 25 mm square wire netting of 1 mm diameter galvanised steel wire netting reinforcement and coated on the top with 15 mm cement plaster smoothed and finished with painting to be completed as Clause B11.8.

B11.2.5 Pre-insulated Panel of Foam Insulation with No Ozone Depleting Substances for Construction of Air Ducts

Whenever the foam insulation is used for pre-insulated duct system without galvanised iron sheet metal, the following guidelines should be followed: -

Wherever necessary, the ducts must be provided with appropriate reinforcements to guarantee sufficient mechanical seal against a

maximum internal pressure of 500 Pa during operation. The maximum deformation of the duct must not exceed 3% of its width or 30 mm in any case.

The joints between one duct and adjacent one shall be performed using flanges with unexposed bayonet coupling and shall be ensured for the appropriate pneumatic and mechanical seal. Elbows shall be provided with turning vanes wherever indicated.

The ducts shall be supported by appropriate supports at intervals of no more than 4m whenever the greater side of the duct is less than 1 m, and intervals of no more than 2 m whenever the greater side of the duct is more than 1 m.

Accessories such as volume dampers, fire barriers or duct heater/heating coil/cooling coil and etc., shall be provided with independent support in such a way that their weights are not imposed on the ducts.

The ducts shall be provided with appropriate test points for the sensors and inspection doors for cleaning and inspection all along the route.

B11.2.6 Pre-insulated Pipes of Foam Insulation with No Ozone Depleting Substances

For pre-insulated pipes, all joints should be made using foam-in-situ (on site foaming) method after joining the service pipes.

All form-in-situ shall be limited to standard straight pre-insulated pipe joints of length below 1 m only. Same foaming chemical shall be used for all foam-in-situ.

All pre-insulated pipe joints and bare service pipes longer than 1 m should be off-site pre-insulated by foaming machine.

All pre-insulated pipes should be supported on the outside of the cladding/ outer jacket and no high-density load bearing or hardwood block is required between the service pipe and cladding/ outer jacket to minimize thermal bridge and enable a seamless foam insulation throughout the whole pre-insulated pipe system.

B11.3 PIPEWORK FITTINGS

Unless otherwise specified, all valves, flanges, strainers, expansion joints, etc., are to be insulated in conformity with the pipework in which they are incorporated, and of the same thickness. All such items where proper treatment on pipework connected to the puddle flanges in tunnel and trench is required shall be provided with relevant insulation filled 0.8 mm thick hammered aluminium split boxes, arranged for easy removal, the box to enclose up to valve handle and to have a lid for valve access. The insulation on the pipes immediately adjacent to flanges, etc.,

shall be neatly swaged off to allow the insulated boxes to be removed without damage to the pipe insulation.

All valves, flanges, strainers, glands, etc. are to be provided with insulation of similar type to that employed on the rest of system (if appropriate to this purpose) fitted into galvanised steel or aluminium sheet split boxes arranged for easy removal so that access to the valves, flanges, etc. can readily be gained without damaging the general run of insulation.

For all chilled water fittings and accessories such as valves, strainers, etc., there shall be external protection of a box constructed with 0.8 mm thick hammer aluminium cladding. The box shall be hinged at a point and fastened together on the other side with a quick action snap catches.

B11.4 CHILLED WATER PUMPS AND ACCESSORIES

All chilled water pumps and their accessories shall be insulated with split box arrangement for easy maintenance without damaging the insulation. Lids of water boxes on chillers and similar places shall be provided so that easy access can be obtained for maintenance without damaging the insulation.

B11.5 DUCT WORK AND AIR HANDLING PLANT - METHODS OF APPLICATION

B11.5.1 Thermal insulation shall be applied to air distribution ductwork and to components within distribution systems such as fans, heater, heating coil, cooling coil casings which convey conditioned air within plant rooms and up to and including all terminal points in the system.

Air distribution systems conveying conditioned, warmed or chilled air through conditioned spaces shall be insulated. Exhaust, ventilation or outdoor air passing any conditioned space should also be insulated.

All ductwork (including re-circulation ductwork) conveying warmed or chilled air through unconditioned spaces or the open air shall be insulated.

Distribution systems conveying untreated outdoor air and exhaust air need not be insulated unless such air distribution interconnecting with heat recovery system/device or passing through conditioned space.

B11.5.2 Fixing methods for insulation shall minimise direct metal paths which thermally bridge the insulation, particularly when the insulation is metal faced. The full insulating effect shall be maintained at connections and access openings and panels including the edges of such openings, fasteners and stiffeners either by means of purposely made boxes or by increasing the general thickness of insulation. Where insulation is applied in layers, all joints in all layers shall be staggered.

B11.5.3 At all points of support, the insulation and outer covering and vapour seal shall be continuous and shall not be pierced or protruded by the supports. The insulation at supports shall be of the material with sufficient compressive strength to take up the loads transmitted to the supports.

B11.5.4 Pre-formed sheet insulation shall be applied with adjacent sides lapped at joints and corners to maintain a uniform thickness. The insulation shall be fixed securely with adhesives conforming to NFPA-90A:2018 and by impaling on fasteners which must be galvanised iron metal studs' split prongs, plastics studs or other approved devices fixed to the thickness and weight of the insulating materials and finishes to be applied and shall be spaced at approximately 300 mm centres. Fastenings shall be finished flush with the surface of the insulation to which they are applied. Adhesives shall be compatible with the insulation and in their dry state be non-flammable. Under no circumstances shall adhesives be used which attack or dissolve the ductwork or insulation.

B11.5.5 Aluminium foil or plastics faced preformed sheet insulation materials shall be placed on the outside of ductwork with adjacent sides lapped to maintain a uniform thickness at joints and corners. All joints shall be sealed with foil tape as indicated in Clause C11.4 and held in place with contact adhesive. The adhesive shall be suitable for the range of ambient temperature and humidity encountered.

B11.5.6 Reinforcement of self-setting cement shall be 25 mm spaced wire mesh of 1 mm diameter galvanised steel wire netting reinforcement. Cement finishes applied to thermal insulation shall always be completely dry before the application of any sealing primer and final decorative coating. Cement application shall be planned and executed in sections to avoid joints between wet cement and cement already dried.

B11.5.7 Where thermal insulation is protected against the effects of weather by plastics sheet or roofing felt, particular care shall be taken to ensure a watertight seal at all joints. The sheet material shall be adhered to the external surface of the insulation and all joints shall be lapped, secured and sealed by adhesives or solvent welding. All jointing and sealing materials and methods of application shall be to the recommendations of the sheet supplier. Poly-isobutylene sheet shall be not less than 0.8 mm thick and have a tensile strength not less than 3.4MN/m2.

B11.5.8 Where an insulated duct passes through an external building element, adequate precautions shall be taken to prevent the entry of rainwater from the outside into the building. Details shall be submitted to the Supervising Officer for approval well before the construction starts.

B11.5.9 Flexible insulation shall have all circumferential and longitudinal joints sealed with tape of the same material or highly compatible with the main insulation facing. The external surface of the insulation shall be wrapped over with 25 mm mesh spaced wire mesh of 1 mm diameter galvanised steel wire netting reinforcement and the netting joints shall

be secured with a lacing of 1 mm galvanised wire. Care shall be taken to ensure that the insulation material is not crushed during this application.

B11.5.10 Thermal insulation and/or acoustic insulation materials shall be applied to the inside of ductwork only where specified by the Particular Specification or Drawing. The insulation material shall be cut to accurately fit the internal duct surfaces. The insulation shall be fastened to the duct using adhesive spread over the entire surface in combination with piercing fasteners finished flush with the insulation surface. Particular care shall be taken to ensure that the edges of all internal insulating materials, whether exposed or butted against similar edges, are sealed and secured to the internal surfaces of the duct. They shall be protected with galvanised iron channel sheet metal of not less than 0.8 mm thickness and 13 mm width. Alternatively, they may be provided with other approved means of protection to prevent erosion and peeling. All materials shall have adequate strength and ability to resist erosion at the maximum design air velocity and shall not produce dust. The provisions of Clauses B8.9 and B8.11 shall also apply where applicable.

B11.5.11 Unless otherwise specified in Particular Specification, fibreglass insulation with scrim glass fibre cloth face finish or elastomeric insulation shall be used for internal lining material.

B11.6 CHILLED WATER PIPEWORK AND EQUIPMENT - MATERIALS AND FINISHES

All thermal insulating materials and finishes shall be as specified in Clause C11.2 subject to the requirements of fire properties (Clause C11.1) and vapour barriers (Clause C11.4).

B11.6.1 Inside buildings for services concealed from view; the insulation shall be provided as specified above and shall be finished as follows: -

(a) In normally non-accessible situations such as ducts, voids and chases, etc., factory applied aluminium foil or plastic film secured by adhesive self-overlaps or by matching tape preformed sections secured by external vapour seal and left unpainted. Where necessary on site vapour sealing compound shall be applied to ensure a 100% seal; and

(b) In all accessible ducts, voids, chases, etc. and where indicated, self-setting cement not less than 15 mm final thickness applied "in-situ" to preformed sections over 25 mm spaced wire mesh of 1 mm diameter galvanised steel wire netting reinforcement, sealed and left unpainted. Alternatively, the insulation shall be vapour sealed as in Clause C11.4 and then protected with neatly applied external aluminium sheet cladding of not less than 0.8 mm thickness with all joints sealed.

B11.6.2 Inside buildings for services exposed to view but not readily accessible; the following shall be applied or as indicated: -

(a) Pliable plastics, elastomeric sheets or rigid plastics, not less than 0.35 mm thick either factory applied to preformed sections and lapped and sealed with adhesive or supplied loose and wrapped on Site with lapped and sealed joints. The sheets shall be either self-coloured or if required by the Supervising Officer finally painted; or

(b) Aluminium foil faced preformed sections secured and sealed by the application of minimum 100 mm wide matching self-adhesive tape over all longitudinal and circumferential joints.

In both of the above cases, the integrity of the required vapour seal must be maintained.

B11.6.3 Services in plant rooms and elsewhere where specified in the Particular Specification or Drawing, shall receive the following treatment in order to avoid possible mechanical damage or make necessary provision as otherwise indicated: -

(a) Enclosed in fabricated sheet hammer clad aluminium casings. The casing shall be not less than 0.8 mm thick for pipework of 150 mm and above measured over the insulation and not less than 0.6 mm thick on smaller pipework;

(b) Be insulated as indicated under Clause C11.2, covered as Clause B11.5.5 and finally painted in accordance with Clause B11.8; and

(c) Be treated with an effective high quality water based vapour barrier coating, Class 'O' surface to BS 5422:2009.

The vapour barrier coating must be non-flammable and safe to transport, store and use. Thixotropic consistency provides easy application with pinhole free, smooth finish, even when bridged over rough substrates. The dried film must be tough, flexible, washable and resistant to acids and alkalis for a long service life.

Glass fibre reinforcing mesh shall also be applied in between coat. The reinforcing mesh should incorporate a thread of 10 strands by 10 strands per 650 mm2 into its construction. When tested according to ASTM D579/D579M-15, the materials should have a tensile strength warp of 50 g/mm2 and fill of 50 g/mm2.

B11.6.4 Outside buildings, services exposed to the weather; either of the following weather-proof covering shall be provided as indicated: -

(a) Enclosed in fabricated sheet hammer clad aluminium casings. The casing shall be not less than 0.8 mm thick for pipework of

150 mm and above measured over the insulation and not less than 0.6 mm thick on smaller pipework;

(b) Enclosed in roofing felt, sealed with adhesive with overlaps of at least 50 mm, wrapped with 25 mm spaced wire mesh of 1 mm thick, galvanised steel wire netting reinforcement, laced with 1 mm thick galvanised wire and painted two coats of bituminous paint or application with 15 mm thick cement plaster and paint;

(c) Enclosed in poly-isobutylene sheet not less than 0.8 mm thick of tensile strength not less than 3.4 MN/m^2, lapped and sealed at all joints; or

(d) Be treated with two coats of elastomeric polymer-based heavy duty mastic with reinforcing membrane to give a weather resistant finish.

The product shall meet the requirement of NFPA-90A:2018. The non-combustible shall be in accordance with NFPA 220:2018. Dry Film Fire Hazard requirements meet GSA and the product should be tested by ASTM E84-18b (Standard Test Method for Surface Burning Characteristics of Building Materials).

B11.6.5 Pre-insulated pipes where specified in the Particular Specification or Drawing, shall be of the following requirement or otherwise indicated:-

All pre-insulated pipe shall be off-site pre-fabricated and pre-insulated by foam injection machine. All pre-insulated pipe shall consist of (i) carrier pipe/ service pipe, (ii) foam insulation and (iii) outer jacket/ cladding. The pre-fabrication and pre-insulation system shall include pipe fittings.

B11.7 CHILLED WATER PIPEWORK AND EQUIPMENT - METHODS OF APPLICATION

B11.7.1 Thermal insulation shall be applied to pipework of chilled water or hot water distribution systems, pipework of thermal fluids of heat recovery systems, cold condensate drain pipes, and all components within distribution systems such as valves and storage vessels, etc.

B11.7.2 Pipework insulation shall also be deemed to include all open vents, cold feeds, chilled/hot water tanks, expansion tanks, valves, flanges, fittings, pumps, accessories, other chilled water plant and hot water plant items whether specifically mentioned or not.

B11.7.3 The insulation shall fit closely to the pipework and other surfaces without gaps between joints. Each section of preformed insulation shall be secured to the pipe by means of circumferential bands of non-ferrous metal, plastics fabric, or adhesive tape. Preformed sheet materials shall be secured to chilled water containers and flat surfaces in the same manner as specified for ductwork. Valves, flanges and

other fittings shall be insulated with "oversize" sections, around valves fittings shall be filled with fibrous material, pieces of shaped insulation or other approved infill. Covers which are to be removable shall be separately secured. Two vapour barriers shall be provided, one to totally enclose the main insulation and the other to cover the removable insulation.

B11.7.4 At all points of support, both insulation and outer covering shall be continuous and shall not be punctured or fouled by the supports. The insulation at supports shall be material of sufficient compressive strength to take the loads transmitted to the supports. The load-bearing insulation shall be extended on each side of the supports.

B11.7.5 At entries into buildings the weather-proofed insulation shall extend not less than 150mm beyond the inner face of the wall and be sealed to prevent the entry of water from the outside into the building to the satisfaction of the Supervising Officer.

B11.7.6 Pre-fabricated and pre-insulated pipe section shall be used and provided for long straight run pipes, such as riser pipes, headers and pipes in plant rooms, etc. as specified in the Particular Specification.

B11.7.7 Unless otherwise indicated, pre-fabrication and pre-insulation shall include but not limit to pipework, valve, flanges, fittings and all accessories.

B11.7.8 The pre-insulated pipes shall be delivered to site with 100mm exposed ends to facilitate field joining. All joints shall be insulated by the same material using foam injection method on site. All foam-in-situ (on site foaming) shall be limited to pipe length below 1 meter. All pipework longer than 1 meter requiring insulation shall be pre-insulated, no on site foaming is allowed except for pipe joints and other piping accessories approved by the Supervising Officer. The insulation shall be applied following the contour of pipework and adhere tightly and evenly with the pipework surface.

B11.7.9 The A/C Contractor shall follow the approved manufacturer’s method statement on installation of pre-insulated pipes and in-situ foaming of pipe joints. Details shall be submitted to the Supervising Officer for approval.

B11.7.10 Pre-insulated pipe supplier shall be engaged to provide training by recognised trainer to the Supervising Officer’s Representative, project installers and inspectors to enable them to understand and familiarise with the installation and to ensure the pre-insulated piping system will be properly installed.

B11.8 PAINTING AND IDENTIFICATION

B11.8.1 Thermal insulation exposed to view (including that within plant rooms) shall be painted the colour of which shall be approved or is acceptable

to the Supervising Officer where insulation is protected by aluminium foil or self-coloured sheet, plastics film or a weather-proof finish and is in concealed space, painting will not be required.

An undercoat and not less than two finishing coats shall be applied. Absorbent surfaces shall also receive an initial coat of priming paint. All paints shall be compatible with the surfaces to which they are applied.

B11.8.2 Painting shall be carried out generally as detailed in Part G. The colour(s) of paint(s) shall be to the requirements of Part G and/or the instructions of the Supervising Officer and shall be selected from the range contained in BS 4800:2011.

B11.8.3 All distribution services shall be colour coded and provided with symbols for identification purposes. Identification coding for ductwork, including thermal insulation, shall be in accordance with B&ES Standard DW/144:2016. For pipework, including thermal insulation, the basic colour and colour coding shall be in accordance with BS 1710:2014.

B11.8.4 Uninsulated pipework or ductwork and thermal insulation which are painted or unpainted shall be identified by bands at least 25 mm wide or colour triangles of at least 150 mm side. The bands or triangles shall be spaced and located to permit ready identification of the services particularly adjacent to equipment positions and at service junctions and wall penetrations.

B11.8.5 In addition to colour bands or triangles all pipework and ductwork in plant rooms and service areas, whether insulated or not, shall be legibly marked with black or white letters and triangles to show the type of service and the direction of fluid flow.

Services shall be shown as follows: -

Chilled water	CHW
Condensing water	CONDW
Hot water	HW
Supply air	SA
Returned or recirculated air	RA
Outdoor air	OA
Exhaust air	EA

The letters F and R shall be added to piped distribution to show "flow" and "return" respectively.

SECTION B12

UNITARY AIR-CONDITIONER

B12.1 GENERAL

B12.1.1 Unitary air-conditioners shall include

(a) Single package unit;

(b) Packaged unit and remote condenser;

(c) Condensing unit and blower coils;

(d) Condensing unit with variable refrigerant flow control and indoor fan coil units;

(e) Multi-split system; and

(f) Water-cooled package and water pump package.

B12.1.2 Unitary air-conditioners shall be factory fabricated and assembled. The equipment shall be rated and tested in accordance with the International Organisation for Standardisation (ISO) Standards 5151:2017 (non-ducted air-conditioners and heat pumps) or 15042:2010 (multiple split system air-conditioners and air-to-air heat pumps – testing and rating for performance) or 13253:2011 (ducted air-conditioners and air-to-air heat pumps) or 13256-1 & -2:1998 (water-to-air and water-to-water heat pumps) or other internationally recognised quality assurance standards approved by the Supervising Officer.

B12.1.3 The most energy efficient model in the series shall be selected for submission and shall be referred to Clause C12.19 of this General Specification.

B12.1.4 Refrigerants adoption for refrigeration and air-conditioning system in government building projects shall comply with flammability safety classification in accordance with Clause B6.1 of this General Specification.

B12.2 INSTALLATION AND SERVICING

Installation and servicing of unitary air-conditioners shall comply with the practice set out in the ISO13261-1:1998 & ISO13261-2:1998 and the manufacturer's recommendation.

B12.3 ANTI-VIBRATION MOUNTING

Vibration mounting shall be installed in accordance with relevant clauses of Section B8.

B12.4 CASING

Removable panel for casings shall be provided to give access to all working components, parts, and connections for installation and service. The casing of condensing unit shall be rigid G.I. Sheets and painted in accordance with relevant clauses of Part G. The compartment housing for the direct-expansion coil and blower shall be adequately insulated to prevent water condensation and shall contain a suitable drip pan in accordance with Clause B3.6.8 with a drain connection. The compartment housing for the compressor shall be treated for effective sound insulation to ensure that the noise emitted is within the limits as specified in the Particular Specification.

B12.5 COMPRESSOR

Each compressor shall form a separate refrigerant circuit with its own condenser, evaporator and controls except multi-split system and VRF.

B12.6 SUPPLY AIR FAN AND MOTOR

All fans shall be statically and dynamically balanced. Fans shall be equipped with permanently lubricated bearings suitable for the installed altitude of the fan. Motors shall be installed in accordance with the relevant clauses of Sections B7 & C7.

B12.7 COOLING AND HEATING COILS

Adequate water collecting tray for run off and removal of the condensation shall be provided. Each coil or circuit shall be controlled by a separate thermal expansion device.

B12.8 AIR FILTER

Air filters shall be installed in accordance with the relevant clauses of Sections B1 & C1 for air duct connection unit.

B12.9 AIR-COOLED CONDENSERS

Condenser fan shall be of propeller type arranged for either horizontal or vertical discharge that shall be specified in the Particular Specification.

B12.10 ELECTRIC DUCTWORK HEATERS

Electric ductwork heaters shall be installed in accordance with Clause C3.2.14.

B12.11 REFRIGERANT PIPING

Refrigerant piping and insulation shall be installed in accordance with relevant Sections in B6, C6, B11 and C11.

B12.12 CONDENSATE DRAIN PIPE

Condensate drain pipe shall lead to the nearest convenient drain in the building or as indicated on the Drawings or as directed by the Supervising Officer on Site.

B12.13 MINIMUM INSTALLATION REQUIREMENTS OF SAFETY AND OPERATIONAL CONTROL FOR UNITARY AIR-CONDITIONERS

Table B12.13 Standard Provision

Associated Components/facilities	Unit Cooling Capacity		
	Up to 7kW	7kW-14kW	over 14kW
1. Self-contained safety and operational components of factory standard	Yes	Yes	Yes
2. Pressure gauges' c/w stop valves, sight glass	-	Yes	Yes
3. Renewable filter-drier c/w accessories	-	Yes	Yes
4. Externally mounted adjustable Hi-Lo pressure cut out with hand reset for High side	-	Yes	Yes
5. Anti-recycling device	Yes	Yes	Yes
6 Emergency Stop Switch	Yes	Yes	Yes
7. Crankcase Heater	-	Yes	Yes
8 Pump down function and facilities	-	-	Yes
9. Refrigerant	R407C/R410a	R407C/R410a	R407C/R410a
10. Mechanical and weather protection to thermal insulation which exposed to view	Yes	Yes	Yes

Note: Room coolers are not covered in this table, relevant clauses in General Specification for Electrical Installation in Government Buildings shall be referred to.

B12.14 SINGLE PACKAGED AIR-CONDITIONER

The entire single packaged air-conditioner shall be housed in a weather-proof and galvanised iron sheet metal casing of robust construction yet painted with attractive appearance.

B12.15 PACKAGED AIR-CONDITIONER WITH REMOTE CONDENSER

The remote condenser shall be air-cooled/water-cooled and installed outside the building. The interconnecting refrigerant piping shall be field connected.

B12.16 SPLIT CONDENSING UNIT AND AHU

The Split Condensing Unit shall be air-cooled/water-cooled and installed outside the building. The interconnecting refrigerant piping between condensing unit and air handling units (AHU) shall be field connected.

B12.17 VARIABLE REFRIGERANT VOLUME SYSTEM

The entire system completed with all necessary piping and accessories shall be supplied and designed by a single proprietary manufacturer who has proven record for its product. The A/C Contractor shall submit their calculation to prove the performance of the equipment with the required length and level difference for approval.

B12.18 MAINTENANCE SERVICING PLATFORM

Where unitary air-conditioners are installed at levels that are normally inaccessible from ground, an adequately sized service platform complete with railings and steel cat ladder with safety wings shall be provided. Such platforms shall be of reasonable substantial rigid galvanised metal construction and shall be well protected against corrosion. The design must be approved by the Supervising Officer before installation.

Under the Labour Department Ordinance, it is required to provide working platform for activity over 3 metres. This maintenance servicing platform requirement shall apply to all equipment and installation.

SECTION B13

WATER HANDLING EQUIPMENT

B13.1 GENERAL PUMP INSTALLATION REQUIREMENTS

The installation details should be in accordance with the instruction prepared by the manufacturer.

Pumps shall be "Type-tested" in accordance with the requirement of BS EN ISO 9906:2012. Test certificates with performance curves shall be submitted to the Supervising Officer.

Pumps and their drives shall be segregated such that failure of pump seals shall not result in damage to the drive motors.

B13.2 STORAGE

The equipment should be stored in a dry space when they are delivered to Site. Special rust preventive measures to protect the internal parts of pumps shall be applied if the equipment must be stored for an extended period of time. Such provisions shall be removed completely before final installation and the bearings should then be re-lubricated.

B13.3 CENTRIFUGAL WATER PUMPS

B13.3.1 Common Installations for Boiler Feed-water, Fresh Water and Saline Water Pumps

(a) Driving Arrangements

The pump and motor shall be direct coupled and mounted on a substantial machined bedplate; accurately aligned, and fitted with guards. The whole assembly including the bedplate shall be designed and supplied by the pump manufacturer. Coupling with spacer shall be used for end suction pumps so that the impeller may be dismantled from the motor side for servicing without neither disrupting the pipe-work nor dismounting the motor.

The pump and motor for vertical multi-stage pump for potable application shall be of close-coupled type.

(b) Stand-By Pumps Arrangement

Where stand-by pumps are specified with automatic changeover provision, the changeover shall be initiated by means of flow sensing devices of an approved pattern. The necessary non-

return valves shall be incorporated in the pipe-work to interconnect such pumps.

B13.3.2 Sump Pumps

The sump pumps shall be of vertical centrifugal design and suitable for dry sump or wet sump installation. Each pump shall be constructed with double mechanical shaft seal and close-coupled to a submersible electric motor.

The sump pumps should operate automatically under level control with an alarm to alert the operator when high water level is being exceeded.

Each pump shall be equipped with factory built-in suspension device and a factory mounted discharge elbow should be provided for wet sump installation, and cast iron or steel base for dry sump installation to provide correct pump alignment for wet sump pump installation, the disconnection shall simply consist of easy removal of each pumping unit for inspection, repairs and services. The pumps when lowered into the pits shall automatically be connected to the discharge piping. There shall be no need for the maintenance or operation personnel to enter the wet well to carry out the work. Each pump shall be complete with guide bars, cable supports and lifting chains.

The pump discharge shall be fitted with a resilient seal that provides a positive hydraulic seal for maximum pump efficiency. Each impeller shall be trimmed to meet the specified flow requirements.

For installation in flammable zones, each sliding guide bracket shall have non-sparking material to prevent ignition of explosive wet well gases.

B13.3.3 Bore Well Pumps

The bore well pumps shall be vertical multi-stage centrifugal construction that is suitable for submersible bore well installation. Each pump shall be of a single shaft and non-shaft coupling type in which a submersible electric motor is coupled at the bottom of the pump. The pump suction shall complete with a perforated strainer located between the submersible motor and the first stage impeller bowl. The pump bearings shall be water lubricated and shall not cause any contamination to the water handled. The submersible motor shall be cooled by water moving around the motor casing.

Each pump shall be equipped with an impact non-return valve located between the pump discharge and rising main to prevent from the flow back of the water in the rising main. A level switch shall be provided for the automatic cut-off of the pump as dry running protection when the water level inside the pit falls below the pump safety suction lift. The level switch shall be maintenance free mercury type.

The bore well pump shall be installed vertically into the pit. No foundation shall be required for the pump on the bottom of the pit. Instead, the pump shall be hung from the pit cover which seals the pit and absorbs all stress resulting from the weight of the bore well pump, cable, rising main and water column. The length of each section of the rising main shall be limited to 3 m long to facilitate the withdrawal of the pump from the pit for maintenance.

B13.4 PLANT ROOM LOCATION

The A/C Contractor shall check and assure that adequate working space must be provided to access for maintenance and sufficient headroom to lift the parts for repairing is provided. For large pumps, a hoist with travelling crane or other facility shall be provided over the pump location.

For an open loop system, the location of pump should be sited so that it will use the shortest and most direct suction and smallest vertical lift. Where possible, the pump centreline should be placed below the level of the liquid in the suction tank.

The A/C Contractor shall take all precautions against flooding when pumps are located in pits or other places liable to flooding. The pumps shall be of the vertical spindle type with the motor mounted above the potential flooding level. Motor and pump shall form one unit being joined by a common stool. Where shaft extension is required, the pump shall be driven through a flexible shaft that consists of a universal joint at each of the drive and driven end and the slip joined at centre of travel.

B13.5 PUMP FOUNDATION

The foundation for a pump should be of sufficient size and rigidity to properly support the full area of the base-plate, to absorb any normal strains and to maintain correct alignment. The minimum mass of inertia block of concrete shall be not less than 2.5 times the mass of the pump assembly with at least 100 mm thick and 150mm wider than the pump base-plate.

The space between the pump unit and the foundation bolts should be allowed in accordance with the manufacturer’s recommendation. Each foundation bolt should be installed in a pipe sleeve type holder and should be cast before the concrete foundation is being poured.

Unless otherwise specified, pump base shall be mounted on the raised housekeeping plinth using appropriate anti-vibration spring mountings. Each spring shall be individually selected according to load distribution and shall have an additional free travel equal to one half of the rated deflection. Spring mounts shall have a levelling bolt and shall be mounted to the concrete inertia block via height saving brackets that allows a base clearance of 50 mm.

A curb ring or soleplate should be used as a bearing surface for mounting of a vertical wet-pit pump. The mounting face of the curb ring or soleplate should be

machined for pump alignment. Tie rods should be installed to secure the pump that is designed to discharge below ground.

B13.6 PUMP ALIGNMENT

The pump unit should be accurately aligned in accordance with the manufacturer's instructions prior to operation. The unit should be supported over the foundation by strips of steel plate close to the foundation bolts, allowing a space of 20 to 50 mm between the bottom of the base-plate and the top of the foundation for grouting. The alignment shall be rechecked after the suction and discharge piping have been bolted to the pump to test the effect of piping strains.

The pump and driver alignment should be rechecked and adjusted correct at the expiry of the Maintenance Period.

B13.7 GROUTING OF PUMP BASE

The base-plate shall be grouted before piping connections are made and pump alignment is finally rechecked. Grouting by Building Contractor should be properly done with concrete that shall compose of one part of pure cement and two parts building sands or be a proprietary non-shrink grout to the acceptance of the Supervising Officer to prevent lateral shifting of the base-plate. Grout holes shall be allowed in the base-plate to serve as vents for air escape. The expose surface of the grout shall be covered with wet burlap to prevent cracking from drying too rapidly. The pump alignment should be rechecked thoroughly after the grouting has hardened for a period that should not be less than 72 hours.

B13.8 SUPPORT FOR PIPING

Suction and delivery pipes shall be supported independently of the pump. The connecting pipes to a pump should not strain the pump. Pipes installation should match up to the respective flanges without being strained into position. The faces of the coupling should be checked with a straight edge to make sure that they are parallel and concentric.

B13.9 CONNECTION PIPING TO PUMP

B13.9.1 Suction Piping

The suction piping shall be properly installed for a satisfactory pump operation. This shall be achieved by keeping as direct and as short as practicably possible with a minimum number of bends. The installations should be laid out such that a continuous fall can be maintained from the pump to water source to prevent air pockets forming. Concentric reducers should not be used on suction branch.
The size of the suction pipe shall be larger than the pump inlet and eccentric reducers shall be used. If the source of supply is located below the pump centreline, the reducer shall be installed straight side

up. If the source of supply is above the pump, the straight side of the reducer shall be at the bottom.

A straight section piping at least 4 to 6 diameters long at the pump inlet and long radius bend shall be used for suction pipeline installations to create less friction and provide more uniform flow distribution.

B13.9.2 Delivery Piping

Unless otherwise specified, the size of the delivery pipe shall be at least one size larger than the pump delivery and the velocity shall be kept around 2 metre per second for pumping water over long distance. The check valve shall be installed between the pump and the gate valve. The gate valve should be installed close to the pump discharge for pump priming and repairing. Provision such as a sprocket rim wheel and chain shall be provided for manually operated valves that are difficult to access.

Air release valves shall be installed at the highest points on each rise to allow accumulated air or vapour or other gases to escape from the pipe.

A 'Y' type branch connection shall be used for distribution of more than one-discharge points.

A taper piece with the included angle between 10-13 degrees shall be used for reduction of pipe diameter.

Adequate support and anchorage shall be provided if the pipes are laid above or below ground. For this purpose, it is acceptable to have thrust blocks in either corner type or puddle flange type that are designed to absorb reactions or turning forces to ensure no mechanical and hydraulic forces imposed on the pump.

B13.9.3 Pipe Flanges

Pipe flanges should match with the sizes of pump flanges with full-face gaskets.

B13.9.4 Expansion Joints

Expansion joints shall be installed in suction and delivery pipelines to avoid transmitting any piping strains caused by expansion when handling hot liquid. A suitable pipe anchor shall be installed between the expansion joint and the pump.

If expansion joints are not specified, expansion loops that are formed by looping the pipe shall be provided to prevent the transmission of strains to the pump.

B13.9.5 Intake

The installation work should be carried out properly to prevent air being entrained as bubble within the water. The intake pipe shall run well below the sump tank level to prevent from forming air gulps.

High level entry into the sump should be avoided as air may be entrained by the falling jet.

Vortex inhibitor shall be installed to prevent air being drawn from bottom of vortex into the intake.

B13.10 SUCTION STRAINERS

The suction strainer shall be installed as close as practicably possible to the pump. This suction pipe strainer should not be used for flushing the pipe. A temporary strainer fitted with a finer mesh than the permanent strainer should be used for flushing all piping and cleaning thoroughly all possible mill scale and other foreign matter. The temporary strainer shall be removed afterwards.

B13.11 VENTING VALVES FOR PUMP-SET

Venting valves shall be installed at one or more points of the pump-casing waterway to provide a means to escape for air or vapor trapped in the casing. These valves shall be connected so as not to endanger the operation staff in handling toxic, inflammable or corrosive liquid.

B13.12 DRAINS FOR PUMP-SET

All drain and drip connections shall be piped to a point where the leakage can be disposed of or collected for reuse if specified.

B13.13 INSTRUMENTATION

Each pump installation shall include pressure gauges and a gas cock to measure the system pressures and pressure drop.

All measuring and isolation instruments, such as the pressure gauges, check valves, globe valves, gate valves and strainers, etc., or as specified in the Particular Specification shall be installed properly to maintain a close check on control on the performance and condition of the pumps.

Instruments shall be mounted in a suitable location so that they can be easily observed.

B13.14 FEED AND EXPANSION TANK

The tank shall be provided and installed on the roof or other location as specified, on a stand if necessary, to suit the NPSH of the pump being selected.

The tank shall be complete with ball float valve, valve, overflow, drain facilities and quickly fill valve, etc. In addition, hinged access door with gasket and rotating hinged bolt-securing device shall also be provided.

Overflow pipe shall be at least TWICE the diameter of the inlet pipe or 32 mm whichever the greater and shall discharge to a conspicuous location outside the building.

Connections to a mild steel tank shall be made by means of bossed, screwed flanges or pads and studs and should be welded before galvanising. Openings for connections to steel tank of other material may be made on site complete with back nuts and plastics that are compatible with the liquid being handled.

Unless otherwise specified, the installation shall include the final connection of the main cold water supply to the ball float valve from a valve point.

B13.15 WATER FILTERS

Unless otherwise specified, water filters shall be provided for the Installations with details as follows: -

B13.15.1 Suitable and approved coarse and fine filters shall be fitted on all non-re-circulating cooling or flushing water supply water system e.g. sea water system.

B13.15.2 For re-circulating systems of the water tower type, fine filters and sludge traps shall be provided.

B13.15.3 For close re-circulating system, filters need only be provided for the "make-up" water if it is drawn from the well or stream water and likely to be contaminated with sediment.

B13.15.4 For the installation of a seawater pump house, in addition to the intake coarse filter, the strainer or the motorised travelling band screen in the plant room shall be an automatic self-cleaning and approved type. The strainers or the motorised travelling band screen in the plant room shall comprise a motorised continuously rotating inner drum, and have an automatic backwash arrangement. Proper drainage facility should be provided by the builder.

B13.16 PLATE TYPE HEAT EXCHANGER

The installation shall be in accordance with the manufacturer’s recommendations and shall be easily accessed for maintenance and repair.

B13.17 SEA WATER STRAINER

The installation shall be in accordance with the manufacturer’s recommendations and shall be easily accessed for maintenance and repair.

PART C - GENERAL TECHNICAL REQUIREMENTS (MATERIAL AND EQUIPMENT SPECIFICATION)

SECTION C1

AIR CLEANING EQUIPMENT

C1.1 GENERAL

Filters shall be of proprietary product and have the specified performance and fire property in accordance with the test methods of one or more of the standards stated hereinafter.

For filters used in corrosion resistant ductwork, the associated housing, holding frames, enclosures and all metal surfaces in contact with the air stream shall be applied with the same coating as the ductwork. Accessories, of which the operation will be affected by corrosive, shall be of AISI 316 stainless steel with the coating omitted.

Unless otherwise stated, the design air velocity at the face of filters shall not exceed 2.5 m/s. Product test reports for the listed efficiency including all details as prescribed in the testing methods of one or more of the standards shall be provided.

To improve indoor air quality and protect air conditioning equipment, outdoor air and re-circulated indoor air shall be filtered to remove dust, bacteria, pollens, insects, soot and dirt particles before it enters the air conditioning system. The following air cleaning devices, dependent on their compatibility with the general air conditioning system, shall be incorporated into the system as in-duct devices or stand-alone devices.

C1.1.1 Particulate Filter

Particulate filters are the most commonly used air cleaning devices in buildings. They are classified into two general categories, pre-filters and final filters, according to the size of the particulate, which they catch and the energy required to circulate air through them. One or a combination of the filters shall be selected depending on the physical characteristics and levels of the dust to be removed, the capacity of the system to overcome the associated pressure drop across the filter and the degree of indoor air cleanliness required :-

Table C1.1.1 – (1) Types of Filters

Stage	Nature	Filter Type
Pre-filters	Washable	Washable Panel Filters
		Automatic Viscous Filters
	Disposable	Disposable Panel Filters
		Disposable Pleated Panel Filters
	Renewable	Renewable Panel Filters
		Automatic Fabric Roll Filters

Final Filters	Disposable	Bag Filters
		Cartridge Filters
		High Efficiency Particulate Arrestance (HEPA) Filters
	Renewable	Automatic Recleanable Filters
		Automatic Recleanable HEPA Filters

The filters shall be cleaned or replaced on a regular basis according to the manufacturer's recommendations or when the specified maximum pressure drop is reached. To prolong service life, two stages of filtration with the minimum efficiency reporting value (MERV) by ANSI/ASHRAE Standard 52.2-2017 as shown in Table C1.1.1-(2) are recommended for buildings designed with a central air handling system to prevent premature clogging and frequent replacement of the high efficiency filter: -

Table C1.1.1 – (2) Filter Efficiency

Conditions	Pre-filters	Final filters
General occupied areas	Required	MERV 11 - 12
Heavy dirt loading areas	Required	MERV 13
Sensitive areas	Required	MERV 14

For critical clean air requirements, such as health care facilities, three filtration stages may be employed with High Efficiency Particulate Arrestance (HEPA) Filter as the third stage.

C1.1.2 Electrostatic Filter

For conditions where low pressure drop, energy saving and minimum servicing are concerned, electrostatic filters shall be used which can also deal with odour of low concentration level.

C1.1.3 Gas Filter

Gas filters are designed to remove gaseous pollutants from the air. Solid sorbents including activated carbons, molecular sieves, silica gel and activated alumina, each of which has a different adsorbing characteristic, shall be used to remove various gaseous pollutants.

C1.2 STANDARDS

C1.2.1 Performance of Air Filter

The performance of air filters shall comply with one or more of the following standards: -

(a) ANSI/ASHRAE Standard 52.2-2017 – Method of Testing General Ventilation Air Cleaning Device for Removal Efficiency by Particle Size;

(b) Underwriters Laboratories UL 586:2009 – High Efficiency, Particulate, Air Filter Units;

(c) European Standard BS EN 16798-3: 2007 - Energy Performance of Buildings – Ventilation for Buildings;

(d) European Standard BS EN1822-1:2009 – High Efficiency Air Filters (EPA, HEPA and ULPA) and BS EN ISO 29463-2:2018 to BS EN ISO 29463-5:2018 – High-Efficiency Filters and Filter Media for Removing Particles in Air; or

(e) European Standard BS EN ISO 16890-1:2016 to BS EN ISO 16890-4:2016 – Air filters for general ventilation; or

(e) Any other standards equivalent to the standards above and approved by the Supervising Officer to suit particular project requirements.

C1.2.2 Fire Property of Air Filter

The fire property of air filters and its associated accessories shall comply with one of the following standards as well as the requirements of the FSD: -

(a) British Standard Institution BS 476-4:1970 - Non-Combustibility Test for Materials;

(b) British Standard Institution BS 476-6:1989+A1:2009 - Fire tests on building materials and structures. Method of Test for Fire Propagation for Products, with Indices "I" $\leq$ 12 and "i_1" $\leq$ 6;

(c) Underwriters Laboratories UL 900:2015 - Standard for Air Filter Units; or

(d) European Standard DIN 53438-3:1984 - Response to Ignition by A Small Flame, Surface Ignition, Class F1.

C1.3 WASHABLE PANEL FILTER

This type of filter shall be constructed of aluminium to withstand washing by water or steam. The filter panel shall be constructed from multiple layers of expanded aluminium mesh or glass, natural or synthetic fibre, with the layers being corrugated or plain and arranged alternately at right angle at one another. Filter media shall be supported on both sides with a rigid and thicker aluminium expanded metal mesh.

Filters shall be 50, 25 or 12.5 mm thick with a rolled or extruded aluminium frame. The frame section shall be ribbed for stiffness and its inner edges treated to prevent sharpness and increase strength. Corners shall be mitred and riveted where it is necessary. Folding handles shall be applied to the short side of all washable filter panels for easy removal and cleaning. The filter support frame shall be suitable for the installation of either side.

It shall have the minimum efficiency reporting value (MERV) by ANSI/ASHRAE Standard 52.2-2017 and initial resistance at 2.5 m/s face velocity as shown in Table C1.3-(1) below, unless otherwise specified in the Particular Specification. The filter shall operate to a final resistance of 150, 100 or 75 Pa for 50, 25 or 12.5 mm thick panels respectively.

Table C1.3 - (1) MERV and Initial resistance of washable panel filter

Thickness	MERV Not Less Than	Initial Resistance Not Exceeding
50 mm	5	50 Pa
25 mm	4	30 Pa
12.5 mm	3	25 Pa

Where coated filtration media is specified, each layer of expanded aluminium shall be furnished with a thixotropic flame resistant filter coating before assembly into a pack. The adhesive shall have a flash point exceeding 180 ^{o}C Performance data for expanded aluminium filter panels oiled with a thixotropic adhesive shall have the minimum efficiency reporting value by ANSI/ASHRAE Standard 52.2-2017 and initial resistance at 2.5 m/s face velocity as shown in Table C1.3-(2) below, unless otherwise specified in the Particular Specification. The filter shall operate to a final resistance of 150, 100 or 75 Pa for 50, 25 or 12.5 mm thick panels respectively.

Table C1.3 – (2) MERV and Initial resistance of coated washable panel filters

Thickness	MERV Not Less Than	Initial Resistance Not Exceeding
50 mm	6	55 Pa
25 mm	5	35 Pa
12.5 mm	4	30 Pa

C1.4 AUTOMATIC VISCOUS FILTER

The filter shall comprise a frame or enclosure, filter plates, motor, drive and fluid tank. There shall be access to the tank containing the fluid to facilitate maintenance and the tools and containers required for the removal of sludge shall also be provided. It shall have the minimum efficiency reporting value not less than 7 by ANSI/ASHRAE Standard 52.2-2017, unless otherwise specified in the Particular Specification. The design air velocity at the face of the filter shall not exceed 2.5 m/s and operating resistance shall not exceed 125 Pa at the design air volume flow rate. To ensure that there is no carry-over of fluid from freshly

wetted surfaces the rate of drive shall be suitably adjusted and set or otherwise the filter shall incorporate shielding devices.

C1.5 DISPOSABLE PANEL FILTER

The filter shall be of glass or synthetic fibres media panel type. It shall have the minimum efficiency reporting value not less than 6 by ANSI/ASHRAE Standard 52.2-2017 and initial resistance not exceeding 75 Pa at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification. The filter shall operate to 250 Pa final resistance.

The glass or synthetic filter media shall be supported between two media retainers inside a reinforced cardboard retaining frame. The media retainers shall be suitably designed and fabricated to provide adequate support, such as combined metal mesh and grilles, throughout its whole working life, the filter element shall be bonded together with a cured resin, with a light adhesive coating, and suitably treated such that the filter media are not affected by air moisture, vermin proof and resistant to fungal growth.

C1.6 DISPOSABLE PLEATED PANEL FILTER

The extended surface pleated filter shall be of similar design for disposal panel filter but it shall be used when higher air cleaning efficiency and higher air flow rate are required. It shall have the minimum efficiency reporting value not less than 7 by ANSI/ASHRAE Standard 52.2-2017 and initial resistance not exceeding 75 Pa at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification. The filter shall operate to 250 Pa final resistance. The pleated media shall be bonded to the expanded wire mesh to maintain its high efficiency and constant air flow rate.

C1.7 RENEWABLE PANEL FILTER

It shall be used for heavy dust loading condition when the maintenance cost is the main decision factor. The filter media shall be of glass or synthetic fibre with a thickness of 50 mm unless otherwise specified. The filter media shall be replaceable and held in position in permanent wire basket, which shall be designed for easy filter element replacement. It shall have the minimum efficiency reporting value not less than 6 by ANSI/ASHRAE Standard 52.2-2017 and initial resistance not exceeding 75 Pa at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification. The filter shall operate to 250 Pa final resistance.

C1.8 AUTOMATIC FABRIC ROLL FILTER

The filter shall comprise the complete assembly of filter frame, motor, drive, filter blockage sensor and filter media. All sheet metal parts shall be of corrosion resistant galvanised steel construction. The filter media, supplied in roll form and 50 mm in thickness, shall be automatically across the face of the filter, while the

used dirty media shall be rewound onto a roll drum at the other end. Each media roll shall not be less than 20 m long for sufficient service life before replacement is required. The filter shall operate automatically to maintain the design operating resistance of the filter media and the required operating efficiency. The filter shall advance the filter media automatically on the command from a pressure switch, timer, or light-transmission control device. The control circuit must operate to ensure uniform feeding of the filter media for constant dirt condition and loading. It shall not require re-calibration if the actual working condition differs from design or if the system is of variable air volume type. Visual or audible warning to notify filter media replacement shall be provided. The driving motor shall be automatically switched off when the filter media end is reached and a filter stop alarm shall be generated to alert maintenance personnel for filter replacement. The controls shall be factory wired and arranged to insure fail safe operation. The filter shall be designed and constructed to enable continuous operation during routine servicing and maintenance of the filter. The filter media shall be provided with an effective seal to minimise air bypass. A spare roll of filter media shall be provided for each unit.

The initial resistance of the filter shall not exceed 45 Pa and a mean of 85 Pa under designed operating conditions. The air velocity through the filter media shall not exceed 2.5 m/s. It shall have the minimum efficiency reporting value not less than 6 by ANSI/ASHRAE Standard 52.2-2017, unless otherwise specified in the Particular Specification.

C1.9 BAG FILTER

The air filter shall be of high efficiency, extended area, deep pleated, disposable type. The media shall be of microfine glass fibre and reinforced by a laminated synthetic backing. It shall have a nominal thickness of 600 mm and the minimum efficiency reporting value shall not less than 13 by ANSI/ASHRAE Standard 52.2-2017 and initial resistance not exceeding 100 Pa at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification. The air filter shall be designed for air velocity of 1.0 to 3.5 m/s and shall operate to 250 Pa final resistance.

The filter package shall be factory assembled as a complete set readily for site installation. The filter assembly shall consist of a holding frame, sealer frame, media retainer, and the disposable element.

The sealer frame shall be constructed of galvanised steel of sufficient thickness and equipped with suitable airtight sealing gasket and sealing mechanism on the sealer frame flange. The media retainer shall be designed to match the filter elements to provide sufficient support for the multiple pleats of the filter element against the direction of the airflow. The media retainer shall be suitably coated and designed to totally eliminate the possibility of oscillation and sagging. The bag or packer shall inflate fully, shall not sag or flutter or be obstructed by contact with other filter faces or ductwork surfaces when operating between 60 - 110% of design air volume flow rate for constant volume system.

C1.10 CARTRIDGE FILTER

This type of filter shall work reliably in the range of medium and high cleaning efficiency. It shall have the minimum efficiency reporting value not less than 13 by ANSI/ASHRAE Standard 52.2-2017 and initial resistance not exceeding 100 Pa at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification. The filter shall operate to 250 Pa final resistance and shall consist of water-resistant media of ultra-fine glass fibres. The media shall be pleated and have suitable separators to maintain the uniform spacing between pleats. The filter assembly shall be of rigid cartridge design, which shall consist of a steel header and cell box to form a supported pleat media pack for various difficult operating conditions. The filter set shall be, unless otherwise specified, of 300 mm nominal thickness disposable extended surface cartridge type. The media shall be water resistant and shall be made of ultra-fine glass fibres formed into thin mate, which shall be supported by suitable corrugated separators and sturdy enough to operate in a VAV system. The filter panel shall be constructed of galvanised steel sheet folded and reverted to form a rigid frame.

C1.11 HIGH EFFICIENCY PARTICULATE ARRESTANCE (HEPA) FILTER

The HEPA filter shall have minimum efficiency of 99.97% in removing small particles of sizes larger than 0.3 micrometre from air by Underwriters Laboratories UL 586:2009. This makes use of a high efficiency glass paper medium and great surface area of medium per cross-sectional area of the filter. It shall reach this rated efficiency when the velocity of the air passing through the media is 2.5 m/s. Unless otherwise specified in the Particular Specification, a normal HEPA filter of a size 600 mm square with 300 mm thickness, shall have a rated flow of 0.75 m^3/s, at a pressure drop not exceeding 250 Pa, and about 23 m^2 of filtering media surface area. The filter shall operate to 600 Pa final resistance.

Filter shall be constructed with the media pack folded over separators to form closely spaced pleats, the whole being sealed into a casing with hard setting synthetic resin cement. This shall enable slower media velocity and increased efficiency. The media of space filter paper produced wholly from glass micro fibres, shall be inert, non-hygroscopic, vermin proof and shall not support bacteria growth. The filter media shall be treated with organic binder materials to provide binder, fungicidal and waterproofing properties.

For clean rooms and clean zones, the HEPA filter shall be selected to meet class 5 of air cleanliness by ISO Standard 14644-1:2015 – Cleanrooms and Associated Controlled Environments - Classification of Air Cleanliness by Particule Concentration, unless otherwise specified in the Particular Specification.

C1.12 AUTOMATIC RECLEANABLE FILTER

The filter system shall include filter media, air compressor unit, air jet nozzles, controller, automatic dust collection unit, etc.

Filter media shall be made of reinforced fibre-glass or other suitable synthetic medium mounted on a rotary tube or a fixed drum. When the pre-set differential pressure between dirty and clean airsides of the filter is exceeded, the cleaning operation shall be initiated. For the rotary tube design, the carrier tube shall rotate and suction nozzle with vibrator motor shall move along the filtering surfaces. For the fixed drum design, an air valve installed at the downstream of the filter shall induce compressed air pulse-jets opposite to normal air flow direction. As a result, dirt particles will be pulsed away from the filter and collected in concentrated form inside a collection chamber, or an external vacuum cleaner, or a central vacuum cleaning system connected outside the filter chamber.

Cleaning shall be carried out both during downtimes of the air-conditioning/ventilation system and during plant operation. It shall have the minimum efficiency reporting value not less than 14 by ANSI/ASHRAE Standard 52.2-2017. The initial resistance across the whole unit shall not exceed 250 Pa at design air flow volume rate and the final resistance shall not be more than 500 Pa, unless otherwise specified in the Particular Specification.

The internal surfaces of the filter set shall be absolutely smooth and the bottom shall be in trough form with drain so that water can be drained away in case of wet cleaning.

The construction of the service door shall be identical to the casing panel. Non-aging steel-inlaid labyrinth seal shall be integrated into the door leaf. Each door shall be fitted with at least two double lever locks with bolts. Safety cams or chains shall be provided for pressure side doors. All the surfaces of the casing shall be protected against atmospheric corrosion by plastic powder coating.

The whole cleaning cycle shall be activated and controlled by a sequence controller with the following basic operations: -

(a) Reverse blowing by air pulses;

(b) Allow a few minutes' time interval for the dust and other contaminant particles to settle at the collector trap;

(c) Operation of the vacuum cleaner/central vacuum cleaning system for a few minutes; and

(d) Actuate alarm for disposal of the contaminant particles when the collecting bag is 80% full.

The filter media shall be selected to suit wet conditions such as market areas and poultry areas.

The controller shall be provided with two operation modes, "Auto" and "Manual". Under the "Auto" mode, the filter media shall be auto-cleaned by the compressor air from the air jet nozzles whenever the pressure difference across the filter media is in excess of the pre-set value. The filter system shall be arranged to connect to CCMS system and operated in accordance with a time schedule which can be set from the CCMS.

An automatic dust collection unit shall be provided to collect dust inside the filter section after each auto cleaning operation.

All of the operation status and fault signals shall be monitored by the CCMS.

The air compressor shall be tested and certified by the laboratories by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved in accordance with relevant statutory requirements.

C1.13 AUTOMATIC RECLEANABLE HEPA FILTER

The whole unit shall be of heavy duty proprietary made air-tight construction. It shall be coated with polyester powder to protect from atmospheric corrosion and to minimise internal friction. By modular construction, each filter chamber of the unit shall be able to be isolated from the air stream without affecting the operation of the unit while cleaning or replacing the filter cartridges within a particular filter chamber. The filter cartridge shall be designed as drawers by sliding in or pulling out for replacement and repairing services from the front panel and entirely from the clean air side. There shall be no contamination on the filter unit and the environment during the replacement. At the bottom, dust collection containers shall be mounted to each filter chamber by clamps via inter-connecting funnel sections.

Automatic cleaning is conducted by using a counter-current compressed air purge sequence. Filter shall be cleaned periodically by compressed air, which is blown in counter-flow direction to the filter cells from nozzles actuated by pneumatic system from the clean air side. A digital measuring and indication device shall be provided to show the differential pressure of all filter cells in one filter chamber.

The controller shall provide two operation modes, "Auto" and "Manual". Under the "Auto" mode, the filter media shall be auto cleaned by the compressor air from the air jet nozzles whenever the pressure difference across the filter media is in excess of the pre-set value. The filter system shall be arranged to connect to CCMS system and operated in accordance with a time schedule which can be set from the CCMS.

An automatic dust collection unit shall be provided to collect dust inside the filter section after each auto cleaning operation.

All of the operation status and fault signals shall be monitored by the CCMS.

The air compressor shall be tested and certified by the laboratories by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved in accordance with relevant statutory requirements.

Filter media shall be made of reinforced fibre-glass or other suitable synthetic medium with minimum efficiency of 99.97% in removing small particles of sizes larger than 0.3 micrometre from air by Underwriters Laboratories UL 586:2009. It shall reach the rated efficiency when the velocity of the air passing through the media is 2.5 m/s. For a nominal HEPA filter of a size 600 mm square with 300

mm thickness, it shall have a rated flow of 0.75 m^3/s and about 23 m^2 of filtering media.

The initial resistance across the whole unit shall not exceed 1500 Pa at design air flow volume rate and the final resistance shall not be more than 2400 Pa, unless otherwise specified in the Particular Specification.

C1.14 AUTOMATIC RECLEANABLE HIGH VOLTAGE ELECTROSTATIC FILTER

The automatic recleanable high voltage electrostatic filter shall be able to control odours in the conditioned space and reduce the permanent deposition of contaminants in the space served. It shall have the minimum efficiency reporting value not less than MERV 14 by ANSI/ASHRAE Standard 52.2-2017 and an initial resistance not exceeding 120 Pa at design air flow volume rate, unless otherwise specified in the Particular Specification. The whole unit shall be tested to meet Underwriters Laboratories UL867:2011 - Electrostatic Air Cleaners and of a type approved by the Director of Fire Services. It shall not be used in hazardous locations or for handling hazardous gases/mixtures.

For kitchen applications, it shall comply with the requirements of the Environmental Protection Department on the treatment of gas fired kitchen exhaust air and the unit shall be leakage proof to avoid oil dripping. It shall have oil mist removal efficiency not less than 90%, odour removal efficiency not less than 50% and an initial resistance not exceeding 120 Pa at design air flow volume rate, unless otherwise specified in the Particular Specification. Oil mist removal performance shall be verified by laboratories by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved. The whole unit shall be tested to meet Underwriters Laboratories UL710:2012 - Exhaust Hoods for Commercial Cooking Equipment (for Fire and Burnout Test only). Filter performance shall be tested according to ANSI/ASHRAE Standard 52.2-2017 and equipment shall be tested to meet Underwriters Laboratories UL867:2011 - Electrostatic Air Cleaners.

The unit shall consist of an ioniser-collector section power generator, an aluminium washable panel filters section against over-spray and a washer and adhesive applicator section. All parts shall be factory assembled into a sectioned housing having an overall depth not greater than 1000 mm in direction of airflow. Each section of the galvanised steel housing assembly shall incorporate a pair of hinged, quick opening access doors permitting access for servicing of all internal components; and a watertight, all welded, galvanised steel, drain pan having drain connections. Access doors shall be sealed against leakage by continuous perimeter gaskets of closed cell neoprene.

C1.14.1 Each ioniser-collector section shall be furnished with the required number of one-piece or multi-piece cells of all aluminium construction. Each cell shall be fitted with stainless steel slides for mounting on the tracks, which form an integral component of the side access housing and to facilitate removal of cells for servicing. Cell support framework shall be completely open beneath the ioniser-collector cells to ensure complete drainage of wash water and excess adhesive, minimising the

possibility of short circuits when high voltage power is restored following completion of the wash cycle. Cells shall be designed so that high voltage input terminals and their high volt rated insulators are located completely out of contact with the moving air-stream to avoid build-up of dirt which could permit dissipation of high voltage charge and reduce air cleaning efficiency. The high voltage bus bars and contactors shall be inherent to the design of each cell and shall permit cell removal without disconnecting any high voltage wiring. Insulators shall be fully exposed, for ease of cleaning, when cells are removed for service. Cells shall be designed for full-face ionisation and shall have completely flat collector plates to prevent build-up of residual, inaccessible dirt accumulations.

C1.14.2 Dual voltage power packs which are designed to provide high voltage to the ioniser circuit and to the plate circuit respectively shall be connected to each ioniser-collector section. The power packs shall be of solid state design to include "fail-safe" low voltage relays to interrupt power to the ioniser circuit in the event of a malfunction in the plate circuit. High voltage connections between the high voltage output terminals and the bus bar terminals mounted on the ioniser-collector section access door shall be adequately installed. Each power pack covers shall include a circuit breaker, a manual reset button and / or automatic reset. Safety type door interlock switches, with suitable length of safety chain and wiring in series circuit for the power pack, shall be furnished to cut-off the power supply whenever the door is opened.

C1.14.3 Each washer and adhesive applicator section shall incorporate slide-in type, perforated, galvanised steel air distribution baffles and a swing or fixed header assembly. The header assembly shall be connected to the inlet water solenoid valve and to the adhesive pump. Washer arms shall be equipped with 360ofixed washer spray nozzles against reactive force to the high inlet water pressure. The removable brass adhesive nozzles shall be mounted on a separate, fixed, vertical header forming an integral component of the assembly. The filter adhesive shall be cold water soluble and non-flammable. A rotary gear adhesive pump with bronze impeller and sufficient adhesive for at least four reconditioning cycles shall be furnished.

C1.14.4 The washer supply water solenoid valve, manifold drive motor, manifold limit switch and adhesive pump shall be pre-wired to an accessible, internally mounted terminal box. The washer control panel shall incorporate a status light to indicate when the reconditioning cycle is energised and the reconditioning cycle is in operation. The complete automatic cleaning by reversing the polarity of the filter element, wet washing by water spray and adhesive application shall be initiated manually or automatically through a push button actuated, internally fused, all solid state and program timer control. The controller shall be provided with two operation modes, "Auto" and "Manual". Under the "Auto" mode, the electrostatic filter shall be automatically cleaned on the timer of pre-set value and cleaning operations shall not be energised when the exhaust fan is in running

status. The filter system shall be arranged to connect to CCMS and operated in accordance with a time schedule set from the CCMS.

All of the operation status and fault signals shall be monitored by the CCMS.

C1.15 GAS FILTER

The gas filters shall remove gas pollutants from the air by absorption or adsorption. It shall comprise a robust enclosure inserted with module banks which contain evenly disposed chemical media. The complete unit is to be factory assembled and manufactured by the same manufacturer. All joints between the robust enclosure and the module banks shall be effectively sealed to eliminate air bypass and to ensure the optimum removal efficiency. Their supports shall be constructed from steel protected against corrosion and designed to provide mechanical protection to the module banks. The chemical media shall be of uniform thickness packed to ensure that compacting does not occur in use.

The chemical media shall consist of solid sorbents including activated carbons for common volatile organic compounds in indoor air and activated alumina suitably impregnated with potassium permanganate for formaldehyde and other gaseous contaminants. The combined media shall be able to operate normally at temperatures 0 ^{o}C to 45 ^{o}C and relative humidity 10 to 95%. It shall be inorganic, non-toxic, non-flammable and shall not support bacterial or fungal growth.

The gas filters shall be selected to give the removal efficiency not less than the following value and an initial resistance not exceeding 140 Pa at 2.5 m/s face velocity, unless otherwise specified in the Particular Specification: -

With 0.0283 cubic metre of media per and 0.472 cubic metre per second of air, media shall have a scrubbing efficiency of not less than 99.95% at 0.5 ppm hydrogen sulphide or ammonia inlet challenge concentration for a period of 3600 hours.

Impregnated alumina media shall meet the following removal capacities: -

Hydrogen Sulphide	-	8% min. by weight
Sulphur Dioxide	-	3.5% min. by weight
Nitric Dioxide	-	2.5% min. by weight
Nitrogen Dioxide	-	1.0% min. by weight

Impregnated carbon media shall meet the below removal capacity: -

Ammonia Gas	-	5% min. by weight

Media in the modules shall be manufactured from a combination of activated alumina impregnated with 4% potassium permanganate by weight in such a manner that the impregnate is available for reaction. The media shall be inorganic, non-toxic, non-flammable and shall not support bacterial or fungal growth.

Laboratory analysis report on media samples to establish life cycles and remaining life shall be submitted to the Supervising Officer for approval.

C1.16 ACTIVATED OXYGEN AIR PURIFIER

The air purifier shall be capable of reducing odours of bacterial, organic and chemical origin and shall also be capable of reducing airborne bacteria and particulates in the treated areas.

All components of the air purifier, which are within the air stream, shall comply with the requirement of the Fire Service Department. The air purifier shall conform to BS EN 61000-6-1:2007, BS EN 61000-6-2:2005, BS EN 61000-6-3:2007+A1:2011 and BS EN 61000-6-4:2007+A1:2011 or similar international standards on Electro-Magnetic Compatibility (EMC) compliance.

The air purifier shall have removal efficiency of not less than 95% of Total Bacteria Count (TBC) Test, 95% of airborne particulates of 0.5 micron to 2.0 micron, 95% of cigarette smoke particles, 80% of odours, and 95% of hydrogen sulphide, unless otherwise specified in the Particular Specification. Test reports and certificates by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved to show the removal efficiency of the unit shall be submitted to the Supervising Officer for approval.

The air purifier shall not generate ozone in the treated areas in excess of the safety standards as specified by the Occupational Safety and Hygienic Association (OSHA), USA or other recognised international standards. A proper control device to shut off part or the whole unit is required when excessive ozone is detected over the limit of OSHA. A site test shall be carried out to verify that the ozone level in the occupied zone does not exceed the specified level.

The air purifier shall be suitable for ductwork mounting and shall consist of a power generator and screw-in or snap-on electrodes. The power generator shall be able to operate at 220 V 50 Hz single phase supply, equipped with on/off switch, on/off indicator lamps, over load circuit breaker (fuses) and electrode tube sockets. Indication lamp for individual ionisation tube shall be provided. The side in contact to air stream of the power generator housing shall be insulated by double skin panel with proper means of thermal insulation in order to prevent condensation.

There shall be a minimum of 1 transformer for every 2 tubes. The output of the transformer shall be at 2800V whenever ionisation is being called for.
For air purifier installed in the exhaust air plenum, the plenum shall be of min. 300 mm length after the exhaust fan and using a stainless steel mounting flange provided by the manufacturer. It shall be interlocked with the respective ventilation fan so that it switches on/off with the air handling unit or ventilation fan.

Energy of each electrode tube shall be good enough for ionising 0.045 litre/s/W oxygen.

The electrode tubes shall consist of screw-in base and a glass tube. The electrode tube shall be covered with a stainless steel mesh and shall be electrically earthed by means of an earth clip or an earth screw securely connected to the power generator. The required number of electrode tubes shall be in accordance with the manufacturers' recommendation.

A control unit shall be supplied to guarantee stable and situation referred ionisation process without generating excessive ozone for this application. Ozone monitoring device shall be provided. The unit shall be able to control several purifiers by either Auto or Manual mode.

Under Auto mode, the control unit shall moderate the output intensity of the purifiers in accordance with the information concerning adaptation, total power consumption, air flow, relative humidity, VOC concentration and also ozone level for human safety. Adaptation values are depending on the application. Control signals shall be provided by relevant duct mounted sensors. Ionisation intensity can be moderated in the range of 0 to 99% in steps of 1%.

The control unit shall be able to switch off the air purifier when the air flow is below the pre-set value in the control unit in order to prevent the accumulation of ozone inside the system.

The control unit shall be able to reduce 50% and 10% intensity of the computed value when the ozone level of supply air is exceeded 30 ppb and 50 ppb, respectively. It shall stop the unit if the ozone level detected in the first supply air outlet is greater than 61 ppb.

Under Manual mode, the intensity of the purifiers shall be in accordance with the pre-set (adaptation) value at the control unit and independent of the sensor values.

The control unit shall include a LCD display or other display device as approved by the Supervising Officer for sensing values, hour counter and an error / alarm logger record of malfunction. All configuration setting shall be adjustable by using keypads and further protected by a password against unauthorised access of untrained staff.

For purposes of monitoring and remote control, the received signals from the sensors, system parameters and alarm status shall be able to be monitored and set by using the CCMS via a RS232 interface. The time interval of signals is at least 2 seconds. A dry contract for system alarm shall be provided for local / remote monitoring of system operation. Causes of the alarm shall include the failure of sensors and the air flow & humidity exceeding the pre-set values.

The air purifier shall be UL listed and tested to comply with Underwriters Laboratories UL 867:2011 – Electrostatic Air Cleaners.

C1.17 ULTRA-VIOLET (UV) STERILISING LIGHT

The UV steriliser light shall be provided to disinfect the supply air and eliminate any health hazard from the mechanical ventilation and air-conditioning system.

It shall be mounted within the air handling unit, return air duct or other appropriate locations as specified in the Particular Specification.

The complete system shall consist of UV tubes, tube fitting set, electric supply unit and monitoring unit. It shall be designed for achieving a minimum bacteria removal efficiency of 90%. Equipment shall be selected on basis of UV lethal dosage requirement, not less than 5,000μWs/cm^2, for bacteria removal. Relevant selection method and test reports and certificates by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved to show the removal efficiency of the unit shall be submitted to the Supervising Officer for approval.

The UV steriliser light shall not generate substances in excess of the safety standards as specified by the Occupational, Safety & Hygienic Association (OSHA), USA or other recognised international standards.

The UV irradiation sections shall be provided with access door, inspection window and safety switch. The A/C Contractor shall ensure sufficient access space is allowed for maintenance purpose. A permanent warning notice shall be placed at the access door to alert personnel the danger of direct sight at the UV lamps.

The UV steriliser light shall be suitable for operation under supply voltage of 220V/50Hz. It shall be of high grade, non-corrosive materials. The housing shall be of high quality stainless steel and lamps shall be made from quartz glass with ceramic bases.

The electric supply unit shall be allowed to mount inside the irradiation chamber. System components exposed under moist air or condensation shall be of IP68. It shall have an implemented safety switch-off after lamp breakdown.

The working range of the electronic ballast shall be linear throughout a wide range of temperature. It shall have an implemented over voltage cut-out to improve safety and material protection. It shall not emit at a temperature above 40 ^{o}C during operation.

The UV steriliser light shall start and work properly even under unexposed, unfavourable working temperatures.

The emitter shall consist of electrodes and high quartz glass tube with ceramic bases. Each tube shall consume not more than 36W but emit pure UVC irradiation at wavelength 253.7nm of not less than 120μW/cm2 measured at 1 m distances from the source after 100 hours under 25^{o}C.

Life span shall be not less than 12,000 hours with residual output of 75 ±5% of the original output, measured after 100 hours under 25^{o}C.

The UV output of the lamps shall be highly stable over an air temperature range of 5 ^{o}C – 25 ^{o}C and in no case the output fluctuation shall be greater than 30% of its nominal value within this temperature range. The UV output reduction shall not be any higher than 10 ±5% of its nominal value after 2000 hrs of burning in air.

The monitoring unit shall be an independent wall mounted unit installed in the vicinity of the sterilisation section. It shall be enclosed with casing of at least IP54.

The monitoring unit shall consist of any easy to reach circuit breaker, an on/off 3-way switch (auto/off/manual), a leakage current protective switch, a good visible general malfunctioning alarm lamp and shall have an indication display with at least two coloured functioning LED's for each connected ultraviolet system.

The monitoring unit shall be able to give information about used life span and lamp replacements for any connected system. It shall be able to monitor up to 42 lamps.

The monitoring unit shall be equipped with an RS 232 interface for external communication via CCMS. All of the operation status and fault signals shall be monitored by the CCMS.

The UV steriliser light shall be UL listed and tested to comply with Underwriters Laboratories UL Standards 153:2014 – Standard for Portable Electric Luminaires, UL 1598:2018 – Luminaires &UL 1995:2015–Heating and Cooling Equipment respectively.

C1.18 WATER SCRUBBER

The water scrubber shall be provided for applications such as Refuse Collection Point (RCP), Cooked Food Centre (CFC), Poultry Stalls, serving as the exhaust systems for central air treatment of odour, gas, liquid and solid contaminants prior to discharge to the atmosphere. Three of the major components of contaminants in the RCP application are hydrogen sulphide, mercaptans and aldehydes. Whereas oil mist will be present in the foul air source of the CFC or poultry stalls.

All components of the water scrubber shall be compatible to each other in all aspect and wholly imported, factory built and assembled as complete units before shipping. The only field connections required on site shall comprise only external control circuitry, pipework, fan and ductwork connections. For very big unit or due to site constraint that on site assembly is necessary, prior approval shall be obtained and installation method statement shall be submitted to the Supervising Officer for approval and as required per the Electrical General Specification.

The manufacturer shall have at least five years' experience and proven record in the design and manufacturing of water scrubber equipment and has considerable amount of job references and installations for similar applications.

Certificates and documentary evidence of excellent chemical resistance of all materials, components and equipment adopted for operation with the selected chemicals and specified application shall be submitted to the Supervising Officer for approval. In addition, the following detailed information and calculations shall be provided: -

(a) Chemical reaction formulation and design criteria;

(b) Selection of the type and depth of packing, mist eliminators, nozzles, etc. with manufacturer's test data or recognised standards;

(c) Scrubber overall height & dimensions, packing depth, mist eliminators depth, etc.;

(d) Selection of water recycle pump head and flow rate in accordance with the system design and configuration to meet specified performance;

(e) Design of maximum air velocity at specified air flow rate and selection of fan duties with respect to the design flow and pressure drop in ductworks, fittings, silencers, scrubber section, etc.;

(f) Dosing rate of chemicals required and feed-in water /bleed-off rate; and

(g) Equipment sound level calculation and acoustic treatment offered for compliance with the specified acceptable noise levels.

All materials, fabrication procedures, manufacturing tolerances, workmanship, tests and product quality shall conform to the U.S. National Bureau of Standards PS 15-69:1969 - Custom Contact Moulded Reinforced Polyester Chemical-Resistant Process Equipment. Product Standard for Custom Contact Moulded Reinforced Polyester Chemical Resistant Process Equipment or equivalent recognised standards as approved by the Supervising Officer.

Before the scrubber is despatched from the factory, the manufacturer shall obtain a certificate from a reputable independent inspection company such as Bureau Veritas, Lloyd or SGS United States Testing Company Inc., etc. The certificate shall state whether the scrubber assembly is standard manufactured product, list the major equipment and materials for construction and advise whether they comply with our specification.

Each complete scrubbing system shall comprise a scrubber housing, a scrubber section with knockdown baffles/packing, mist eliminator, scrubbing liquid distribution system, chemical feed pumps, fan, chemical tanks, silencers, instrumentation, acoustic enclosure and all necessary controls as well as any other accessories required to build up a functional plant to the satisfaction of the Supervising Officer.

All material and components adopted in the scrubbing system shall be suitable for operation with the selected chemicals including sodium hypochlorite, sodium hydroxide and the resulting by-products of scrubbing.

Those items specified to be constructed of FRP shall be fire retardant grade to Class 1 of BS 476- 7:1997 – Method of Test to Determine the Classification of the Surface Spread of Flame of Products and shall be stabilised against ultraviolet degradation. The type of resin to be used shall be approved by the Supervising Officer.

Acoustic treatment shall be provided to ensure the sound level at site boundaries complies with the latest requirements of the Environmental Protection Department.

C1.18.1 Performance Requirement

(a) Application

Removal of odour, gas, liquid and solid contaminants of foul air source at the RCP, CFC, Poultry Stalls or other specified areas through water scrubbing, absorption and chemical oxidation of malodorous compounds in the exhausted air.

(b) Odour Removal Efficiency

- Not less than 99% based on hydrogen sulphide at 25 ppm, mercaptans, aldehydes and other airborne contaminants; or

- Not less than 60% for kitchen exhaust.

(c) Oil Mist Removal Efficiency

Not less than 99% for 4μm oil particles.

(d) Chemical Selected for Operation

Sodium hydroxide, sodium hypochlorite, or other chemicals as specified in the Particular Specification.

C1.18.2 Construction

The scrubber shell shall be constructed of fibreglass reinforced polyester resin (FRP).

Scrubber section of horizontal draw-through non-clogging venturi type shall be used for exhaust air treatment from kitchens of CFC. A series of knockdown baffles of FRP or other approved equivalent type shall be placed directly following the venturi section. The knockdown baffles shall be designed to remove 90% liquid coming from the venturi section and entering the mist eliminator.

Scrubber section of horizontal draw through cross-flow packed tower bed type shall be used for exhaust air treatment from RCP or Poultry Stalls. The packing shall have a free volume of 95% and minimum 100 square metres of surface area per cubic metre of packing. Pressure drop per metre of packing shall not exceed 165 Pa. The packing shall be made of polypropylene or other approved equivalent type. All packing support shall be made from heavy duty FRP construction. The packing depth, recirculation rate, and recirculation solution shall be designed to meet the required performance and efficiency.

Each scrubber shall include a scrubber housing, internal structural members, scrubber section with knockdown baffles/packing, mist eliminator, scrubbing liquid distribution system, chemical feed pumps, fan, chemical tanks, silencers, instrumentation, acoustic enclosure, lifting and hold down lugs, etc. All components and accessories shall have sufficient mechanical strength and designed to withstand the extremely corrosive continuous operating environment and pressure even with the absence of chemical dosing.

Sufficient access manholes/panels and facilities shall be provided for inspection, removal and maintenance of all internal parts. Panels shall be completed with handles and neoprene gaskets secured with wing nuts to avoid spill out of water from the scrubber. The whole assembly shall be supported on structural members made of FRP or other approved equivalent material with mechanical strength and properties compatible with conventional steel members.

The mist eliminator section shall be replaceable, corrosion resistant, mesh type or other approved type fabricated of FRP or equivalent as approved and capable of removing not less than 90% of the entrained moisture in the air exhausting through the scrubber. The eliminator section shall be in modular form of adequate surface area and strength to withstand the handling air flow rate and pressure and placed in last section of the scrubber.

The scrubbing liquid distribution system shall be of the spray type or other approved type, sized for the flow rate to suit the design of the scrubber system to meet specified performance. No liquid distributors shall be permitted. Material of construction shall be polypropylene or FRP of same material as the shell.

Spray nozzles shall be constructed of polypropylene or other approved equivalent material.

Each scrubber shall be designed with a sump for collecting the recirculated scrubbing liquid. It shall be finished with three nos. of recycle pumps, one of which as standby. Manual selection switch shall be provided to enable selection of either one of them as standby pump. The pumps shall be direct coupled to TEFC motors, self-priming, horizontal end suction, corrosive resistant, centrifugal type. Accessories such as pressure gauges, stop and vent cocks shall be provided for each pump. The flow rate shall be determined by the A/C Contractor to suit the performance specification with adequate flow rate and pump heads to cater for the piping and scrubber plant friction losses. The pump casing, impeller shall be of rigid PVC and the impeller shaft shall be of stainless steel or equivalent corrosion resistance materials approved by the Supervising Officer.

Corrosive resistant flexible connectors shall be provided between all ductwork joints of the water scrubber.

All pipework, fittings and valves shall be made of UPVC or other approved equivalent material. All internal and external bolts and fasteners, including anchor bolts and flange bolts shall be of high grade 316 stainless steel.

The scrubber shall be suitable for application involving hot gas streams containing relatively high particulate loadings.

C1.18.3 Chemical Feed System

Each scrubber system shall be provided with a complete chemical feed system for storing and feeding the chemicals required. The A/C Contractor shall provide all adequate provisions for the storage, installation and operation of the chemical solutions in compliance with the Fire Services Regulations as the scrubbing chemical solutions used are in the list of Dangerous Goods Category. The Chemical feed system shall comprise chemical storage tank and feed pump for each scrubbing chemical solution, piping and valves, and all necessary controls.

Chemical storage tanks shall be vertical flat bottom type made of FRP with scale and lockable screw lid and shall be suitable for storing the scrubbing chemical solution. Each tank shall have a minimum effective capacity of holding the exempted quantity at specified concentration allowable by the FSD, typically of 250 litres. One set of protective goggles, gloves and overalls shall be provided for each scrubber.

Chemical metering pumps shall be solenoid operated diaphragm pump for the type of weatherproof protection. The pumps shall be operated on 220 V/single phase/50 cycles. Housing and liquid end shall be corrosion proof as well as dust and waterproof to protection Class IP65. Housing shall be die cast light-metal alloy. Solenoid shall be proofed against overload and excessive counter pressure such that it will not result in failure. Pumping capacity shall be adjusted in ratio of 1:10 through stroke length and 1:25 through stoke frequency, accessories shall include PVC dosing valve and foot valve.

C1.18.4 pH and ORP Control

Each scrubber shall be provided with pH and ORP probes suitably located for analysing the contents in the scrubber sump. Probes shall meet the following specifications: -

	pH Probe	ORP Probe
Range	0 to 14 pH	0 to 990 mV
Stability	0.03 pH units	0.5 MV per 24 hr. per day, non-cumulative
Temperature	0 ^{o}C to 40 ^{o}C	0 ^{o}C to 40 ^{o}C
Pressure Rating	4.83 kPa	4.83 kPa

Wetted Materials	Glass	Glass
Accuracy Sensitivity	0.1 pH unit	5 HV

Each probe shall be supplied with analyser and level alarm at the local and remote control panels and they shall be actuated when the chemical levels at chemical tanks are lower than the pre-set values.

C1.18.5 Fan

Motor driven fans shall be provided for each scrubber unit and shall be of sufficient capacity and horsepower, as indicated in the Equipment Schedule to deliver the required volume of air against the total pressure losses in the air intake, duct pickup systems, packed bed, mist eliminator, silencers and exit ducting, etc.

Fans shall be of high efficiency and low speed backward curved aerofoil types with lowest noise level suitable for outdoor application. Sound power level spectrum shall be submitted for approval and the data shall be verified on Site as specified.

Fan housings, flanges and impellers shall be constructed of FRP laminate as approved by the Supervising Officer.

Inlet connections shall be Neoprene slip type flex connector with stainless steel draw-bands. Outlet connection shall be a rectangular undrilled flange.

Each of the blowers shall have V-belt drive with a minimum service factor of 1.5 times the rated brake horsepower of the fan motor and shall be equipped with heavy-duty, self-aligning sealed ball bearings.

Fan shafts shall be carbon steel and sized to run below critical speed. A steel hub encapsulated with FRP shall be provided to a point flush with the housing. Wheel and shaft assemblies shall be statically and dynamically balanced in 2 directions according to recognised international standards.

The fan base shall be made of corrosion resistant material of sufficient strength or carbon steel treated with anti-corrosion coatings as approved by the Supervising Officer. No metal parts shall be exposed to the corrosive air stream.

Fan shall be completed with motor, drive, belt, FRP motor and drive canopy, housing drains, access doors and flexible connectors for inlet and outlet, etc.

C1.18.6 Motor

Unless otherwise specified in the Equipment Schedule each fan shall be provided with a horizontal squirrel cage induction type motor of sufficient power such that no point on the fan curve requires more than the horsepower of the motor plus a 15% spare capacity.

Each electric motor shall be suitable for 380 V, 3 phase, 50 Hz and 24 hours' continuous operation.

The motor enclosure shall be totally enclosed, fan cooled and suitable for outdoor application.

The motors shall be designed, constructed and tested in conformance with all the requirements of the applicable standards of the IET, NEMA and ANSI and as required in the Electrical General Specification.

The A/C Contractor shall be responsible for calculating and submitting for approval the fan static pressure to suit the ducting configuration and proposed equipment with calculations.

Acoustic treatment, such as silencers and acoustic enclosures shall be provided to ensure the noise break out to adjacent areas is at an acceptable level complying with Government Authorities' regulations.

Silencers shall be of pack less type or be completed with adequate coating and shall be suitable for the chemical corrosive environment.

C1.18.7 Control

The water scrubber system shall be capable of both automatic and manual operation. In "DDC/auto" mode, the central exhaust fan shall be started or stopped automatically by the DDC system. The scrubber exhaust fan shall be interlocked with the recycle pumps' operation such that it will not be operative unless the pumps are operating. A 2-way motorised valve and flow regulating valve at water feed-in pipe shall be provided and interlocked with the fan.

Chemical feed pumps shall dose proportionately to maintain the desired concentration of the scrubbing liquid. NaOH shall be controlled with pH analyser to maintain a pH value of 8 to 9 while NaOCl shall be controlled with oxidation-reduction-potential (ORP) analyser to maintain an ORP value of 300 to 400 mV or to values as recommended by the manufacturer in order to comply with the specification.

Low level sensors in the water scrubber chamber shall be provided and installed to give audio and visual warning signals at the local & remote control panels and to stop the circulating pumps when the pre-set extra low water level condition is reached.

Corrosion resistance low level sensors shall be provided and installed for each of the chemical tanks to give audio and visual warning signals at the local & remote control panels during low chemical level condition.

Flow switch shall be provided and installed at the feed-in water pipe to give audio and visual warning signals at the local & remote panels during "no flow" condition.

In "manual" mode, the fan and pumps shall be operated by means of start/stop buttons at the water scrubber control panel.

Emergency stops shall be provided adjacent to each of the pump and fan unit.

Local and remote control panels shall be provided for the water scrubber systems at location as shown on the Drawings. Local/remote selector switch shall be provided at the local panels for choice of control mode. In "remote" mode, the water scrubber system shall be started or stopped via manual push buttons at the remote control panel. The scrubber exhaust fan shall be interlocked with the recycle pumps' operation such that it will not be operative unless the recycle pumps are operating.

In "Local" mode, the fan and pumps shall be operated by means of start/stop buttons at the local control panel.

The following minimum facilities shall be provided at the local control/starter panel: -

- Power on indication – green;
- Local/remote selector;
- Recycle pumps sequence selector;
- Start and stop push buttons for fan and pumps;
- Hour run meters for fan;
- Running (blue) and fault (red) indication for fan and pumps;
- Ammeters for fan;
- Low level alarms (red) for each chemical tank;
- Low level alarm (red) for the water scrubber chamber; and
- No flow alarm (red) for the feed-in water pipe section.

C1.19 WASHING FACILITIES FOR WASHABLE FILTER

Where washable filters are provided, the A/C Contractor shall provide one set of duplicate cleaning tanks (one to wash, one to rinse). These tanks shall be big enough to accommodate the various filters sizes provided, subject to the approval of the Supervising Officer or if the A/C Contractor wishes several sets of tanks may be provided to accommodate the various filter sizes provided.

The filter cleaning tanks shall be constructed of at least 1 mm thick stainless steel of AISI 316 and suitably stiffened around the top edges by continuous external turned over inverted "U" sections. The tanks shall be 0.4 m deep. They shall be supplied with 18 mm drain down cock for emptying but shall also have external handles to facilitate turning over to clear sludge.

C1.20 FILTER PRESSURE DIFFERENTIAL MEASUREMENT AND INDICATION

A differential pressure gauge of the inclined manometer type shall be provided for each filter bank.

The gauge shall incorporate a graduated scale on which the reading of maximum pressure drop shall occur in not less than 75% of the total scale length.

C1.21 ADDITIONAL REQUIREMENTS (SPARE FILTER MEDIA)

The A/C Contractor shall replace all filters used during testing and commissioning stage and in addition provide the following to the Supervising Officer for use by Employer’s operation staff during Maintenance Period: -

(a) For disposable type filters, one complete set of unused filter cells;

(b) For washable type filters, 20% in number of each size of filter cells provided. These shall be new and in good condition. Besides, 10 litres of the approved cleaning detergent per filter installation shall be provided. Regarding filters of viscous type, a drum or drums of fluid amounting to one complete change or 10 litres per filter installation where thixotropic coatings are used shall be provided;

(c) For renewable type filters, one complete set of unused filter media; or

(d) For gas filters, one complete set of unused filter cells.

Within one month before expiry of the Maintenance Period, all the filter cells/media shall be replaced with new ones. In addition, 10 litres of the approved cleaning detergent per washable filter installation shall be provided. Regarding filters of viscous type, a drum or drums of fluid amounting to one complete change or l0 litres per filter installation where thixotropic coatings are used shall be provided.

SECTION C2

DUCTWORK AND ACCESSORIES

C2.1 GENERAL

Ductwork shall be off site pre-fabricated according to the requirement as specified in the Particular Specification. The ductwork shall be fabricated from good quality full sized zinc coated hot dipped galvanised flat steel sheet to BS EN 10346:2009, Grade DX51D+Z, coating type Z275 unless otherwise specified in the Particular Specification or the Drawings.

C2.2 OFF SITE PRE-FABRICATION

The development of components for round, oval and rectangular ductwork shall be carried out by a computer software which can produce all development plans from the proposed ductwork layouts including all type of ductwork fittings and accessories. The software shall be able to work out the development plans with utilisation factor not less than 94%.

The above utilisation factor is based on a ratio of the Standard Size Straight Ductwork: Ductwork Fittings, which is 7 : 3. For standard straight ductwork, the utilisation factor is about 100% and that for fittings is about 80%. If the ratio of Ductwork to Fittings is not 7 : 3, the overall utilisation factor shall be submitted to the approval of the Supervising Officer.

The remaining materials that cannot be used for fabrication of ductwork shall be used for other purpose or at least to be recycled instead of being disposed of as scraps. The software used shall also be linked to the Numerical Control Cutting Machines, such as the Plasma Cutting System for the cutting, development and forming of the required ductwork components and accessories.

Automatic or semi-automatic machines shall be employed for the bending, folding and assembly of ductwork from sheet metal components developed. Proper machines are required for the manufacturing of all ductwork accessories including flanges, stiffeners, splitter dampers, etc. in order to enhance quality.

Construction and materials used for ductwork, fittings and accessories shall be inert, non-hygroscopic, vermin and moisture proof, asbestos and CFC free, and shall not support growth of bacteria.

Bends and branch vanes, dampers, etc. shall be of the same material as used for the ductwork and/or of heavier gauge, securely mounted.

C2.3 SPECIFICATION AND STANDARDS

Ductwork shall comply with the following B&ES publications with additions or amendments as required by this General Specification and/or elsewhere in the Contract.

(a) DW/144:2016
Specification for sheet metal ductwork;

(b) DW/154:2000
Specification for plastics ductwork; and

(c) DW/191:1973
Code of Practice for ductwork made from resin-bonded glass fibre.

Where any part of the Installations is not covered by the above, the recommendations of the "HVAC Duct Construction Standards-Metal and Flexible" issued by the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) of USA shall be applied.

C2.4 FLEXIBLE DUCTWORK

Flexible ductwork shall be provided as connections between vibration generating equipment and/or ductwork and where air duct passing across building expansion joint. Flexible connection shall be fitted with acceptable alignment and effective length suitable for the elimination of vibration transmission.

The flexible ductwork shall have a liner and a cover of tough tear-resistant fabric equal in durability and flexibility to glass fibre fabric. The fabric shall be impregnated and coated with plastics. It shall be reinforced with a bonded galvanised spring of stainless steel or other approved wire helix between the liner and the cover. An outer helix of glass fibre cord or equal shall be bonded to the cover to ensure regular convolutions. Flexible ductwork without a liner may not be used.

In no cases shall material containing asbestos fabric be used.

Alternatively, flexible ductwork shall consist of flexible corrugated metal tubing of stainless steel, aluminium, tin plated steel or aluminium coated steel. The metal surface(s) may be coated with a plastics material.

The leakage from any section of flexible ductwork shall not exceed 1% of the local design air flow rate at the local maximum static pressure.

Flexible ductwork shall be suitable for the air velocity, pressure and an operating temperature range of -5°C to 90°C and shall comply with BS 476-12:1991, Rating Class P; BS 476-6:1989+A1:2009 having an index of performance not exceeding 12 of which not more than 6 should derive from the initial period of test; Part 7 Class 1 (surface of very low flame spread) and current requirements of the FSD unless otherwise indicated.

C2.5 DUCTWORK FOR CORROSIVE FUMES

Ductwork used to carry corrosive fumes shall be of non-corrosive material. Where PVC material is used, the minimum thickness shall be 2.4 mm.

Plastic ductwork and all associated moulded or extruded sections, angles and fittings shall be unaffected by the range of substances conveyed and under the conditions indicated. Unless otherwise indicated, and providing the requirements above can be met, sheet material shall be pressed unplasticised PVC sheet complying with ISO 6453:1985.

Where PVC ductwork is thermally insulated or is not readily visible, Type A3 sheet shall be used; elsewhere Type Al shall be used.

Any plastic ductwork system incorporating a heater battery shall be installed such that no part of the system is impaired by the heating effects of the battery or its casing.

Circular ductwork up to 300 mm shall preferably be fabricated from unplasticised PVC pipe complying with relevant ISO and BS EN standards. Unless otherwise indicated, the colour of sheet and pipe shall be industrial grey. Ductwork shall be constructed (thickness, angles, stiffness, etc.) in accordance with Specification DW/154:2000.

Where any part of the Installations is not covered by "DW/154", then the recommendations of the "Thermoplastic Ductwork (PVC) Construction Manual" issued by the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) of USA shall apply.

The methods of construction recommended in B&ES Specification DW/154:2000 shall be used, i.e. cemented joints shall be used for circular (pipe) jointing and hot gas/filler rod, welding shall be used for all other fabrication. For circular ductwork constructed from pipe, sufficient angle joints shall be provided to enable the ductwork to be dismantled in the space available. Where so directed by the Supervising Officer, all welders shall carry out the test detailed in B&ES Specification DW/154:2000.

The requirements of B&ES Specification DW/154:2000 with regard to expansion joints, ductwork supports, access doors and gaskets shall be met.

Extruded or moulded sections, angles and fittings shall be of the same plastic materials and colour as the sheet or tube.

PVC ductwork shall not be used in situations where it will be subjected to temperatures of 50 ^{o}C and above. Where heater batteries are required in the system, the PVC ductwork shall be isolated from these by a suitable length of stainless steel ductwork, generally as described for glass fibre ductwork in Clause C2.6.

C2.6 GLASS FIBRE DUCTWORK

C2.6.1 General

Where specified in the Particular Specification or the Drawings, glass fibre ductwork made from 25 mm/38 mm thick resin bonded glass fibre in rigid board form may be used. The board shall have an integral external vapour barrier of hard grade, flame retardant, damage-resistant reinforced aluminium foil and an internal smooth, durable acrylic coating that isolates the glass fibre substrate from the air stream and inhibits penetration of the insulation by dirt, dust, microorganisms and other pollutants.

Special attention shall be paid to ensure that the material itself/fabrication/erection of the ductwork does not contribute towards suspected health hazard.

Thickness of the ductwork board to be used shall be selected in accordance with manufacturer's ductwork sizes, static pressure and reinforcement schedule and recommendation.

C2.6.2 Specification and Standards

Specification and Standards for glass fibre ductwork shall comply with the recommendations of the B&ES Publication DW/191:1973 Code of Practice for ductwork made from resin-bonded glass fibre, or the "Fibrous glass Ductwork Construction Standards" issued by the Sheet Metal and Air Conditioning Contractors' National Association, Inc. USA. The flexural rigidity rating of the rigid glass fibre board shall be 8OOE1 (33.7 kg/m^2) as defined in the above Standards. Glass fibre ductwork shall meet with the requirements of NFPA-90A:2018 and 90B:2018 by complying with the requirements of Under-writer's Laboratories Standard for safety UL 181:2013 for Class 0 ductwork.

Glass fibre ductwork to be used shall resist fungal or bacterial growth when subjected to microbial attack described in Standard Practices ASTM G21-15(fungus test).

Glass fibre ductwork shall be easily cleanable using methods and equipment described in North American Insulation Manufacturers Association (NAIMA) Publication AH-122, Cleaning Fibrous Glass Insulated Ductwork Systems.

C2.6.3 Mounting Fittings

Where the following items are installed in a ductwork, a suitably sized section of galvanised sheet ductwork shall be installed completed with independent supports and insulation: -

(a) Electric or hot water, etc. ductwork heaters and access panels;

(b) Volume control dampers;

(c) Fire dampers and access panel; and

(d) Fan and access panel.

C2.6.4 Mountings of Instruments

All control/metering probes, etc. which requires mounting in fibre glass ductwork shall be adequately supported by a sheet metal panel securely fixed to the internal face of the ductwork. The A/C Contractor shall fix a removable insulated cover over the complete probe to ensure condensation will not occur on any exposed metal surfaces.

C2.6.5 Special Tools and Manufacturers Fabrication Instructions

The construction and installation including all cutting tools employed to fabricate the ductwork shall be strictly in accordance with the recommendations of the fibre glass ductwork manufacturer's instructions issued for the correct installation of their product. Fabrication and installation by any method other than that endorsed by the fibre glass ductwork manufacturer may be rejected by the Supervising Officer.

C2.7 FOAM DUCTBOARD DUCTWORK

C2.7.1 Phenolic Foam Duct Board Ductwork

C2.7.1.1 General - Where specified in the Particular Specification or the Drawings, pre-insulated ductwork made from 20 mm thick rigid closed cell phenolic foam in rigid board form may be used and should be approved or accepted by the FSD.

C2.7.1.2 The ductwork material shall be covered with a layer of vapour barrier on both board facing. The vapour barrier shall be of minimum 20 micron thick aluminium foil. The circumferential and longitudinal seams of the vapour barrier foils shall be sealed with self-adhesive foil tape as specified in Clause C11.4.3.

C2.7.1.3 All material shall have a class 'O' fire rating and approved or accepted by the FSD. Details refer to Clause C11.2.1. Low smoke emission shall comply with BS EN ISO 5659-2:2012 and shall be CFC free.

C2.7.1.4 The flange system for the phenolic foam ductwork shall be designed to eliminate the effect of "Cold Bridge" and for the purpose of sealing, the flanges shall be coated with fire resistant gaskets and securely mounted with sufficient bolts, nuts and clips. An established joining system shall be employed in connecting the ductwork and accessories such as air outlets and dampers. The joining system shall be approved by the Supervising Officer.

C2.7.1.5 Where the following items are installed in the ductwork, they shall be adequately supported by a sheet metal panel securely fixed to the internal face of the ductwork with due consideration to ensure that condensation will not occur on any exposed metal surface: -

- Ductwork heaters;
- Volume control dampers;
- Fire dampers; and
- Fans & access panels.

C2.7.1.6 The construction and installation including all cutting tools, adhesives, flange system shall be strictly in accordance with the recommendations of the phenolic foam duct board manufacturer's instruction.

C2.7.1.7 Unless specified in the Particular Specification or the Drawings, the width and length of pre-insulated ductwork made from phenolic foam in rigid board form shall not exceed 500 mm.

C2.7.2 Polyurethane Foam Duct Board Ductwork

C2.7.2.1 General - Where specified in the Particular Specification or the Drawings, pre-insulated ductwork made from 20 mm thick rigid polyurethane foam in rigid board form may be used and should be approved or accepted by the FSD.

C2.7.2.2 The ductwork material shall be covered with a layer of vapour barrier on both board facing. The vapour barrier shall be of minimum 60 micron thick aluminium foil. The circumferential and longitudinal seams of the vapour barrier foils shall be sealed with self-adhesive foil tape as specified in Clause C11.4.3.

C2.7.2.3 All material shall have a class 'O' fire rating and approved or accepted by the FSD. Details refer to Clause C11.2.1. Low smoke emission shall comply with BS EN ISO 5659-2:2012 and shall be CFC free.

C2.7.2.4 The flange system for the polyurethane foam ductwork shall be designed to eliminate the effect of "Cold Bridge" and for the purpose of sealing, the flanges shall be coated with fire resistant gaskets and securely mounted with sufficient bolts, nuts and clips. An established joining system shall be employed in connecting the ductwork and accessories such as air outlets and dampers. The joining system shall be approved by the Supervising Officer.

C2.7.2.5 Where the following items are installed in the ductwork, they shall be adequately supported by a sheet metal panel securely fixed to the internal face of the ductwork with due

consideration to ensure that condensation will not occur on any exposed metal surface: -

- Ductwork heaters;
- Volume control dampers;
- Fire dampers; and
- Fans & access panels.

C2.7.2.6 The construction and installation including all cutting tools, adhesives, flange system shall be strictly in accordance with the recommendations of the polyurethane foam duct board manufacturer's instruction.

C2.7.2.7 Unless specified in the Particular Specification or the Drawings, the width and length of pre-insulated ductwork made from polyurethane foam in rigid board form shall not exceed 500 mm.

C2.8 DAMPERS - GENERAL

The respective functions, types and general constructional requirements of dampers shall be in accordance with the B&ES ductwork specification DW/144:2016 CIBSE Commissioning Code Series A and BSRIA Application Guide where appropriate unless otherwise indicated, sufficient dampers shall be provided to regulate and balance the system. Dampers on grilles or diffusers shall be used for fine control only.

All dampers shall be of flanged type with independent housing and control mechanism for connection to ductwork and shall be sufficiently rigid to prevent fluttering and comply with BS EN 1751:2014.

Air volume control dampers shall be of the aerofoil, double skin, opposed blade low leakage type with seals on blade edges and casing jambs, low pressure drop and noise regeneration characteristics. Damper blades in rectangular ductwork shall not exceed 225 mm in width and 1500 mm in length. Blades shall be of hollow section constructed from the same material of the ductwork or of stainless steel encapsulating an internal double contoured steel longitudinal reinforcing bar, mounted on square section steel spindles. The units shall be of low-leakage design by incorporation of synthetic trailing edge seals and a peripheral gasket which shall be tested according to BS 476-6:1989+A1:2009 and BS 476-7:1997 and shall be approved or accepted by the FSD. All manually and automatically operated dampers shall be fitted with position indicators provided externally and the final setting position shall be permanently marked. Manual dampers shall include a device for positioning and locking the damper blades. Damper handles shall be equipped with device for padlocking in the final balanced position.

Each air volume control damper in the ductwork shall be fitted with a non-corrodible label stating the actual air flow in m3/s when in the fully open position, its overall cross sectional area, and the degree to which the damper has been closed in order to achieve the design or actual air flow.

Unless otherwise indicated, quadrants and operating handles shall be of die-cast aluminium or other material approved by the Supervising Officer with the words "OPEN" and "SHUT" cast on the quadrant.

Quadrants shall be securely fixed and the damper spindles shall be closely fitted in the quadrant hubs to prevent any damper movement when the damper levers are locked.

Access openings with readily removable air sealed covers shall be provided adjacent to all dampers except the volume control dampers of which the adjustment can be made outside the ductwork. Subject to limitations of ductwork size the dimensions of access openings shall not be less than 300 mm x 300 mm and they shall be located within 300 mm of each damper so as to afford easy access for inspection and maintenance.

C2.9 BUTTERFLY, BIFURCATING AND MULTILEAF DAMPERS

Butterfly dampers shall each consist of 2 plates, edge seamed, of at least the same thickness as the material from which the associated ductwork is made, and rigidly fixed to each side of a mild steel operating spindle, the ends of which shall be turned and housed in non-ferrous bearings.

Bifurcating dampers shall be of 2 mm thick sheet for sizes up to 450 mm square, for larger sizes the thickness shall be as specified. The damper blades shall be rigidly fixed to square section mild steel spindles, the ends of which shall be turned and housed in non-ferrous bearings.

Each leaf of a multi leaf damper shall consist of 2 plates of material of the same thickness as the associated ductwork and rigidly fixed to each side of an operation spindle, the ends of which shall be housed in brass, nylon, oil impregnated sintered metal, PTEE impregnated or ball bearings. The ends of the spindles shall be linked so that one movement of the operating handle shall move each leaf for an equal amount. The mechanism shall be located outside the air stream.

For system, static pressure below 1000 Pa or ductwork velocity below 12 m/s, blade of at least 50 mm wide shall be used. For static pressure at or above 1000 Pa, at least 100 mm wide blade shall be used. Central blade reinforcement bar shall be provided for damper span longer than 1500 mm. Single module of a damper shall not exceed 2000 mm width and 1000 mm height.

Alternatively, multi leaf damper blades may be of a single plate, at least 1.6 mm thick and suitably stiffened, and the blade linkages may be within the ductwork. These dampers shall have bearings and inspection doors as specified in Clause C2.7.

C2.10 SELF-CLOSING (NON-RETURN) DAMPERS

Self-closing dampers shall present a minimum resistance to air flow under running conditions and take up a stable position in operation. Maximum

resistance shall be presented under reverse air flow conditions such that they will be forced to close and remain so. Resilient strips or other purpose made devices shall be provided to prevent the damper from rattling and as an aid to air sealing under reverse flow conditions.

Blades shall be rigidly constructed of steel or aluminium sheet of not less than 0.8 mm (22 gauge) and shall be free of all buckles. Blades of less than 300 mm in height shall be fitted with a 3 mm (10 gauge) bright steel spindle at each end. Blades of 300 mm and over in height shall be fitted with an 8 mm bright steel spindle at each end. Spindles shall be carried by sealed ball bearings. Bearing shall be accessible for cleaning and lubrication and shall be mounted in a rigid galvanised steel frame. The maximum length of each blade without a central bearing shall be 1000 mm.

C2.11 FIRE, SMOKE AND COMBINED FIRE AND SMOKE STOP DAMPERS

C2.11.1 Fire and Smoke Stop Dampers

Fire or Smoke dampers shall be provided in ductwork in the following locations: -

(a) Wherever a ductwork passes through a floor slab or a fire resisting wall which is expressly built for the purpose of preventing the spread of fire;

(b) Other locations where requirements of compartmentalisation are stipulated in the Code of Practice for Fire Safety in Building 2011 under the Buildings Ordinance of HKSAR; and

(c) Other locations as required by the Particular Specification and the Drawings.

Fire or Smoke dampers used singly or in combination shall have an overall fire resistance rating not less than that indicated and certainly not less than that for the wall or floor slab in which they are situated.

In all cases, evidence of fire rating in accordance with ISO 10294-1:1996/Amd 1:2014 Classification E (BS 476-20:1987 to BS 476-23:1987) or NFPA-90A:2018 with 2-hour UL fire damper label shall be provided by an independent testing organisation approved by the Supervising Officer. All Fire or Smoke dampers shall also be approved or accepted by the FSD.

Fire or Smoke damper blades of proprietary made shall be constructed to the approved and recognised testing authority and possess a rating equivalent to the fire resistance of the structure it protects.

Local made fire or smoke damper blades shall comply with the requirements of the Circular Letters issued by the FSD and the Buildings Ordinance of HKSAR. These blades shall be housed in a corrosion resistant casing constructed to avoid distortion due to stress

in fire conditions. Stainless steel spring tempered flexible gasket shall be inserted between the blade and the casing for elimination of closing friction and retardation of smoke. Provision shall be made to accommodate expansion of the damper blades within the casing in fire conditions to prevent jamming and to retard the spread of smoke. A Fire or Smoke damper installation frame supplied by the same manufacturer shall also incorporate provision for expansion within the surrounding structure together with masking flange for building into the structure.

Fire or Smoke damper assemblies for installations in corrosive environments shall be fabricated from suitable materials resistant to the corrosive substances and environments indicated. Alternatively, the material may be coated with a protective finish to produce the same effect.

Power fail-safe remote electromagnet release or electro thermal link (ETL) shall be provided to explosion hazardous areas. The electromagnet shall normally not consume more than 10 mA by 220 V AC supply or 120 mA by 24 V AC/DC supply. The A/C Contractor shall be responsible for the power fail-safe fire dampers to the fire control relay at the fire service control panel.

Each Fire or Smoke damper casing shall be air tight, continuously welded and clearly marked with a permanent indication of the direction of air flow and the side at which the access/maintenance opening is located.

The folded continuous interlocked blade type of damper may be used for vertical or horizontal ductwork applications. The closing force for these types of dampers shall be provided by stainless steel spring or springs. An automatic locking device shall be provided to ensure that the blades are held in the closed position after release.

Spring actuated pivoted single-bladed or multi-bladed dampers may be used for vertical or horizontal ductwork applications.

Multi-bladed dampers shall be provided with a means to ensure that all the blades close simultaneously.

Gravity operated multi-bladed fire dampers shall not be used in vertical ductwork.

Gravity operated single bladed dampers may be used for horizontal ductwork provided means are incorporated which ensure reliable and positive closure when operating in maximum air flow rate conditions.

Locally fabricated gravity fire dampers shall be provided with a coaming or casing of the same material and shall be physically bolted to the structure through which the ductwork penetrates.

Fire or Smoke dampers shall be rated in accordance with the fire resistance rating of the wall, ceiling or floor, etc. as shown in the drawings and the Particular Specification, to the requirements of the FSD and approved by the Supervising Officer.

For locally fabricated fire dampers, the thickness of metal for the dampers shall comply with the Circular Letters issued by the FSD and the Buildings Ordinance of HKSAR.

Where gravity acting, off-centre pivoted dampers incorporate spindle bearings long term corrosion effects shall be minimised by the choice of suitable materials. Bearings shall be sealed or capped to exclude dirt and dust. Damper blades shall close to comply with the stability and integrity requirements of ISO 10294-1:1996/Amd 1:2014 Classification E (BS 476- 20:1987 to BS 476-23:1987).

For high velocity air systems, fire/smoke dampers shall provide 100% free area when damper blades are in the open position to give minimum interference to the air flow.

Unless otherwise indicated, each Fire or Smoke damper shall be held in the open position by a corrosion resistant retaining device incorporating a fusible element which shall operate at a temperature of 69oC, unless otherwise indicated.

Fire or Smoke dampers shall be located in a position and be of a type which could facilitate periodic 1 handed manual release and re-setting for test purpose.

Proprietary access doors shall be installed adjacent to each Fire or Smoke damper and, in the case of conditioned air or kitchen exhaust ductwork, the access doors shall be encapsulated and pre-insulated.

C2.11.2 Combined Fire and Smoke Stop Dampers

Combined fire and smoke stop dampers shall be tested to ISO 10294-1:1996/Amd 1:2014 Classification ES and approved by the FSD.

The dampers shall be of stainless steel, aerofoil bladed construction with the blades held in stainless steel bearings and framed in stainless steel spring tempered flexible gasket. The blades shall have trailing edges forming an interlocking metal to metal seal when the blades are closed, providing tight, low leakage closure of the air path and maximum impedance to the passage of smoke and products of combustion from either flow direction.

The blades shall be driven by externally mounted and totally enclosed stainless steel gearbox and drive mechanism providing accurate blade control with minimum torque and without accumulative backlash.

The damper casing shall be of double-skin galvanised steel construction with continuously welded corners and integral spigot

connections. The dampers shall be supplied completed with the manufacturer-installed frames.

Each damper shall have an externally replaceable combination thermal actuator and fusible link completely exposed to the air stream.

In addition to the thermal actuation/fusible link, the damper shall be normally held by actuator. The damper shall be released to the closed or fail-safe position by a closure spring on loss of power supply, either by genuine power failure or by the zone fire signal actuated by the smoke detection system. The time for closing the damper shall meet the requirements laid down by the FSD.

The damper shall be automatically reset on resumption of power supply by built-in motor of 220 V AC or 24 V AC/DC.

The whole control mechanism and actuation shall be of the same manufacturer and mounted inside a totally enclosed casing for protection against airborne contamination and to ensure unique reliability.

For smoke extraction at 250 ^{o}C for 1 hour application, damper control actuator shall be totally shielded by a proprietary thermal insulation jacket. The whole damper assembly shall have undergone a high temperature operation test followed by a leakage test at 1500 Pa differential pressure and ultimately approved by the FSD.

Leakage rate shall be tested in accordance with UL555S:2014.

Fire rating shall be to BS 476-20:1987 and the whole damper assembly shall have undergone a temperature exposure test by laboratories by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved in accordance with the temperature and duration as indicated in BS 476-20:1987. Test report shall be submitted to the Supervising Officer for reference.

C2.12 MOTORISED SHUT-OFF DAMPERS

Motorised shut-off dampers shall be similar to fire/smoke dampers and shall be open or close by motorised mechanism. Each of the dampers shall be in "Open" position normally, but shall be closed when there is a fire or the air handling unit is shut off. The motorised mechanism shall be actuated by associated automatic fire control. Air leakage rate for motorised shut-off dampers shall be tested according to BS EN 1751:2014.

C2.13 TERMINAL DAMPERS

Grilles and air diffusers with rectangular neck connections shall be provided with an opposed blade damper, screwed or riveted to the neck connection and designed specially to facilitate final balancing of the system.

Damper frames, blades and operating mechanism shall be constructed from an aluminium alloy or, alternatively, formed mild steel suitably finished to give protection to the material during the design working life.

Blades shall be made of solid section material and shall be firmly held in position by a spring steel retaining mechanism. The blade setting mechanism shall be accessible through the grille or diffuser blades and shall be suitable for operation with an "Allen" key. Where dampers are visible through the grille or diffuser they shall be finished with a matt black paint.

C2.14 ACCESS DOORS AND PANELS TO DUCTWORK, CABINETS, COLD STORES

Unless otherwise indicated, locally fabricated Access Doors or Panels shall be constructed of marine plywood on hardwood in accordance with the Supervising Officer's issued Standard Details, suitably insulated where necessary and finished with at least three coats of shellac, lacquered and polished.

The insulation in the door shall be equal to that of the ductwork or cabinet into which it is installed. When closed, the door shall be effectively vapour sealed.

On doors through which a man can pass, the opening handle must also be operable from the inside of the door.

Access doors and panels on factory made equipment shall be approved by the Supervising Officer.

All fittings and screws shall be made of brass.

Access doors or panels to ductwork heaters shall be constructed in accordance with the Supervising Officer's issued Standard Details for ductwork heaters.

Access doors shall be of proprietary manufacture, double-skin, 25 mm sandwich G.I. construction with fibreglass or CFC-free foam insulation infill. Access doors shall be of lift off type having a minimum of 4 cam-lock action retaining locks for fixing to ductwork frame. Gaskets shall conform to DW/144:2016 &DW/143:2013. Access doors shall be supplied and fitted with retaining chain tied back to the frame. Multiple screw fixings shall not be allowed.

C2.15 DUCTWORK FLANGES

All rectangular ductwork shall be flange joints. Flanges shall be of a proprietary type, tested and certified for air leakage and deflection to DW/144:2016. Certificates must be submitted during the equipment submission period.

The proprietary ductwork flanges shall be roll-formed from zinc coated hot-dipped galvanised sheet metal to BS EN 10346:2009 Grade DX51D+Z, coating type ZF180. Flanges shall be constructed with prefabricated flange profile consisting of manufacturer provided integral sealant with corner joints inserted

into the end of the flange profiles and the whole frame shall be firmly secured including the corner component. The already established ductwork flange shall be fastened into the associated ductwork with spot welding. Gaskets strip to BS 476-7:1997, Class 1 and ductwork sealant to BS 476-7:1997, Class 2 shall be applied at the flange joints and corner joints respectively to ensure maximum leakage-proof. All sealant used shall be fire proof and vermin proof, non-toxic and acceptable to the FSD.

Sealant and gaskets shall be provided as recommended by the flange manufacturer.

C2.16 DUCTWORK CLEANING POINTS

The ductwork cleaning point shall generally be of a type consisting of a 50 mm diameter metal flange with a 20 mm diameter hole closed with an air-tight screwed plug through which inspection, cleaning and disinfection of the ductwork can be carried out.

The ductwork cleaning point shall be of proprietary product, so constructed and installed that no cold bridge which causes condensation will occur.

All ductwork shall be constructed to facilitate cleaning to be carried out. Ductwork fixings shall not intrude within the ductwork and all sharp edges shall be provided with protective finishing to the approval of the Supervising Officer.

When specified in the particular specification, ductwork support shall be designed to support the weight of a person and industrial vacuum cleaner. Similarly, provisions for injecting steam or detergent cleaning devices and access panels shall be provided wherever specified.

C2.17 TEST HOLES

Test holes shall be provided according to B&ES ductwork specification DW/144:2016, CIBSE Commissioning Code Series A, BSRIA Application Guide, etc. wherever necessary for effective balancing and testing, whether these provisions are shown in the Drawings or not. Test holes shall be of 25 mm diameter and fitted with an effective removable sealed cap made of plastic plugs or die cast metal cupped blanking plates. Test points shall be provided for all dampers and items of equipment to enable fan duties and items to be assessed and for the commissioning of the system.

Test holes shall be positioned at points with stable air flow and not affected by upstream and downstream fittings or obstructions. Test holes shall be located at the inlet and discharge of all fans and air handling units to measure static pressure, before and after air heaters and cooling coils, filters to measure temperature and pressure differentials and other points required for regulating and commissioning of the air distribution system.

C2.18 TRANSFER DUCTWORK

The internal lining material shall be in accordance with Clause C8.7 of this General Specification.

SECTION C3

AIR HANDLING AND TREATMENT EQUIPMENT

C3.1 GENERAL

C3.1.1 Air handling units shall be "type" tested in accordance to a recognised standard, such as Euro vent, AMCA, ISO, etc., and shall meet the minimum requirements as stipulated in Clause C3.2.1.

C3.1.2 All fans should be constructed to a fully developed design and shall be capable of withstanding the pressures and stresses developed during continuous operation at the selected duty. Additionally, all belt driven fans shall be capable of running continuously at the range of 10% to 15% in excess of the required duty speed.

C3.1.3 Fans shall be selected to give the air volume flow rates and sound power levels specified in the Contract. Fan performance curves giving values of sound power levels and fan efficiency at the selected duty shall be submitted to the Supervising Officer for approval. Values of resistance to airflow of items of equipment, ductwork and/or the total distribution system indicated in the Contract are based on basic design assumptions, the A/C Contractor shall verify these values based on the actual equipment offered and installed and to provide fans capable of delivering the required air volume when operating against the actual total installed system resistance.

C3.1.4 Fan Construction

(a) Centrifugal fans having dimensions over 1000 mm in any direction shall have split casing or by other means for easy removal and repair.

(b) The shaft and impeller assembly of all centrifugal, axial flow and mixed flow fans shall be statically and dynamically balanced. All propeller fans shall be statically and dynamically balanced. Limits of vibration severity shall be in accordance with BS ISO 20816-1:2016 or another acceptable standard, such as AMCA, as appropriate.

(c) Fan shall be equipped with self-aligning bearings suitable for the installed altitude of the fan. They shall be of the grease/oil ball and/or roller type or alternatively oil lubricated sleeve type. All bearing housings shall be precisely located in position and arranged so that bearings may be replaced without the need for realignment. Bearing housings shall be protected against the ingress of dust and, where fitted with greasing points, they shall be designed to prevent damage from over-greasing. For grease lubricated systems the bearings shall be provided with grease of the amount and quality as recommended by the bearing manufacturer. For oil lubricated systems the housings shall

provide an adequate reservoir of oil and shall include a filling plug and be oil tight and dust proof. Systems other than total loss types shall include an accessible drain plug. All bearing lubricators shall be located to facilitate maintenance. Extended lubricators outside the fan casing shall only be required if sealed for life bearings are not incorporated.

C3.1.5 Fan and motor for smoke extraction and staircase pressurisation ventilation system shall be suitable for continuous operation at 250 ^{o}C for at least 1 hour. All control and power cables shall be of the fire resistance type complying with BS 6387:2013 or IEC 60331-21:1999 Category CWZ or AWX where appropriate. The requirements specified by the FSD shall also be complied.

C3.2 AIR HANDLING UNITS (AHUs)

C3.2.1 General

Each type of AHU offered shall be the product of a manufacturer who has made similar product for a period of at least five years.

Individual components forming part of the air handling unit shall, in addition to this section, comply with the appropriate sections contained elsewhere in this General Specification.

Air handling unit shall comply with the manufacturer's own ISO 9001:2015 quality assurance standard in respect of design and manufacturing and be "type" tested to the following minimum requirements:- (i) air leakage test to HVAC Standard DW/144:2016 Class B or BS EN 1886:2007 Class L2; (ii) thickness of casing according to Table C3.2.2; (iii) conductivity of thermal insulation not greater than 0.02W/m^{o}C rating at the operating temperature; and (iv) insertion loss through panels at 125 Hz and 250 Hz of 20 dB and 20 dB reduction respectively.

The A/C Contractor shall submit technical information of each unit together with the above "type" test certificates for the Supervising Officer's approval.

The entire construction of the AHU should have following mechanical characteristics in accordance with the BS EN 1886:2007.

Mechanical Characteristics (minimum requirement)	
Characteristics	Class
Casing strength	D2
Casing air leakage under -400 Pa	L2
Casing air leakage under +700 Pa	L2
Filter bypass leakage	F9
Thermal transmittance	T2
Thermal bridging factor	TB2

Alternatively, the entire construction of the AHU should have mechanical characteristics not lower than the above table in accordance with AHRI-1350.

C3.2.2 Construction

AHU assemblies shall be of rigid double skin fully modular construction with each section having matching cross sectional dimensions and same construction type. All individual components and sections shall be assembled using proprietary and approved fastening techniques. Locking devices shall be used with all fastenings which are subject to vibration.

Each module shall be supported by rigid galvanised steel post frame or extruded aluminium alloy framework or other composite material frame as specified with thermal break design and flush mounted with dismountable sandwich panel, corrosion resistant treated and strengthened where necessary to prevent minimum deflection and drumming even at 2500 Pa differential pressure. The post frame and corner pieces shall be fixed together to provide strength equal to welding. The removal of the side panel shall not affect the structural integrity of the unit.

The construction of the unit shall be such that the inner surface of the unit is thermally broken from the outside surface without any cold bridge formed. The frame member and corner piece shall be filled with injected foam insulation or other approved insulation.

The double skin or sandwich panel shall be no less than 50 mm thick with injected expanded polyurethane foam insulation or other approved insulation encapsulated by epoxy or approved coated finishing solid sheet steel. Non-hydroscopic sealing shall be provided between the panel and the framework. The width of the frame member & corner piece shall be the same as the thickness of the panel.

The whole construction shall be hygienically designed and the internal surface shall be smooth to avoid any framework protrusion inside the casing.

Casing material shall not be less than the thickness as shown in Table C3.2.2 unless otherwise specified in the Particular Specification.

Table C3.2.2 Minimum material thickness for AHU casing

Component	Minimum material thickness (mm)
Casing framework	2.0
Cooling coil casing	1.6
Panel for polyurethane insulation (each face)	0.8
Other	1.2

For sections with UV equipment installed, the casing material of the internal surface shall be aluminium alloy, stainless steel 304 or better.

C3.2.3 Fan

All fans shall be Electronically Commutated (EC) plug fans as described in the relevant content of Section C3.14 or backward curved centrifugal fans, double inlet, double width, or single inlet, single width unless alternative requirement is specified in the particular specification and/or equipment schedule. All fans other than plug fans shall be mounted together with their motors on a galvanised steel base frame isolated from the main casing by means of 98% efficient spring vibration isolators. The vibration isolators shall have a minimum deflection of 25 mm.

Other than plug fans, fan discharge shall be isolated from the casing by a flexible connection. Fan shall be direct driven or driven by at least two-belt arrangement for motor rated higher than 4kW. Selection of fan and motor shall be at their peak operating efficiency. Fan motor shall be supplied and installed by the AHU manufacturer unless otherwise specified.

C3.2.4 Access Doors

These shall generally be as detailed for acoustically treated doors described in the relevant content of Section C8. They shall also meet with the insulation requirements stated in the relevant content of Sections B11 & C11. The access doors shall be no less than 400 mm wide and vertically sized for the full height of the unit or no less than 400 mm wide by no less than 1550 mm high where the unit height exceeds 1900 mm. Quick access doors shall be provided for filter section, coil section, transfer section, humidifying section, damper section, etc. Heavy duty double hinges and two quick release fasteners shall be provided for all quick access doors.

Where return or fresh air ductwork connects to air handling units, access to the filters shall be through side access panels at the filter chambers.

C3.2.5 Access Sections

Access section shall be provided between heating and cooling coils to allow air blasting or steam blasting of coils for cleaning and/or sterilising purposes. Adequate access must be provided both upstream and downstream of coils to facilitate cleaning and sterilising.

C3.2.6 Anti-Corrosion Treatment

For outdoor or other specified applications, all metal surfaces must be properly treated and suitably painted. Galvanised sheet metal finish is not acceptable. All external metallic surfaces of the units shall be

painted with two coats of undercoat, and two coats of anti-corrosion epoxy based paint with each layer dry film thickness of 150 microns; or other approved finishing applied in the factory. Field painting after the installation is not accepted. Finishing coating shall be non-toxic. For indoor applications, all metal surfaces shall be suitably painted with anti-corrosion paint.

C3.2.7 Thermal and Acoustic Insulation

The unit shall be cold bridge free without sweating as per the specified Thermal Bridging Factor TB2 Class BS EN1886:2007. Thermal insulation shall be expanded polyurethane foam or other approved material meeting the thermal transmittance factor T2 Class to BS EN 1886:2007. The insulation shall provide a high degree of noise attenuation.

Thermal insulation shall be securely fixed to or built into all sections of plant and equipment handling heated or cooled air. Thermal and/or acoustic insulation characteristics and fixings shall be in accordance with Sections B11 & C11 and B8 & C8.

Special surface protection shall be provided as specified to avoid damage in sections having walk-in access. Adequate lighting completed with door operated switch equipped at the factory shall be provided for AHUs with handling capacity greater than 5 m^3/s.

C3.2.8 Air Filters

The filter section shall be provided by the air handling unit manufacturer or specialist manufacturer of filter holding frame approved by the Supervising Officer. The construction of filter section shall comply with the requirements of Clause C3.2.2 and shall ensure that there will not be bypass of un-filtered air. The filter section consisting of the filter elements and the filter fixing frames must have a positive means of sealing off the unfiltered air by-passing the filter elements.

Intermediate bag filter or HEPA filter with 50 mm thick permanent washable pre-filter shall be provided as specified. HEPA filter and bag filter cartridges shall be mounted on non-corrosive aluminium or stainless steel tightness proof holding frame for side service or front release depending on the restriction of access. Neoprene gaskets shall be provided along the contact surfaces of the filter element and the holding frame. Filter cartridges shall be clamped against the slide rails with spring type clamping devices.

Each individual filter section in the AHU shall be completed with a dedicated pair of copper tuber pressure tapings, adequately sealed for filed connection of differential pressure sensor. Each individual filter section shall also be connected to a dedicated manometer mounted on outside for local indication.

Sections B1 and C1 shall also be referred for the quantity of spare filters required, construction of filter holding frames, type-test certificates requirement and the standards of various types of air filters.

The filter section shall not be located closer than 500 mm to any electric heaters or water heating battery.

The following air filters shall be provided in accordance with the application of the air handling systems or as specified: -

Table C3.2.8 – (1) Pre-filter

Application	Minimum Efficiency Reporting Value (MERV) ANSI/ASHRAE Standard 52.2-2017 or equivalent, e.g. BS EN ISO 16890: 2016
For use where grease or moisture is prevalent	MERV 2-4 Aavg*≥ 65% or 70% or 75%
General ventilation system suitable for sport halls, swimming pools, ice rinks, garages, plant rooms, laundries	MERV 5-6 E3^≥20% or 35%
General ventilation system suitable for office, auditoria, law courts, TV studios, hall and lobby, kitchens, station concourses, etc.	MERV 7-8 E3^ ≥50 or 70%

Remarks:
*: Average Arrestance % (Aavg)
^: E3 is Composite Average Particle Size Efficiency (E) % in Size Range, 3.0um-10.0um

Table C3.2.8 – (2) Intermediate filters

Application	Minimum Efficiency Reporting Value (MERV) ANSI/ASHRAE Standard 52.2-2017 or equivalent, e.g. BS EN ISO 16890:2016
General ventilation system for church, hotel	MERV 11-12 E3^≥85% or 90% & E2^≥65% or 80% & E1^≥20% or 35%
General ventilation systems suitable for foyer, dressing room, bar/lounge, restaurant, library, office, building society, department store, supermarket, airport	MERV 13 E3^≥90% & E2^≥85% & E1^≥50%

General ventilation system suitable for museum/art gallery, computer room	MERV 14 E3^≥95% & E2^≥90% & E1^≥75%
General ventilation system suitable for hospital, research laboratory	MERV 15-16 E3^≥95% & E2^≥90% or 95% & E1^≥85% or 95%

Remarks:
^: E1 is Composite Average Particle Size Efficiency (E) % in Size Range, 0.3um-1.0um
E2 is Composite Average Particle Size Efficiency (E) % in Size Range, 1.0um-3.0um
E3 is Composite Average Particle Size Efficiency (E) % in Size Range, 3.0um-10.0um

Table C3.2.8 – (3) High efficiency and HEPA filter

Application	Efficiency % (E) BS 3928:1969 (or EUROVENT 4/4 & 4/5)
Special ventilation systems for hospital, clean room, research laboratory	99.999 > E ≥ 95

Special air by-pass prevention devices and testing facilities with the following components and requirements shall be provided by the A/C Contractor where specified in the Particular Specification.

(a) Volumetric flow meters to measure leakage flow rates;

(b) Hand-pump;

(c) Connection for external compressed air system (max. 1.1 bar);

(d) Pressure gauge for hand-pump and external system;

(e) Connection tube linking the testing device and the tightness proof frame;

(f) Throttle valve; and

(g) A test groove shall be provided on the filter seat of the holding frame of each filter element with a testing port for the connection to the above portable tightness testing device.

C3.2.9 Identification Plate

All AHU shall bear the manufacturer's nameplate giving manufacturer's name, serial and model number, and date of manufacturing; and an identification plate showing the AHU

equipment number and essential performance data as indicated on the Equipment Schedule.

C3.2.10 Air Cooling Coils

(a) General

Cooling coils shall be mounted on non-corrosive aluminium or stainless steel slide rails. Coil sections shall be arranged to provide removal of coils from the access side of the section. Cooling coil casing shall equip with flanged ends drilled and corrosion treated to receive counter flanges on connecting ductwork or other associated equipment.

Cooling coils shall utilise the full unit available cross sectional area. Cooling coils shall be constructed from one of the following combinations:-

(i) Copper tubes expanded into aluminium fins;

(ii) Copper tubes expanded into copper fins;

(iii) Copper tubes expanded into tinned copper fins; and

(iv) Copper tubes expanded into epoxy coated aluminium fins.

Tube thickness shall not be less than 0.4 mm. Fin thickness shall not be less than 0.13 mm with suitable fin spacing.

(b) The resistance to airflow through a coil section shall not exceed 125 Pa taking into account the wet air condition. The face velocity of airflow shall not exceed 2.5 m/s. for primary air handling unit, the face velocity shall not exceed 2.2 m/s.

(c) Access doors with air seals shall be provided on both the upstream and downstream of the cooling coils.

(d) Cooling coils shall be factory tested and certified to at least one and a half times the working pressure.

(e) The number of rows of coil for primary air handling unit and other air handling units shall be optimised. Detail calculations to determine the number of rows required to meet the performance with safety margin shall be submitted for Supervising Officer’s approval.

(f) All coil capacities, pressure drops and selection procedures shall be rated in accordance with AHRI 410:2001.

C3.2.11 Drain Pan

(a) Drain pan shall be made of insulated 1.2 mm thick AISI 304 stainless steel. Water shall not be carried over from a cooling

coil into the remainder of the system and an eliminator section shall be provided, wherever necessary or indicated. The eliminator shall be readily removable for cleaning.

(b) The drain pan serving the cooling coil shall be extended or a separate tray be provided to collect water from the eliminator. Drain pan shall be sloped towards a bottom drain connection and pipework shall be installed from each connection to the nearest sump or gully. The drain pan shall be accessible for cleaning and disinfecting without the coil having to be removed.

(c) The drain pipework shall include a water trap of minimum 50 mm deep depends on the maximum fan pressure at the rated speed to prevent entry or exit of air to or from the system. On stacked coil, intermediate drain troughs shall be provided. All drain pans shall be adequately insulated with durable, non-smell and non-peeling under cooling/heating and air flow design conditions. Sealing devices shall be provided at tops and bottoms of coils to minimise air by-pass and water carry-over.

C3.2.12 Chilled Water Connections to Cooling Coils

The flow and return connections and headers shall be made of heavy gauge seamless flanged copper tube or steel tube with external coating. Provision shall be made for thermal expansion of the tubes, for effective venting of the coils and their connections and for the draining of the headers and tubes.

Coil connections shall be arranged so as to enable same side connections to the flow and return pipework, and to have the supply and return connections to headers to give counter flow of air and water. Equal flow of water shall be through all the tubes in the coils.

(a) Up to and including 50 mm bore connections may be made using ground-in spherical seated unions. Pipework of 65 mm bore and above shall be connected using flanged joints. Isolating valves shall be provided on flow and return connections and arranged so as to facilitate easy removal of the coils.

(b) For the connection between the coil header and the external G.I. or black steel pipe work, suitable fitting/device or methodology approved by the Supervising Officer to prevent galvanic corrosion effect of different pipe materials jointing together shall be provided.

C3.2.13 Hot Water Air Heating Coils

(a) General

The construction of casing coil mounting method and access door requirements are same as air cooling coils.

(b) The heating coil shall be constructed from one of the following types: -

(i) Copper tubes expanded into aluminium fins;

(ii) Copper tubes expanded into copper fins;

(iii) Copper tubes expanded into tinned copper fins; and

(iv) Copper tubes expanded into epoxy coated aluminium fins.

(c) The performance of heating coils shall be as specified and the method of testing for rating of the coils shall be in accordance with BS 5141-2:1977 or AHRI 410:2001; or

(d) Coils connection shall be same as for cooling coils.

C3.2.14 Electric Type Air Heaters

(a) Electric air heaters shall consist of a number of sheathed heating elements of the enclosed type mounted in a sheet steel casing. The elements shall be so installed that they can be removed for cleaning or renewal without dismantling ductwork. The surface temperature of the elements shall not exceed 400 ^{o}C when measured in an air flow of 2.5 m/s at ambient temperature. A high temperature limit cut-out device with hand reset button shall be incorporated such that the limit device sensor is nearest to and above the heating elements which are energised by the first control step. The device shall operate within two minutes at a temperature of 68.5 ^{o}C.

(b) The control of electric air heaters, except for remote boosters, shall be interlocked with the fan motor starters and an air flow control of the pressure or sail switch type so that the heaters cannot operate unless the fan is running.

(c) Electric air heaters which are installed as boosters in branch ducts remote from the fans shall have an air flow control of the pressure or sail switch type which shall isolate the heating elements from the electricity supply in the event of the failure of air flow.

(d) The number of elements in the heater shall be the same as or a multiple of the number of steps in the controller, or using modulating power controller alternatively. All heaters and heater sections of more than 3 kW loading shall be balanced over 3-phases and the complete heater bank shall be arranged for balanced operation on a 3-phase 4-wire system.

(e) The connections from each element shall be taken to a readily accessible terminal box arranged for conduit entry. Each heater section shall be separately fused and the neutral point of all 3-phase star-connected sections shall be brought out to a link in the terminal box. Near hot areas the wiring insulation shall be of a quality suitable for the maximum working temperature.

(f) The total resistance of the heaters to airflow shall not exceed 15 Pa and the face velocity shall not exceed 6 m/s.

Note for energy efficiency design: - Heating by hot water from waste heat reclaim or from heat pump system aiming for high operating efficiency should be considered.

C3.2.15 Humidification Equipment

Steam humidifiers shall be used. They shall be of the steam injection type using electric elements/electrodes or be of the evaporative pan type with a minimum efficiency of 95%. Steam available from a central plant may also be used.

It shall be possible to isolate the electrical supply from the elements/electrodes and they shall be arranged to facilitate removal for maintenance and replacement. Electric heating elements shall incorporate a high temperature cut-out and shall be interlocked to break the electrical circuit on low water level. Steam injection distribution pipes shall be provided for condensate return and be so designed and installed that free moisture is not carried over into the air stream. Steam generating equipment, other than remote central plant, shall be an integral part of a purpose-made humidifying unit and shall incorporate automatic water-level control, overflow protection and drain connections. Automatic intermittent or continuous blowdown shall be incorporated as appropriate.

The evaporative pan type humidifier shall be positioned so that it is not affected by the radiant heat from heater batteries.

C3.2.16 Additional Modular Sections

Additional modular sections shall be provided with ease for the accommodation of ultra-violet steriliser, heat wheel or other devices as specified for the improvement of air quality and energy efficiency.

C3.3 AXIAL FLOW FANS

C3.3.1 Axial flow fans shall be of either the single-stage type or the multi-stage contra-rotating type with each impeller mounted on an independent motor.

C3.3.2 Fans shall be tested for air performance and sound ratings in accordance with ANSI/AMCA Standards 210-16 and 300-14, ISO

5801:2017 or equivalent recognised standards as approved by the Supervising Officer.

C3.3.3 Casing shall be rigidly constructed of mild steel stiffened and braced to obviate drumming and vibration. Cast iron or fabricated steel feet shall be provided where necessary for bolting to the base or supports. Inlet and outlet ducts shall terminate in flanged rings for easy removal.

C3.3.4 The length of the duct casing shall be greater than the length of the fan(s) and motor(s) in order that the complete section may be removed without disturbing adjacent ductwork.

C3.3.5 Electrical connections to the motor(s) shall be through an external terminal box secured to the casing.

C3.3.6 Impellers shall be of galvanised steel or aluminium alloy; the blades shall be secured to the hub or the blades and the hub shall be formed in one piece. The hub shall be keyed to a substantial mild steel shaft carried in two bearings and the whole statically balanced. Unless otherwise indicated blades shall be of aerofoil section.

C3.3.7 Where axial flow fans are driven by a motor external to the fan casing the requirements of the relevant content in Sections B7 & C7 for pulleys and for V-belt drives and guards shall be met. An access door of adequate size to facilitate inspection, cleaning and other maintenance shall be provided.

C3.3.8 Axial flow fans of the bifurcated type shall be used on application for greasy gases, hot gases or vapours. Motors shall be out of the air-stream and shall normally be placed between the two halves of the bifurcated casing in the external air. The motor and the bearings shall be suitable for operation at the temperature they may experience. The bifurcated section containing the motor shall be mounted vertically in order to maximise convection air flow over the motor.

C3.3.9 Special design multi vanes to reduce turbulence and increase fan efficiency shall be provided as specified in the Particular Specification.

C3.4 CEILING FANS

C3.4.1 Dimensions

The sweep diameter of the units shall be 1200 mm or as otherwise indicated.

C3.4.2 Capacity

The 1200 mm unit shall be capable of an air delivery of 3.9 m^3/s or as otherwise stated.

C3.4.3 Duty

(a) The unit shall be suitable in all respects for operation under ambient air conditions of 40°C and 95% RH.

(b) The unit shall be suitable for operation in 220 V, 50 Hz single phase AC mains.

(c) The unit shall be designed for heavy duty commercial and domestic usage.

(d) The fan shall operate without generating unnecessary noise at all speeds.

C3.4.4 Motor

(a) The motor shall be a totally enclosed, capacitor run induction motor, with internal stator and external squirrel cage rotor.

(b) The rotor shall be mounted in grease lubricated ball bearings.

(c) The power factor shall not be less than 0.85 at any speed.

(d) The motor shall be rated for continuous operation under ambient air conditions of 40°C and 95% RH and the temperature of the windings shall not exceed 50°C after 2 hours of continuous operation.

(e) All electrical components, cables, etc. shall conform to the appropriate specifications or shall be of fully equivalent quality and capacity.

C3.4.5 Blades

(a) The fan shall be fitted with three blades. "Twisted" blades are preferred.

(b) The blade assemblies shall consist of blades manufactured from heavy gauge aluminium securely riveted to steel blade carriers.

(c) The blade carriers shall be manufactured from mild steel plate of not less than 3 mm in thickness and of not less than 40 mm width at the narrowest point, pressed to shape.

(d) Where the blade carriers are twisted to give the required angle of incidence to the blades, there shall be large radius bends to prevent stress concentrations in the blade carriers.

(e) Anti-vibration bushes shall be installed between the blades and blade carriers.

(f) The blade carriers shall be securely fastened to the frame of the motor by machine screws and spring washers, the whole assembly shall be designed and constructed to ensure that there is no possibility of a blade becoming detached during operation.

C3.4.6 Terminals and Capacitor

(a) The plastic terminal block and capacitor shall be mounted in a ferrous metal connecting piece, located between the fan and the down-rod. The leads from the stator windings shall be connected to the terminal block. An earthing terminal, consisting of a round head brass, screw and washer, shall be provided on the connecting piece. All exposed metal parts of the fan unit shall be connected to this earthing terminal.

(b) The bottom portion of the connecting piece shall be screwed on to the shaft of the motor. The connecting piece shall be tightened onto a shoulder formed on the motor shaft. A 4 mm minimum thickness steel hexagonal lock-nut with lock bracket underneath shall then be fitted and tightened in position. The connecting piece shall additionally be screwed in the fully tightened position by two hardened steel grub screws. These screws shall engage in shallow depressions drilled in the shaft after the connecting piece has been tightened in place to ensure positive locking.

C3.4.7 Down-Rod Assembly

(a) The down-rod assembly shall consist of a down rod and a steel shaft with a hard rubber roller for suspension of the fan. The down rod shall be supplied to the length indicated for the job which shall be measured from the top of the connecting piece to the centre of the pin in the shackle at the top.

(b) The down-rod shall be manufactured from 12 mm bore standard mild steel pipe of not less than 3 mm wall thickness, having an external diameter of approximately 20 mm. It shall be accurately threaded at one end and shall be screwed into the top portion of the fan connecting piece (capacitor housing) from which it shall protrude by a minimum of 2 mm.

(c) It shall be locked in position by two hexagonal steel lock nuts, having a minimum thickness of 6 mm, tightened onto the upper machined surface of the fan connecting piece.

(d) The down-rod shall also be locked to the fan connecting piece by means of a steel split-pin, of not less than 5 mm diameter, passing through both the fan connecting piece and the down-rod.

(e) The split-pin holes in the fan connecting piece shall be of such a diameter that the split-pin is a light push fit there-in. The matching split-pin holes in the down-rod shall be just

sufficiently large so that the split-pin shall be a light push fit, when the hole is in its worst position relative to the threading. All burrs and sharp edges shall be removed from the split-pin holes both in the fan connecting piece and the down-rod.

(f) The steel suspension shackle shall be welded to the down-rod. Welding shall be of good quality and to the satisfaction of the Supervising Officer. The rubber roller shall be mounted on an 8 mm diameter steel clevis pin secured by a split-pin.

(g) The ends of the down-rod shall be rounded off and free from burrs. There shall be no sharp edges which could cause damage to the insulation of the wiring.

C3.4.8 Suspension Joints and Threaded Parts

(a) Joints along the suspension rod must be of double-locking design, i.e. at least two independent positive locking devices must be employed to prevent a joint from loosening itself.

(b) The maximum clearance between threaded mating parts must not exceed 1% of their mean diameter.

(c) The direction of rotation of the fan shall be such that all screw joints tend to be tightened when the fan is in operation.

C3.4.9 Canopies

Two canopies manufactured from plastic or pressed steel sheet shall be provided and fitted over the upper and lower ends of the down-rod. They shall be fixed to the down-rod grub screws.

C3.4.10 Balance

(a) All fans shall be fully balanced after assembly, with any necessary adjustment being made to ensure that they shall not oscillate due to out-of-balance forces.

(b) All blades shall be given a single identification number, or letter, permanently stamped on the supply side, with a corresponding mark stamped on the motor body so that the fan blades may be reassembled in the correct position.

C3.4.11 Finish

The whole fan shall be finished in high quality stove-enamel, white, ivory or other colour where required by the Supervising Officer.

C3.4.12 Speed Regulator

(a) Solid-state speed regulator shall be with five speeds and an "OFF" position in white or ivory or another colour to match the fan.

(b) An earth terminal shall be provided on the base with an earth wire permanently connected to the steel core of the choke unit.

(c) The speed regulator shall move smoothly and easily between positions.

C3.4.13 Inspection

At least one typical unit for those to be supplied for a given Contract shall be submitted for an acceptance test carried out for the Supervising Officer before delivery of any quantity is made to the Contract Site.

The test units shall be provided and collected by the A/C Contractor at no extra cost to Supervising Officer.

C3.5 CENTRIFUGAL FANS

C3.5.1 Centrifugal fans for high-velocity high-pressure systems as defined within B&ES Standard DW/144:2016 shall be of the backward bladed type.

C3.5.2 Centrifugal fans with motor brake power of 5 kW or more shall be of the backward bladed type having a fan total efficiency not less than 75%.

C3.5.3 Fans shall be tested for air performance and sound ratings in accordance with ANSI/AMCA Standards 210-16 and 300-14, ISO 5801:2017 or equivalent recognised standards as approved by the Supervising Officer.

C3.5.4 Fan casings shall be constructed to permit withdrawal of the fan impeller after fan installation. Fans other than those in factory constructed air handling units (AHUs) shall be provided with flanged outlet connections and spigot inlet connections suitable for flexible joint connections except those for use with negative pressures greater than 500 Pa in which case inlet connections shall be flanged.

C3.5.5 Except for factory constructed AHUs, all fan casings of 900 mm diameter or greater shall be provided with removable access panels which shall incorporate purpose-made air seals. The sizes of access panels shall be such as to facilitate cleaning and maintenance of the impeller and shall not be less than 300 mm x300 mm.

C3.5.6 For all kitchen extract ventilation fans an access door, for inspection and cleaning, shall be fitted to the scroll casing in an accessible position; it shall be of full width of the impeller. A plugged drain point shall be fitted at the lowest point of the fan.

C3.5.7 Permanent indication shall be provided to show the correct direction of rotation of the fan impeller.

C3.5.8 Impellers shall be of galvanised steel or aluminium alloy where indicated, of riveted or welded construction, with spiders or hubs of robust design, and shall be capable of running continuously at 10% in excess of normal speed. Impellers shall be keyed to a substantial mild steel shaft and the impeller completed with shaft shall be statically and dynamically balanced and tested for satisfactory overspeed performance before leaving the maker's works.

C3.5.9 Fan shaft shall enable pulley to be mounted at both ends. Shaft bearings of belt driven single inlet fans shall be truly aligned and rigidly mounted on a pedestal common to both bearings. Double inlet, double width fans shall have a pedestal mounted bearing at each side of the fan. Fan bearings shall be of the ring oiling sleeve type, or the ball or roller type. Where silence is important the bearing pedestal shall not be attached to the fan casing, instead ring oiling sleeve type bearings shall be supplied.

C3.5.10 Centrifugal fans shall be driven by electric motors through V-belt drives complying with the relevant content in Sections B7 &C7.

C3.5.11 Three phase powered variable flow centrifugal fans where specified shall be variable speed driven. Variable speed drive shall be in accordance with Sections B7 & C7 of this General Specification.

C3.6 FAN COIL UNITS

C3.6.1 General

Fan coil units shall comply with the manufacturer's own ISO 9001:2015 quality standard in respect of design and manufacturing and be type-tested to BS 4856-2:1975 or other acceptable standards, such as ANSI/AHRI, Euro vent, GB/T, etc., for thermal volumetric and acoustic performance.

Fans, filters, cooling coils, heating coils, motors, thermal and acoustic insulation shall comply with the appropriate sections of this General Specification and the following requirements: -

(a) Fans shall be of the Double Inlet Double Width (DIDW) forward curved centrifugal or tangential flow types and shall be of galvanised/mild steel, aluminium, reinforced glass fibres or rigid plastic material as specified in Particular Specification;

(b) Air filters shall be as indicated in the relevant content of Section C1 but with minimum efficiency reporting value (MERV) of 1-2; Average Arrestance ≥50% or 65% by ANSI/ASHRAE Standard 52.2:2017 or other equivalent;

(c) Motors shall be quiet running and have sleeve or ball bearings factory lubricated for life. Motor windings and electrical

components shall be impregnated or protected to avoid trouble from condensation;

(d) The fan motor shall be of the single phase permanent split capacitor type provided with three speed tapped windings, or brushless direct current (BLDC) type provided with low noise pulse width modulation for variable speed control as specified in the Particular Specification;

(e) BLDC type fan motor shall comply with the following requirements:

(i) The motor shall consist of hall magnetic pole sensing elements and be controlled by pulse width modulation (PWM) of modulating speed with minimum speed setting. Sensorless technology as an alternative will be considered subject to the approval by the Supervising Officer;

(ii) The motor shall be totally enclosed in an aluminium alloy casing, complete with 8-pole (or above) coil, permanent magnet rotor and permanently lubricated ball bearing;

(iii) The motor shall be insulated with class B (or above) with built-in thermal cut-out protection;

(iv) The motor converter and driver shall be enclosed and complete with overload, start and stall protection;

(v) The motor shall be capable to deliver over a speed range of 30% to 100% continuously and smoothly; and

(vi) The power factor shall have performance not less than permanent split capacitor type. The total harmonic distortion shall be submitted to the Supervising Officer for approval.

(f) All fan coil units capacity and air flow rate shall be selected based on the performance of the units at optimum fan speed; and

(g) In selecting the fan coil units, allowance shall be made for the actual resistance imposed on the air flow of the units due to ducts and grilles. The added resistance is to be applied to all fan coil units whether shown to have ducts connected or not, and shall be taken as not less than 30 Pa external to the unit.

(h) For the connection between cooling coils of fan coil unit and chilled water pipe, suitable fitting/device or methodology approved by the Supervising Officer to prevent galvanic

corrosion effect of different pipe materials jointing together shall be provided.

C3.6.2 Casings

Casings shall be of G.I. sheet metal with thickness not less than 1.0 mm suitably stiffened to minimise drumming and vibration and shall be protected against corrosion and, for those exposed to view, finished i outside with stove primer. All corners shall be rounded off without sharp edges. Casings shall be lined with material to act as both thermal and acoustic insulation which shall comply with the relevant of Sections B11, C11, B8 & C8. Casings shall include space for pipework connections and valves, and there shall be ready access to the fan and motor, filter, damper, drain pan, pipework connections and valves, for maintenance purposes.

The motor and fan shall be mounted on a detachable mounting chassis that can be removed from the fan coil enclosure as one assembly (with extended cables) to facilitate fan and motor cleaning. It shall then also be possible to remove the fan impeller scroll casing in order to properly clean the fan blades. Fan and motor assemblies shall be completed with neoprene rubber anti-vibration mountings.

C3.6.3 Coils

(a) Cooling coils shall be minimum two-row and shall include an air vent cock and drain valve.

(b) The chilled water cooling coil shall be rated in accordance with AHRI 410:2001 and constructed from seamless copper tubes mechanically bonded to aluminium fins.

(c) Each coil shall be provided with motorised 2-way solenoid control valve and isolation valves. Flexible pipe connectors completed with union joints to facilitate removal of the entire unit shall be provided. The connector shall be copper or stainless steel braided polymer tubing limited to 300 mm long and suitable for the system pressure.

(d) Working pressure of coils shall suit specific requirements.

C3.6.4 Components

(a) All units shall include an easily removable filter capable of treating the total air volume. Filters shall, unless otherwise specified, be washable. It shall be supported in a stiff aluminium/stainless steel detachable frame.

(b) Drain pans shall be made of 1 piece stamped stainless steel sheet with no weld and protected against corrosion, or made of plastics or reinforced glass fibre materials insulated with a minimum of 10 mm thick flexible closed cell elastomeric

insulation. Drain pans shall be large and deep enough to collect all condensate from the coil, return bends and pipework connections. The pan shall be removable and have a slight fall to the drain connection. For units whose loads include a high proportion of latent cooling the fall to the drain point and the size of the drain connection shall be adequate to deal with the condensed moisture.

C3.6.5 Controls, Dampers and Grilles

Fan coil units shall have a combined room temperature sensor completed with 3-speed controller with heating/cooling mode selector as required for standalone control, or connected to CCMS as specified. For BLDC motor, the control logic shall include the modulation of fan speed and control valve to provide feedback control in response to the difference between the room temperature and the set point.
Where indicated they shall have connections for both fresh and recirculated air and shall include a damper which shall be adjustable to give up to 25% of the fan capacity drawing from the fresh air source. Outlet grilles shall be capable of adjusting the direction of airflow without adversely affecting pressure drop. On floor mounted units, supply grilles shall be on the top of the unit.

C3.6.6 Noise level

The noise data provided shall include an octave band analysis of the sound power level of each unit when operating at its full or the stated design speed.

C3.6.7 Electric Heaters for Fan Coils

Electric heaters shall be of maximum 2 kW capacity of the black heat sheathed element type, plain or finned, and shall be provided with a safety cut-out thermostat set to operate at 50 ^{o}C.

Sail switch is to be fitted for each heater battery and is to be connected in series with the safety cut-out thermostat to switch off the heater in the event of reduced air flow.

The mounting, arrangement and terminals, etc. for Electric Duct Heaters shall be in accordance with Drawings or other installation standard approved by the Supervising Officer.

C3.7 CASSETTE TYPE FAN COIL UNITS

C3.7.1 Generally, the cassette fan coil units shall comply with Clause C3.6 of this General Specification.

C3.7.2 The fan coil unit shall be of integrated cassette type which combines the supply air slot, return air grille, fan, casing, cooling coil, heating

coil or electric heater (if required) into a single unit. No connection of ductwork is allowed except for fresh air.

C3.7.3 Fan coil units shall be selected at design duty and specified noise level with fan running at medium speed.

C3.7.4 Remote control unit shall be provided as specified.

C3.7.5 Cooling coil shall be constructed with copper tubes and shall be arranged horizontally. Tubes shall have brazed copper return bends. Fins shall have smooth drawn collars of length equal to fin spacing and mechanically bonded to tubes. Fins shall be of the plate type, corrugated to ensure maximum air contact. All coils shall have an air release valve and a drain valve. Working pressure of coil shall be of a minimum of 1200 kPa and to suit system pressure design. Connection of water piping shall refer to Clause C3.6.3(c).

C3.7.6 Each fan coil unit shall be provided with a drain pan made of high grade AISI 316 stainless steel or any corrosion resistant material complying with relevant fire safety requirements situated beneath the cooling coil and arranged so that all moisture will collect in and drain from the pan. Drain pans shall be insulated externally with a minimum of 25 mm approved type foamed plastic. Each drain pan shall be fitted with a drain pipe which shall be connected via suitable runs (correctly laid to fall) to the drainage system. Drain pans shall have copper male connectors for connection to the condensate drain. The connector shall be positioned to ensure rapid discharge of moisture from the pan.

C3.7.7 Built-in condensate pump shall be provided for the removal of condensate. A water sensing system with low, high and warning limits shall be provided which actuates the running of condensate pump at high water limit and trigger the alarm system at warning level. When water level reaches the warning limit, the sensing system shall cut off the unit operation. An alarm signal shall be given locally. The signal shall be connected to CCMS or remote indication system as specified. Condensate pump shall be designed to run continuously at some essential areas as specified. The power source for condensate pump and the associated control system shall be independent from that of the fan coil unit such that the pump can still be operated after the units have been switched off.

C3.7.8 The filter media shall be of the washable type and shall be enclosed in a one-piece formed frame made of stainless steel or any corrosion resistant material with covers flush mitred and reinforced by a die-formed inverse bead.

C3.7.9 Fan shall be of the quiet running direct driven centrifugal type with blades made of aluminium or any corrosion resistant material mounted to a solid steel shaft. Fan motors shall be of the "split capacitor" type suitable for single phase electrical supply, or BLDC type in accordance with Clause C3.6.1(e). The motor shall be resiliently mounted to the

fan tray or scrolls. The motor/fan tray assembly itself shall also be resiliently mounted to the casing structure.

C3.7.10 Adjustable louvres for directional airflow shall be provided for supply air slot in each fan coil unit. Options shall be given to choose from 2-way, 3-way or 4-way supply air discharge.

C3.8 MIXED FLOW FANS

Mixed flow fan casings shall be rigidly constructed of mild steel, or aluminium alloy stiffened and braced where necessary to obviate drumming and vibration. Mounting feet shall be provided where necessary for bolting to a base or supports. Inlet and outlet shall terminate in flanges to facilitate removal. Stator vanes shall be of mild steel or aluminium alloy. The unit shall be designed to facilitate access to the impeller. Where motors are mounted external to casings, drives and guards shall be provided in accordance with Sections B7 & C7. An access panel with purpose-made air seal shall be provided in the fan casing; the access panel shall be sized and so positioned as to facilitate maintenance.

C3.9 MECHANICAL ROOF EXTRACT UNITS

The fans used in roof extract units shall meet with the appropriate requirements of the preceding content relating to fans generally and in particular to the types of fans involved. The materials of cowls and bases shall be resistant to weather, solar radiation and appropriate to the location of the unit and type of fan installed. Casings shall be formed to facilitate a weatherproof fixture to the building structure. Adequate access to electrical supply terminals and lubrication points shall be provided by means of hinged cowls or otherwise as appropriate. Back-draught dampers and/or fire release dampers shall be provided where indicated. Bird entry preventive guards of not greater than 25 mm mesh shall be provided as an integral part of the unit.

C3.10 PROPELLER FANS

Impellers shall be of steel or aluminium; the blades shall be fastened to the hub or the blades and hub shall be formed in one piece. The bearings may be ball, roller, or sleeve type. Propeller fans may be ring mounted, diaphragm mounted or diaphragm mounted in a casing, as indicated.

The tip speed of propeller fans shall, unless otherwise indicated, not exceed 20 m/s. All ring mounted propeller fans which are exposed, i.e. not installed within a ductwork or other enclosure, shall be adequately protected by safety guards.

C3.11 PROTECTIVELY COATED FANS AND FANS FOR CORROSIVE OR HAZARDOUS APPLICATIONS

Where fans are required to handle toxic, corrosive, flammable, explosive or high temperature gases, the materials and form of construction shall be selected and

suit the particular application. Protectively coated fans shall meet with the appropriate requirements of the previous content relating to fans generally and to particular types of fans; the form of protection shall be as indicated. Where a protective coatings is required for use with corrosive gases, the coating shall cover all parts of the complete fan, motor and casing assembly which will be in contact with the corrosive gases. No fan shall be installed if the protective coating has been damaged in any way. Impellers shall be of coated steel, stainless steel, aluminium or fire-proof plastic as indicated.

Where fans are installed in a potentially explosive atmosphere, the EU ATEX 100a directive shall be complied.

C3.12 ROTARY FANS (WALL OR CEILING MOUNTED)

C3.12.1 Capacity

The unit shall be capable of an air delivery of not less than 1.1 m^3/s.

C3.12.2 Dimension

The blade sweep diameter of the unit shall be 400 mm.

C3.12.3 Duty

(a) The unit shall be suitable in all respects for operation in ambient air conditions of 35°C and 95% RH.

(b) The unit shall be suitable for operation on 220 V, 50 Hz, single phase AC supply.

(c) The fan shall not require periodic lubrication.

C3.12.4 Construction

(a) These units shall be of deluxe and pleasing appearance with smooth safe edges and of "easy-to-disassemble" design for cleaning. Units not considered of suitable appearance may be rejected by the Supervising Officer.

(b) The fan shall have high quality aluminium or plastic blades.

(c) The fan shall be fully balanced after assembly.

(d) The blades shall be enclosed by a high quality chromium plated metal wire-mesh metal guard. The gap in between the guard wires shall not be greater than 15 mm at any point.

(e) The fan shall be provided with rotary mechanism for a rotational sweep of 360° when mounted on the ceiling for rotary ceiling fan or for a swing of 150° when mounted on a wall or column for rotary wall fan.

(f) The whole unit shall be finished to manufacturer's standard light colour or as otherwise approved by the Supervising Officer.

C3.12.5 Electrical

(a) All electrical components, cables, etc. shall conform to the appropriate standards and specifications stipulated in Sections B7 & C7.

(b) All exposed metal parts of the unit shall be suitably earthed via the 3 core flexible cable.

(c) The fan shall be provided with speed regulator and be capable of being switched on and off by a remote 5A DP switch.

(d) The fan shall be provided with an adequate length of 0.75 mm^2 3 cores PVC insulated and sheathed flexible cable and connected to the associated socket outlet. Where provided but not fixed, the cable provided shall be 2 m in length.

C3.12.6 Inspection

As Clause C3.4.13.

C3.13 IN-LINE CENTRIFUGAL FANS

Fans shall be rigidly constructed and fabricated from heavy gauge galvanised sheet. Fan housings shall have flange on the suction and discharge side for connection of flexible joints and ducting. Impellers shall be made of galvanised steel or aluminium, single inlet backward inclined or forward curved centrifugal type. Removable access panels with purpose made air seal shall be provided with sufficient size to permit easy access to all internal components. Motors shall be completed with permanently lubricated ball bearings and being removed from the fan assembly for maintenance.

C3.14 EC PLUG FANS

C3.14.1 Fans shall be direct driven single inlet centrifugal fans. Fans shall be backward bladed type unless alternative requirement is specified in the particular specification and/or equipment schedule. Fan total efficiency shall not less than 75%.

C3.14.2 Fans shall be tested for air performance and sound ratings in accordance with ANSI/AMCA Standards 210-07 and 300-14, ISO 5801:2017 or equivalent recognised standards as approved by the Supervising Officer.

C3.14.3 Fan casings shall be constructed to permit withdrawal of the fan impeller after fan installation. Fans other than those in factory constructed air handling units (AHUs) shall be provided with flanged

outlet connections and spigoted inlet connections suitable for flexible joint connections except those for use with negative pressures greater than 500 Pa in which case inlet connections shall be flanged.

C3.14.4 Except for factory constructed AHUs, all fan casings of 900 mm diameter or greater shall be provided with removable access panels which shall incorporate purpose-made air seals. The sizes of access panels shall be such as to facilitate cleaning and maintenance of the impeller and shall not be less than 300 mm x 300 mm.

C3.14.5 Impellers shall be made of aluminium, air foil type with rotation diffuser mounted on electronically commutated external-rotor motors with variable speed drives.

C3.14.6 Motor efficiency for the fans shall be of minimum IE4 under International Efficiency (IE) classes according to IEC 60034-30-1.

C3.15 JET FANS

Fans shall be direct driven and manufactured in unidirectional as standard with option of fully reversible operation, providing almost same duty in either direction where specified. Fans shall be constructed of either single nozzle or multi nozzle type with each impeller mounted on an independent motor. Fan casings shall be integrated with sound attenuator. Casing materials shall not be less than 0.8 mm galvanised steel, coated with powder to protect from atmospheric corrosion. Fans shall be rigidly constructed and correctly proportioned to allow optimum fan performance. Fan motor assembly shall be designed for easy maintenance and shall be capable of being slide out without dismounting the complete attenuator. Impellers shall be of galvanised steel or aluminium with high efficiency pitch adjustable at unidirectional flow.

C3.16 CONDUCTING FANS

Fans shall consist of 3 to 10 modules of fans in parallel and operate without duct connection. Each module shall consist of aerodynamically shaped aluminium alloy housing with built-in guide vanes and rotor unit. Fan casings shall be made of aluminium alloy and coated with powder. Fan inlets shall be completed with mild steel wire or rod powdered coated protective screen. Mounting brackets and legs shall be of powdered coated rigid steel sheet and shall be installed by means of suspension bolts from ceilings or walls. Mounting legs shall have at least 8 adjustment angles from horizontal to vertical positions. Impellers shall be made of aluminium sheet, axial type and dynamically balanced. Fans shall be compatible for connection with remote controller or field made control panel for remote on/off and high/low speed operation.

C3.17 TERMINAL AIR CONTROL DEVICES

C3.17.1 General

(a) Terminal units shall be factory fabricated and tested in accordance with British Standard BS 4954-1:1973, BS 4954-2:1978, BS 4857-1:1972, BS 4857-2:1978 where appropriate.

(b) Casing of the unit shall be manufactured from galvanised steel sheet of thickness comply with DW/144:2016.

(c) Noise including in-duct sound power level, which emitted through the unit casing shall not exceed the value as indicated and/or as stated in Sections B8 & C8 of this General Specification.

(d) The entire unit shall be internally lined with thermal and acoustic insulation in compliance with the relevant content in Sections B11 & C11 and B8 & C8 enclosed in a galvanised perforated metal liner. The lining shall be securely fixed and shall be proof against erosion by the air flow. The acoustic and thermal insulation shall comply with NFPA-90A:2018, UL 181:2013 and BS 476-4:1970, BS 476-12:1991, BS 476-6:1989+A1:2009 & BS 476-7:1997 standards (or the related content of ISO 1182:2010and the requirements of the FSD.

C3.17.2 Induction Units

(a) Filters, cooling coils, heating coils and thermal and acoustic insulation shall comply with the appropriate sections of this General Specification, with the following exceptions or alternatives: -

Air filters shall be as specified in Clause C3.6.1(b) for fan coil units.

Unless otherwise indicated, cooling coils and/or heating coils shall be formed of copper primary surface tubes with aluminium secondary surfaces.

(b) Casings shall include space for pipework connections and ductwork as necessary, and there shall be ready access to the filter, the primary air nozzles and any valves and controls.

(c) Primary air plenums shall be treated with thermal and acoustic insulation which shall comply with the relevant content of Sections B11 & C11 and B8 & C8**.** Units shall be completed with a suitable device to regulate primary air pressure and air volume flow rate. Primary air nozzles shall be arranged to induce an even secondary circulation across the cooling and/or heating coils. The unit air outlet shall incorporate means of directional control of air supply where indicated.

(d) Cooling/heating coils shall include an air cock and shall be effectively sealed to prevent air by-pass around the coil. Drain

pans of cooling coils shall be of a material which is resistant to corrosion or is protected against corrosion and shall have a slight fall to a drain connection.

C3.17.3 Single Duct Constant Air Volume (CAV) Terminal Units

(a) Unit shall be constructed in accordance with Clause C3.13.2 where appropriate.

(b) Units shall incorporate a self-acting constant flow rate device. The pressure drop across the unit at design air volume flow rate shall not exceed 250 Pa.

C3.17.4 Single Duct Variable Air Volume (VAV) Terminal Units

(a) Unit shall be constructed in accordance with Clause C3.13.2 where appropriate.

(b) Unit shall be rated in accordance with ANSI/ASHARE Standard 70-2006 and Air Diffusion Council Test Code 1062R4. The performance data shall be certified by laboratories by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved. The casing of the VAV terminal unit, re-heater box and multi-outlet box shall be manufactured from galvanised steel sheet of thickness comply with DW/144:2016.

(c) Unit shall be of the pressure independent type throughout the entire range and shall be capable of resetting the air flow to ±5% of the nominal air flow regardless of the change in the system pressure.

(d) The unit shall be capable of being reset to any airflow between zero and the rated air volume automatically to compensate for duct pressure fluctuation.

(e) The air velocity sensor shall measure the true velocity across the inlet of the unit and be unaffected by changes in duct air temperature and humidity. The sensor shall be field replaceable without opening the associated ductwork.

(f) The entire package shall be calibrated and factory-set for the maximum and minimum flow rates as specified but shall be capable of easy re-adjustment in the field. Each terminal box shall be provided with factory-calibrated, direct reading air flow indicator. Separate gauge taps shall be provided for field re-calibration and commissioning.

(g) The velocity controller and the damper actuator shall be of an integral unit directly mounted onto the damper shaft. The actuator shall be capable of operating in the stalled position without overheating or mechanical damage. Mechanical limit

switch will not be accepted. The damper shall remain in a fixed position when electrical power source is interrupted. The control equipment must be easily accessible through an access door provided with quick-release fasteners.

(h) The damper shall be made of heavy gauge galvanised steel with peripheral gasket, pivoted in self-lubricating bearing. In the fully closed position air leakage past the closed damper shall not exceed 2% of the nominal rating at 250 Pa inlets static pressure.

(i) VAV terminal unit shall be pneumatic, electronic or DDC controlled as specified. One thermostat shall be provided for each VAV terminal unit unless otherwise specified. The thermostat offered shall match the unit and include temperature set point and velocity adjustment point located inside.

The thermostat shall have a calibrated scale showing set point temperature with a constant approximately 1 ^{o}C proportional band regardless of minimum and maximum velocity settings. Air flow set point shall be adjusted by screw and voltmeter tap in the thermostat or by other approved means for both high and low air volume limits. The location of the thermostat shall be determined on Site.

(j) The unit shall not be selected at the top of the catalogue range in order to ensure it meets with the specified room noise level requirement.

(k) Circular connection spigot of insertion dimensions, with self-sealing rubber gasket shall be provided at both the inlet and outlet of the unit. Each multi-outlet section shall be completed with at least one spare outlet, capped for future use.

(l) Unit shall be completed with a mixing attenuator section where specified.

The attenuator shall be factory-fitted to the basic unit and of a length not less than 900 mm. The casing shall be constructed as the terminal unit, but with acoustic insulation of mineral wool with a minimum density of 70 kg/m3.

(m) Unit shall be completed with electric heater section where specified. All sections within one metre of the heating elements shall be constructed by double skin casing. The internal insulation shall be lined with minimum 0.7 mm thick galvanised steel sheet. The heater shall be easily withdrawn from the casing for servicing and maintenance. Heating element shall be of the sheathe and black heat type. The heater shall be controlled by contactor and step controller fully interlocked with a sail switch and duct type overheat thermostat with fail safe feature and manual reset. The heating element shall be switched off when the mean temperature inside the air duct

exceeds 50 ^{o}C±10% and within 90 seconds of reaching this temperature.

(n) VAV terminal unit completed with VAV section (air measuring station, modulation damper with actuator and controller), re-heater section, attenuator section and supply air section shall be supplied by the same manufacturer.

C3.17.5 Dual Duct Terminal Units

Dual duct terminal units shall be constructed as single duct CAV unit and VAV unit and shall incorporate devices for varying the proportions of hot and cold air and for providing thorough mixing of the air.

C3.18 GRILLES AND DIFFUSERS

C3.18.1 General

(a) The grilles and diffusers shall be rated in accordance with ANSI/ASHRAE standard 70-2006 and Air Diffusion Council Test Code 1062R4.

(b) All grilles and diffusers shall have concealed fixing system and shall have quick release frame to facilitate cleaning.

(c) All supply grilles and diffusers shall be mounted on substantial frame and shall be provided with soft rubber or felt joining ring inserted under the frame to prevent air leakage and the formation of condensate on the fitting.

(d) All grilles and diffusers shall not be less than the size indicated; where no size is given they shall be capable of handling the air flows and distribution indicated without producing unacceptable air flow noise. The A/C Contractor shall select the supply air grilles and diffusers to achieve good air distribution and adequate air movement in the conditioned space.

(e) In order for the ceiling grilles and diffusers to match with the false ceiling layout pattern, the actual size of the grilles and diffusers shall be confirmed by the Supervising Officer before ordering.

For all grilles and diffusers which are smaller than the ceiling tile on which they are installed, they shall be located in the centre of the ceiling tile. The exact location of the ceiling grilles and diffusers shall be co-ordinated with other services. The A/C Contractor shall confirm the exact location with the Supervising Officer before works commence.

Where grilles and diffusers are to be incorporated into false ceilings before any grilles or diffusers are installed into ductwork or fan coils, the A/C Contractor shall ensure that the Building Contractor marks out the ceiling line on the adjacent plastered walls or columns and also indicates where ceiling tee bars line up or the ceiling joints occur in order that such datum can be worked to.

(f) The finishing colour of the grilles and diffusers shall be approved by the Supervising Officer as different colour may be specified in different areas. The A/C Contractor shall co-ordinate with the Building Contractor and other specialist contractors especially the ceiling and electrical contractor for the integration of the air diffuser into the ceiling and luminaire (for light troffer diffuser).

C3.18.2 Grilles

(a) Grilles shall be of steel, aluminium, PVC or as otherwise indicated. Steel grilles shall be protected against rusting and supplied in fully finished stove-enamelled or otherwise specified condition.

(b) Each supply air grille shall have 2 sets of separately adjustable louvres, 1 set horizontal and 1 set vertical, and shall be completed with an opposed blade multi-leaf damper. Alternatively, in lieu of the opposed blade multi-leaf damper a rhomboidal air controller may be provided; this air controller shall control both the volume of air passing and the distribution of air across the grille face. The louvre and the damper or air controller shall be adjustable from the front of the grille. For up to 10 grilles, 1 set of tools required for adjusting the louvre and dampers or air controllers shall be provided. From eleven to 24 grilles, 2 sets and above 25 grilles, 3 sets of tools shall be provided.

(c) Return air grilles shall have either a single set of louvre or bars (either vertical or horizontal) or a lattice, egg crate or expanded metal front.

Each return air grille shall be completed with an opposed blade multi-leaf damper or a rhomboidal air controller operable from the front.

Where return air grilles are fitted for fan coil units, they shall be arranged such that the central core of the grille is hinged and demountable for access to the filter for cleaning. Mounting frames for these grilles shall include provision for fixing the filter in position.

C3.18.3 Diffusers

(a) Diffusers shall be of steel or aluminium. Steel diffusers shall be protected against rusting and shall be stove enamelled for finished colour approved by the Supervising Officer. Diffusers shall incorporate an edge seal; diffusers mounted on ceilings shall have anti-smudge rings. Pan type diffusers shall be provided except where cone type diffusers are indicated.

Diffusers shall be provided with volume control dampers of the iris, flap or sleeve type which shall be adjustable from the front of the diffuser. Where the length of a vertical duct to a diffuser is less than twice the diameter of the diffuser an equalising deflector shall be fitted.

The design of the supply air diffuser shall be capable to induce adequate air movement and provide the throw to cover the entire air-conditioning space without causing air turbulence and cold draft.

(b) Linear diffusers shall be constructed of extruded aluminium section and include a control damper at the rear of the vanes giving volume control down to complete shutoff and operated from the face of the diffuser. Linear diffusers for supply air shall have adjustable blades to give directional control of air flow. The linear diffuser shall be capable of maintaining a horizontal discharge pattern at a turn down ratio down to 20% of the maximum specified air volume without air dumping.

The linear diffuser shall be completed with factory fabricated plenum with suitable inlet connection for flexible ductwork. The plenum and diffuser neck shall be constructed of galvanised steel sheets internally lined with 25 mm 48 kg/m3 glass cloth faced fibreglass insulation enclosed in galvanised perforated metal liner.

The insulation shall comply with NFPA-90A:2018, UL 181:2013 and BS 476-4:1970, BS 476-12:1991, BS 476-6:1989+A1:2009 & BS 476-7:1997 standards (or related content of ISO 1182:2010).

Where linear diffusers are mounted in a continuous line there shall be means of ensuring alignment between consecutive diffusers and of equalising pressure behind the vanes. The dummy portion of the diffuser shall be internally covered by a demountable galvanised metal enclosure to block the view into the ceiling void from below.

(c) The square face diffuser for VAV system shall be constructed of aluminium and with large turn down ratio.

Each ceiling mounted square face diffuser shall have a factory assembled diffuser and an air plenum. The air plenum shall be provided with dividing plates such that the diffuser back is divided into an annulus area and a square central area. In the entry to the diffuser plenum, the flow cross section shall also be divided into two parts, one part serving as a bypass and the other equipped with a self contained, weight balance damper. The damper shall be balanced with a weight in such a way that the horizontal outlet jet velocity remains nearly constant over a flow rate range of 100 to 20% of maximum in order to prevent stagnant area, wide temperature gradient and drop of air jet in the conditioned area.

(d) The linear slot diffuser shall be constructed of extruded anodised aluminium, with multiple slots for the required air flow rate.

Each diffuser shall be completed with a factory fabricated plenum of the same construction as the linear diffuser.

C3.19 ENERGY EFFICIENCY AND PERFORMANCE

(a) The efficiency of fan and motor used for all air treatment equipment shall be in accordance with Section C7 of this General Specification and Section 6.7 of the Code of Practice for Energy Efficiency of Building Services Installation (2018 Edition).

(b) The type of insulation used shall have optimised thermal conductivity, and the design of the insulation thickness for pipe, drain pan, ductwork, panel enclosure, etc. of the air handling equipment shall be in accordance with Section C11 of this General Specification.

(c) The A/C Contractor shall submit relevant factory test certificates and field test records for calculation and assessment by the Supervising Officer.

C3.20 DESICCANT DEHUMIDIFIERS

C3.20.1 Wheel Type Desiccant Dehumidifier

(a) The dehumidifier shall be of the absorption or adsorption type and completed with rotor, electric or gas type reactivation heater, process air fan, reactivation fan, process air prefilter, reactivation air prefilter, control panel and all other accessories for a complete unit. The heater shall be fitted in a factory built unit casing.

(b) Rotor shall be impregnated with desiccant such as lithium chloride, silica gel, aluminium oxide or other specified type. The desiccant shall be incombustible, resistant to chemicals and

non-dusting. The rotor shall have a service life of minimum 8 years with non-stop operation. The seals between the process and reactivation airflows shall be designed to good standards, and their low frictional properties shall guarantee long and continuous service life.

(c) The casing of the dehumidifier shall be constructed of sheet steel with oven-curved enamel coating to minimise corrosion. Casing shall comply with leakage standard to Eurovent Document 2/2 1996, Class B and the leakage volume shall be of maximum 0.81 l/s per cu. metre at 1000 Pa.

(d) A control panel shall be provided for the control of the dehumidifier. The control panel shall include control mode switch for switching between manual and humidistat operation. Indicators for power on, unit running, alarm (for high temperature cut-out, fan motor overload unit, trip and high humidity, etc.), reactivation fan running, reactive heater on, rotor drive motor running, process fan running, humidity normal, and any other control indication requirements as specified. There shall also be digital displays for fan speeds, humidity level, and reactivation temperature readings, etc.

(e) The heater control shall be of multi-step. The dehumidifier shall be capable of operating with the services conditions as specified under Clause A3.11 of this General Specification.

(f) The unit shall be capable of local or remote control, and be completed with interlock control for operation with the connecting air handling unit. The unit itself shall be completed with built-in direct digital controller (DDC) for all control and monitoring functions.

(g) The following safety devices shall be provided as a minimum requirement: -

- Electric safety interlock to prevent the dehumidifier from running with the electric control panel open or the mechanical access panels removed;

- Automatic shutdown in case the control system detected a fault; and

- Two independent thermostats for the heater shall be provided to trigger automatic shutdown in accordance with IEC regulation.

C3.20.2 Liquid Type Desiccant Dehumidifier

(a) The unit shall employ an approved liquid type desiccant as the dehumidification media.

(b) The unit shall comprise three separate operation sections (i.e. collection, heat pumping and regeneration).

(c) In the collection operation, liquid desiccant shall be continually added to the top of a honey comb cellulose material which shall form a flowing liquid film. The untreated air (i.e. process air) shall be cooled and dehumidified when flowing through the liquid desiccant.

(d) The heat pump section shall transfer the heat of the liquid desiccant absorbed during collection operation to the regeneration operation.

(e) The liquid desiccant shall be heated in the regeneration section. The moisture previously collected shall be removed by the regeneration air stream following the same operation principles in collection section.

(f) The equipment shall be a single compact unit of weatherproof design.

C3.21 DOMESTIC EXHAUST FANS

The exhaust fan shall be completed with a safety front grille at suction side and shall be suitable for installation on wall or window opening. Cord control is not acceptable.

Electrical operated shutter blades, covered by internal grilles, shall be overlapped and interlocked for maximum back-draught protection.

Each fan shall be fitted with quiet motor. The shutter mechanism shall be of quiet and vibration free operation.

C3.22 HEAT PIPE

Heat pipe coils shall be provided for humidity control process of the AHU as specified and indicated in the drawings. The heat pipe coils shall be installed into the AHU and tested in the factory.

The heat pipe coil act as a humidity control coil forms a "wrap-around" configuration which wrap around the chilled water cooling coil inside the AHU, with one section of the heat pipe coil upstream and one section downstream. The heat pipe system is being driven entirely by the temperature difference between the two air steams. There are no moving parts and no external power required.

The heat pipe coils shall be at least 2 rows and are partially filled with a suitable working fluid such as R134a or R407C, and hermetically sealed.

SECTION C4

AUTOMATIC CONTROL

C4.1 ELECTRICAL WIRING

Refer to Section C7 for Electrical wiring & cable material specification.

C4.2 AIR COOLER CONTROL

Unless otherwise specified, the output of chilled water cooler batteries shall be controlled by modulating two or three-way valves having a valve authority as indicated in the Particular Specification or Drawings.

(a) All valves shall be sized in accordance with the recommendations of the manufacturer to assure fully modulating operation.

(b) Valves shall be sized on fully open pressure drop equal to the pressure drop of coil under 120% of design flow.

(c) Control valves smaller than 20mm diameter shall be normally closed, electrically operated, cage-guided, stainless steel trim, flanged cast-steel body.

(d) Valve opting pointer shall be provided at each valve actuator for direct indication of valve opening.

(e) Valve actuators shall be mounted directly on the control valve without the need for separate linkage and the need for any adjustment of the actuator stroke. Actuators shall have a manual operation capability.

(f) All valve actuators with valve size over 20 mm diameter shall maintain its last position for fail-safe operation.

C4.3 AIR HEATER CONTROL

C4.3.1 2 -Way or 3-Way Modulating Valves

(a) Unless otherwise specified, the output of hot water air heater batteries shall be controlled by modulating valves having an authority as indicated in the Particular Specification or Drawings.

(b) All valves shall be sized in accordance with the recommendations of the manufacturer to assure fully modulating operation.

(c) Control valves smaller than 20mm diameter shall be normally closed, electrically operated, cage-guided, stainless steel trim, flanged cast-steel body.

(d) Valves shall be sized on fully open pressure drop equal to the pressure drop of coil under 120% of design flow.

(e) Valve opting pointer shall be provided at each valve actuator for direct indication of valve opening.

(f) A manual override device together with auto/manual switch and automatic change-over relay shall be provided as the manual setting facility for the control valve opening and back-up in case of local controller outage.

(g) Valve actuators shall be mounted directly on the control valve without the need for separate linkage and the need for any adjustment of the actuator stroke. Actuators shall have a manual operation capability.

(h) All valve actuators with valve size over 20 mm diameter shall maintain its last position.

C4.3.2 Electric Ductwork Heaters

Specifications for the electric ductwork heaters shall be referred to Clause C3.2.14. They shall also comply with the requirements of the FSD.

C4.3.3 Differential Pressure Switches

Differential pressure switches shall be able to de-energise the heaters when the air flow stops.

Differential pressure switches are designed for use only as operating controls. A/C Contractors are responsible to add devices (safety, limit controls) or systems (alarm, supervisory systems) to protect against control failure.

The operating temperature range of the pressure switches shall be from 40 ^{o}C to 75 ^{o}C.

The diaphragm housing shall be made of cold rolled steel with zinc plating.

Sensors shall comply with relevant standards of UL or BS/EN/BSEN or other international standards.

C4.4 ELECTRICAL/ELECTRONIC (LOCALISED) CONTROL SYSTEM

The systems shall be operated at single phase mains voltage or at extra low voltage such as 12 V or 24 V as indicated in the Particular Specification.

Where a particular manufacturer's system is offered and accepted, the Installations shall be installed to comply with that manufacturer's recommended technical details and methods of installation.

C4.4.1 Standalone Direct Digital Controllers/Outstation (DDC/O)

Unless otherwise specified, the direct digital controllers shall have sufficient memory to support its own operating system and databases.

(a) Each controller shall have sufficient memory to support its own operating system and database including: -

- Control Processes;
- Energy Management Applications;
- Alarm Management;
- Historical / Trend Data for all points;
- Maintenance Support Applications;
- Operator I/O; and
- Manual Override Monitoring.

The memory board shall be expandable to a larger size as needs grow.

(b) Communication Ports

Each controller shall be equipped with at least two communication ports for simultaneous operation of multiple operator I/O devices such as modems, printers, personal computers, and portable operator's terminals.

The controller shall have provisions to allow temporary use of portable devices without interrupting the normal operation of the permanently connected modems, printers or network terminals.

(c) Network Communication

The automation network shall be based on PC industry standard of Ethernet TCP/IP. The network shall be capable of operating at a communication speed of 100 Mbps.

Switches shall be provided for manual override on digital and analogue outputs, to allow the user to manually control the position of the end device.

(d) Expandability

Each outstation shall be factory pre-wired comprising a factory fabricated metal enclosure, hinged door with master lock and name plate holder. The outstation shall be of modular design

with standard function modules or similar to accept plug in printed circuit cards.

Each outstation shall contain interface hardware modules to accept a plug-in portable operator terminal (POT) with visual display and analogue facility to enable commissioning and fault finding to be achieved.

(e) The direct digital controller shall provide local LED status indication for each digital input and output. Status indication shall be visible without opening the panel door.

(f) Real Time Clock (RTC)

The real time clock shall be able to display in the forms of year, month of the year, day of the month, hour of the day, and minutes.

(g) Automatic Start After Power Failure

The control station shall be provided with a power fail safe and restart feature.

An orderly restart controlled from the data processing controller shall occur on resumption after a power failure without manual intervention.

There shall be no loss of system memory on power failure.

(h) Battery Backup

Battery shall be able to support the real time clock, programme, and all volatile memory for a minimum of 72 hours.

When the battery replacement is necessary, the open processor shall illuminate a "battery low" status LED and shall send an alarm message to the selected printer or terminals.

(i) Time Scheduling

The following commands shall be able to be time-scheduled for issue at a later day and time:-

- Start and stop a point;
- Change alarm limits, warning limits or set-point;
- Lock/unlock point reporting or point control;
- Demand limit target setting; and
- Alarm summary.

Separate schedules shall be stored for:-

- Regular weeks;
- Special weeks; and
- Holidays.

After recovery from a power failure, the system shall determine any time-scheduled commands which should have been issued during the period that the power was off. These commands shall automatically be issued.

The system shall allow holidays to be scheduled with a minimum of one year in advance.

(j) Alarm Management

Each analogue point shall have the following defined:-

- High Alarm Limit;
- High Warning Limit;
- Low Warning Limit;
- Low Alarm Limit; and
- Differential.

When an analogue point goes outside the High Warning or Low Warning Limit for more than one minute, a user defined warning message shall be sent to the appropriate alarm printers.

When a binary point goes into alarm, a user defined alarm message shall be sent to the appropriate alarm printers.

When a point returns to normal, the event shall be recorded in the printer output.

When the point module is placed in override, an alarm shall be sent to the output of the printers.

C4.4.2 ACMV Sub-System Controllers

Temperature/humidity/pressure controllers shall have separate zero and proportional band adjustments. Local display and keypad shall be provided for viewing and controlling each output. Analogue output of controllers shall be available with either 0 to 10V or 0/4 to 20 mA DC proportional output, two positions, or any combination. Controller shall have internal switches for each output to change the output signal to either direct or reverse. Controller shall be available with integral electronic circuit for absolute high or low limit control.

Air contamination controllers shall be available in one or two stages. Controller shall close its contacts to initiate ventilation system when the air contamination exceeds its set point.

Chilled water reset controller shall have integral reset action to eliminate sustained system offset and be capable of receiving signals from chilled water and outdoor air sensors to control chilled water supply temperature according to an adjustable reset schedule. The controller shall have an adjustable set point for absolute high limit. Controller shall have an indicating lamp that will vary in intensity with the controller output. Controller shall be available with either proportional or 3-point floating output.

Rate/reset controller shall be of the proportional type with adjustable integral and derivative actions. The controller shall be field adjustable for either direct or reverse action and shall be supplied with a switch to eliminate the integral and derivative functions for calibration purposes. The output of the controller shall be 0-20V or 0/4 to 20 mA DC. An indicating lamp shall be provided which will vary in intensity as the output varies.

Constant temperature controller shall be of the proportional type with integral reset action to eliminate sustained system offset. The controller shall have capability to adjust the integral reset times.

C4.4.3 Control Panel

The Control Panel shall be installed in the A/C Control Room of the building at location as shown in the Drawings with a sub-panel, if required, for monitoring and data logging in location as specified.

The panel shall be constructed with 1.5 mm thick hairline finished stainless steel sheets c/w all flush galvanised iron (G.I.) supports and accessories. All the lettering shall be in English and Chinese characters and to be engraved on the panel. All lettering and characters shall be approved by the Supervising Officer before fabrication. The front cover shall be of 2 mm thick hairline finished stainless steel with sectional recessed hinged cover for easy inspection and maintenance.

The panel shall include the following: -

(a) Indicating lights, ammeters, gauges, control switches, push buttons, control wiring and other necessary equipment to enable remote operation and monitoring of all A/C equipment;

(b) The running and alarm indicating lights for a particular equipment shall be fitted onto the panel as standard module blocks; and

(c) An alarm chime shall be provided to sound an alarm condition when any of the alarm indicating lights is energised. An alarm mute button shall also be provided to acknowledge the alarm by the operator. Alarm indicating lights shall remain on until the conditions causing the alarms are returned to normal state.

C4.4.4 ACMV Sub-System DDC Controller Resident Software Features – Energy Conversation

For full specification of the energy calculation feature of the DDC controller, refer to Clause C5.41.

C4.4.5 ACMV Sub-System DDC Controller Resident Software Features – Other Features

(a) Power Demand Monitoring / Load Shedding

For full specification of the power demand monitoring / load shedding feature of the DDC controller, refer to Clause C5.43.

(b) Optimum Start Time

For full specification of optimum start time feature of the DDC controller, refer to Clause C5.44.

(c) Supply Air Reset

For full specification of supply air reset feature of the DDC controller, refer to Clause C5.45.

(d) Chilled Water Optimisation (CHO)

For full specification of chilled water optimisation feature of the DDC controller, refer to Clause C5.46.

C4.4.6 DDC Sensors

All sensors specified in this Clause shall meet with the requirements in the Guidance Notes for Management of IAQ in Offices and Public Places and the Guide for Participation in the IAQ Certification Scheme published by HKSAR Government.

(a) Temperature Sensors

Temperature sensors shall be either of the thermister (NTC) type with a high linear resistance change versus temperature change or Platinum (PT1000) to ensure good resolution and accuracy.

Sensors shall be factory calibrated and shall be connected to remote controller by means of suitable cables.

Sensors shall not require compensation for cable length etc.

For immersion temperature sensors, sensors shall be provided with immersion pocket. The sensing range shall be selected according to its application.

For room / wall mounted temperature sensors, sensors shall have a connection plate to permit easy removal of the sensor during decorations etc. The sensing range shall be of 0 ºC to 40 ºC. The accuracy shall be within ±0.5%. There shall be option for temperature display at 0.5K interval in the sensors.

For ductwork type temperature sensors, sensors shall have a separate mounting flange with snap-on connection to permit sensor adjustment.

For outdoor temperature sensors, the sensing range shall be of -40 ºC to 40 ºC. The accuracy shall be within ±0.5%.

All sensors shall comply with relevant standards of UL or BS/EN/BSEN or other international standards.

(b) Humidity Sensors

Humidity sensors shall be of the capacitance type with operating range of 5% to 95% and the accuracy shall be within ±3% R.H. between 23ºC and 25ºC. Sensors shall be suitable for use on the duty expected.

The sensors shall vary the output voltage with a change in relative humidity.

Humidity sensors shall be available for room or ductwork mounting.

Sensors shall be connected to remote controller by means of suitable cables. Sensors shall not require compensation for cable length etc.

All sensors shall comply with relevant standards of UL or BS/EN/BSEN or other international standards.

(c) Absolute Humidity (Dew Point) Sensors

Absolute humidity (dew point) sensors shall utilise an active element to sense the actual quantity of water vapour per volume of dry air when the relative humidity is from 12 to 100 percent.

Sensors shall be highly repeatable and change resistance with a change of moisture content in the air.

Sensors shall be connected to remote controller by means of suitable cables. Sensors shall not require compensation for cable length etc.

Accuracy of the sensors shall be within ±3% R.H. between 23ºC and 25ºC.

All sensors shall comply with relevant standards of UL or BS/EN/BSEN or other international standards.

(d) Combined Type Humidity and Temperature Sensors

Sensors shall have elements mounted in a common enclosure and be able to be connected to remote controller by means of suitable cables.

Sensors shall not require compensation for cable length etc.

Accuracy of the sensors shall be within ±3% R.H. between 23ºC and 25ºC for temperature and humidity control respectively.

All sensors shall comply with relevant standards of UL or BS/EN/BSEN or other international standards.

(e) Differential Pressure Sensors

Differential pressure sensors shall vary the output voltage with a change in differential pressure.

Sensors shall be connected to the remote controller by means of suitable cables, and sensors shall not require compensation for cable length etc.

All sensors shall comply with relevant standards of UL or BS/EN/BSEN or other international standards.

(f) Carbon Dioxide Sensors

Non-dispersive technology with sensing range of 0 to 2000 ppm shall be used for carbon dioxide sensors.

The accuracy shall be within 5%.

Carbon dioxide sensors shall be available for room or ductwork mounting.

All sensors shall comply with relevant standards of UL or BS/EN/BSEN or other international standards.

(g) Carbon Monoxide Sensors

Carbon monoxide sensors shall be factory assembled units, designed to continuously monitor and indicate the level of carbon monoxide in parts per million on its meter with 4 mA to 20 mA or 0V to 10V DC output and to activate the alarm circuit, alarm horn and warning light when the carbon monoxide concentration reaches the alarm point and deactivate the alarms when the carbon monoxide concentration drops below the alarm point.

The alarm point shall be factory set at 200 ppm and shall be internally or through CCMS adjustable from 10 to 300 ppm. Sensor response shall be 90% of maximum reading within 20 seconds with 200 ppm carbon monoxide concentration.

The sensor coverage shall be based on the requirements of the appropriate regulations but not be less than 500 m2 per one sensor.

Unit shall be designed for operation with either 24 V DC, or 220 V AC, single phase supply and shall have solid-state circuitry, terminal strip with contacts for recorder, alarm and fault outputs, replaceable factory-matched pair of catalytic, semi-conductor sensors, meter calibrated 0 to 300 ppm, illuminated ON, PURGE, ALARM ON, FAULT/TEST switches, momentary ALARM RESET switch and an alarm horn, all mounted on the unit's cover or through CCMS to display.

Unit shall have environment-proof, fibreglass polyester case with hinged, latched and lockable cover. Alarm light shall be mounted on the top of the case and conduit connector or opening and a test gas connector at the bottom of the case.

Sensors should have at least a life time of three years. Replacement shall consist of replacing the detector head and filter.

Sensors shall comply with relevant standards of UL or BS/EN/BSEN or other international regulations / standards for gas monitoring.

(h) Nitrogen Dioxide Sensors

Nitrogen dioxide sensors shall be factory assembled units, designed to continuously monitor and indicate the level of nitrogen dioxide in parts per million on its meter with 4 mA to 20 mA or 0V to 10V DC output.

Electrochemical type sensor with resolution of 0.1 ppm shall be used for the nitrogen dioxide sensors.
The sensing range of 0 to 5 ppm shall be used.

Unit shall have environment-proof, fibreglass polyester case with hinged, latched and lockable cover. Alarm light shall be mounted on the top of the case and conduit connector or opening and a test gas connector at the bottom of the case.

Sensors should have at least a life time of three years. Replacement shall consist of replacing the detector head and filter.

Sensors shall comply with relevant standards of UL or BS/EN/BSEN or other international regulations / standards for gas monitoring.

(i) Air Velocity Sensors

Air velocity sensors shall be capable of linear indication of the velocity of air in a ductwork from 0 to 15 m/s, and shall vary its output voltage with a change in air velocity.

Sensors shall have range selection for low velocities.

Accuracy of the air velocity sensors shall be within ±1% of the range.

Sensors shall be connected to the remote controller by means of suitable cables, and sensors shall not require compensation for cable length etc.

All sensors shall comply with relevant standards of UL or BS/EN/BSEN or other international standards.

(j) Contamination Sensors

Contamination sensors shall vary the conductivity as the degree of gas or smoke concentration changes.

The sensor shall be connected to the remote controller by means of suitable cables, and sensors shall not require compensation for cable length etc.

(k) Flow Sensors

Flow sensors shall be of the electromagnetic or ultrasonic type.

Sensors shall be capable of measuring range suitable for the application.

Electrodes shall be of stainless steel or other approved material suitable for the liquid to be measured.

Energy saving function for external battery power supply shall be provided as required.

Complete self diagnostic function of the measurement system (sensor and converter) shall be provided.

Accuracy of the flow sensors shall be within ±1% of the range.

(l) Flow Switches

Flow switches shall be electric and two-position with snap action.

Operating pressure of the switches shall conform to the requirement of the Installations and shall not be less than 1000 kPa.

Switches shall be adjustable for sensitivity to flow and the adjustment range shall include flow valves applicable to the equipment protected by the flow switches.

C4.4.7 Electric / Electronic Damper Actuators

For full specification of the electric / electronic damper actuator, refer to Clause C5.52.

C4.4.8 Control Valves

For full specification of the control valve, refer to Clause C5.50.

C4.4.9 Automatic Dampers

For full specification of the automatic damper, refer to Clause C5.51.

C4.4.10 Digital Temperature Display

For full specification of the temperature digital display, see Clause B4.1.7.

SECTION C5

CENTRAL CONTROL AND MONITORING SYSTEM (CCMS)

C5.1 CCMS ARCHITECTURAL OVERVIEW

The CCMS shall consist of a Server with terminal, keyboard and other necessary peripherals, User/Operator Workstations if specified, router, gateway and/or interfacing unit, CCMS Sub-systems to be integrated, General Purpose Controllers, Unitary Controllers, Analogue/Digital Input and Output devices such as sensors, actuators, etc. of each CCMS Sub-system interconnected via Local Area Network, Field Bus and / or Remote Communication.

CCMS Sub-systems that are required in the Particular Specification to be integrated in the CCMS shall include, but not be limited to, the followings: -

- ACMV Monitoring and Control;
- Electrical System Monitoring;
- Lighting Control;
- Energy Conservation Programmes;
- Emergency Electrical System Monitoring;
- Fire Installation Monitoring;
- Security Installation Monitoring;
- Lift Programme Control and Monitoring;
- Garage CO Monitoring and Control where required;
- Mechanical Pumping and Plumbing Control and Monitoring;
- Normal, Emergency and Preventive Maintenance Notification and works ordering; and
- IAQ measurement where necessary.

The CCMS shall comply with all the operational requirements as indicated in the drawings, specifications or point schedule.

The CCMS shall be a distributed system, any single point failure shall not impair the operation of the whole system.

Each CCMS Sub-system shall be self-contained and be able to continue to perform all Sub-system control and monitoring functions in the event of failure of the CCMS server.

Each General Purposes Controller or Unitary Controllers shall have intelligence and be able to continue to operate all local control functions in the event of failure of any higher hierarchy control systems.

C5.2 TERMINOLOGY

Operator Workstation is the operator's window into a system. While it is primarily used for the operation of a system, it may be used for configuration activities. It is not intended to perform direct digital control.

General Purpose Controller/Building Controller is a device for the regulation or management of a system or component. General Purpose Controller/Building Controller is a general purpose, field programmable device capable of carrying out a variety of building automation and control tasks.

Advanced Application Controller is a control device with limited resources relative to General Purpose Controller/Building Controller. It is intended for specific applications and supports some degree of programmability.

Application Specific Controller is a controller with limited resources relative to Advanced Application Controller. It is intended for use in a specific application and supports limited programmability.

Unitary Controller is a device for controlling or monitoring a single piece of equipment.

Gateway/Interfacing Unit is a device that connects two or more dissimilar networks, most likely with different communication protocols permitting information exchange between them.

Smart Actuator is a simple control device with limited resources and designed for specific applications.

Smart Sensor is a simple sensing device with very limited resources.

C5.3 RELEVANT STANDARDS

Where applicable standards exist, the products provided shall comply with the standards etc. of the relevant authorities as stated in Section A2 of this General Specification or equivalent standard, and the list below where applicable: -

(a) ASHRAE. Standard 135-2016 - A Data Communication Protocol for Building Automation and Control Networks (BACnet);

(b) International Organization for Standardization ISO/IEC 9075-9:2016 - Information Technology - Database Languages SQL – Part 9 : Management of External Data (SQL/MED);

(c) ANSI /CEA-709.1-B:2002 - Control Network Protocol Specification (known as Lontalk);

(d) TIA/EIA 232-F Interface Between Data Terminal Equipment and Data Circuit Terminating Equipment Employing Serial Binary Data Exchange;

(e) TIA/EIA 485-A - Electrical Characteristics of Generators and Receivers for use in Balanced Digital Multipoint Systems;

(f) TIA/EIA 568-.1-D - Commercial Building telecommunications Cabling Standard;

(g) Transmission Control Protocol/Internet Protocol of Defence Advanced Research Project Agency (TCP/IP);

(h) International Organization for Standardization ISO/IEC 1989:2014- Information Technology – Programming Languages - COBOL; and

(i) International Organization for Standardization ISO/IEC 8802-3:2017 – Standard for Ethernet.

C5.4 MANUFACTURING STANDARDS

The system shall be built from standard packages. The estimated amount of customisations to suit the requirements of the Particular Specification shall be specified in the tender submission.

All materials and equipment used shall be standard components, regularly manufactured and not custom designed specifically for the project. All systems and components shall have been thoroughly tested and proven in actual field use for at least 6 months and with at least 3 relevant job references locally either private sector or with government.

The CCMS shall be a fully integrated system of computer-based building automation. The system shall be modular, permitting expansion by adding hardware and software without changes in communication or processing equipment. The CCMS, while "on-line" must be capable of adding, modifying, deleting points and inter-lock sequences without changes to "hardware" and field wiring or control devices. These changes shall be input through various input/output devices incorporated into the CCMS.

All CCMS server and associated devices shall be able to operate properly under environmental conditions as specified in Clause A3.11. The CCMS Server and peripheral devices shall not be installed until the operating area is air conditioned and reasonably free of dust and other contaminants which could impair their operation.

All controllers' cubicles shall be supplied factory pre-wired and terminated for connection to the field devices.

Controllers' electronics shall be solid state, utilising distributed processing techniques, and of the plug-in circuit board type. Separate fusing shall be provided for all control voltages.

Construction standards for panels, racks, cabinets and other equipment provided shall meet with the following minimum standards:-

(a) Racks and panels shall comply with ANSI/EIA-310-D:1992 or equivalent standard;

(b) Panels shall be made of steel, suitably reinforced and braced so as to provide flat-surfaced, rigid construction;

(c) Material surfaces shall be free of scale, welding slag and dirt;

(d) Panel surfaces shall be flat and free from waviness;

(e) Stiffness and bracing shall be provided as required;

(f) Handling during installation shall be such that the panels will not suffer distortion or buckling; and

(g) Cut outs shall be square with consoles to ensure that the controls shall be installed level and square. Finished cut outs and holes shall be free of burrs and sharp edges and fitted with rubber grommets to prevent cable insulation damage.

C5.5 CCMS INTER-NETWORKING STANDARD

The CCMS Server, Workstations shall be inter-connected with Local Area Network (LAN) or remote communication. Each CCMS Sub-system shall be connected to the LAN through a gateway, router or remote communications.

The General Purposes Controller, Unitary Controller, Smart Actuator and Smart Devices of each Sub-system shall be inter-connected with field bus.

The LAN's physical and data link layer shall comply with ISO/IEC 8802-3:2017 standard with a minimum speed of 100 Mbps.

The Remote Communication's physical layer shall comply with TIA/EIA 232-F standard.

The field bus's physical layer shall comply with TIA/EIA 485-A standard with a minimum speed of 19200 bps.

The communication protocol of CCMS Server and Workstations with CCMS Sub-systems shall comply with BACnet Standard. The CCMS Server and Workstation shall conform to BACnet Operator Workstation (B-OWS) or Advanced Operator Workstation (B-AOWS).

The CCMS Server and Workstations shall comply with ANSI/ASHRAE standard 135-2008 - A Data Communication Protocol for Building, Automation and Control Networks (BACnet) and support BACnet/IP with BTL listed.

The communication protocol of General Purposes Controllers, Unitary Controllers, Building Controllers, Advanced Application Controllers, Application

Specific Controllers, Smart Devices in field bus shall comply with either BACnet and BTL listed or LonWork standard.

General Purposes Controllers, Unitary Controllers, Smart Devices in field bus complying with LonWork standard shall conform to the LonMark interoperability guidelines.

Building Controllers complying with BACnet shall conform to BACnet Building Controller (B-BC).

Advanced Application Controller complying with BACnet shall conform to BACnet Advanced Application Controller (B-BAAC).

Application Specific Controller complying with BACnet shall conform to BACnet Application Specific Controller (B-ASC).

Smart Actuators complying with BACnet shall conform to BACnet Smart Actuator (B-SA).

Smart Sensors complying with BACnet shall conform to BACnet Smart Sensor (B-SS).

C5.6 CCMS CONFIGURATION

The central control monitoring system shall comprise a central and satellite operator workstation, controllers, Gateway/interfacing unit, communication network for signal/data transmission among controllers and various field support hardware to form a true "Distributed Intelligence Techniques".

C5.7 CCMS OPERATOR WORKSTATION

The operator workstation shall be an operator’s terminal and comprise the followings: -

- Computer capable to meet the requirement of the CCMS software and expandability in Clause B5.1.3;
- Mouse and keyboard;
- Minimum 21" monitor;
- Alarm printer capable of handling papers;
- A3 ink/laser printer;
- UPS capable of backup for more than 1 hour of operation for the PC, monitor, printer as well as other UPS connected equipment; and
- A 16-bit/full duplex audio system c/w speakers.

All equipment, where applicable, should have obtained a Recognition Type Energy Label under the Energy Efficiency Labelling Scheme of EMSD.

C5.8 UNINTERRUPTED POWER SUPPLY

The CCMS Server, Operator Workstation and all connected peripherals shall be backed up by an Uninterrupted Power Supply (UPS) against voltage surge and spike.

In case of power failure, the UPS shall invoke alarms to all operators and supply power for more than one hour.

In the event that the unit is shut down due to prolonged power failure, CCMS shall receive input signal from the UPS to trigger the shutdown procedure automatically. All information contained within the CCMS server and workstation shall be backed up to hard disk.

Upon restoration of the power supply, the CCMS Server, Operator Workstation and connected peripherals shall automatically restart, reloading all data including time and date automatically at high speed. No operator action shall be necessary for this process.

C5.9 PORTABLE OPERATOR TERMINAL HARDWARE

Portable Operator Terminal (POT) hardware shall meet with the following requirements: -

- Weight of less than 2 kg;
- Run on rechargeable battery;
- Capable of retrieving and storing information to and from CCMS server and controllers; and
- Input method can be keyboard, touch screen, track point and/or mouse.

C5.10 DDC CONTROLLER HARDWARE

The Direct Digital Control (DDC) Controller shall include General Purposes Controller, Unitary Controller, Building Controller, Advanced Application Controller and Application Specific Controller.

The DDC Controller shall have blinking LED's to identify malfunction for speedy replacement without changing or undoing wiring.

Any Analogue/Digital Inputs and Outputs shall be relayed or optically isolated.

The DDC Controller shall be capable of complete standalone operation.

The firmware shall be upgradable through uploading of software.

The EPROM/Flash Ram containing the firmware shall be socketed for easy site replacement.

RAM and the clock shall be provided with power backup of 72 hours instant recharged capacitor or 12-hour trickle recharged batteries. The real time clock shall be automatically synchronised upon system recovery.

The DDC Controller shall be automatically reinitialised upon restart or power restoration.

The DDC Controller shall provide universal inputs (0-10VDC, 4-20 mA, 100 ohm, Dry Contact Closure, Voltage Level Transitions, and Pulse Accumulator Inputs) capable to accept information on any point in the above form with only a programming command for differentiation between the input types. No hardware changes shall be required. The Analogue Inputs shall have a resolution of 50 mV or 0.08 mA and a digital buffer for interrogation. The Analogue to Digital conversion shall have a minimum resolution of 12 bits. The pulse accumulator input shall accept pulses at a minimum of 2 per second and up to 25 MHz.

The DDC Controller shall provide universal outputs (0-10VDC or 4-20 mA), digital outputs (contact closure for momentary and maintained operation for devices) and pulse width modulation capable to give information on any point in the above form with only a programming command for differentiation between the output types. No hardware changes shall be required. Analogue outputs shall have a minimum incremental resolution of 1% of the operating range of the controlled device. Output pulse width shall be selectable between 0.1 and 3200 seconds with a minimum resolution of 0.1 seconds. All contact rating shall have a minimum of 2 amps of 240VA/C. Manual/Off/Auto switch shall be provided for each digital output for temporary override control during start-up and service. An LED shall be provided to indicate the state of each digital output.

C5.11 UNITARY CONTROLLER HARDWARE

The processor speed of Unitary Controller shall be at least 10 MHz with a minimum of 512 Kbytes RAM.

C5.12 GATEWAY/INTERFACING HARDWARE

The Gateway/Interfacing unit shall basically resemble the hardware of the DDC Controller without the necessary controller's functional components. The processor speed shall be at least 16.7 MHz with a minimum of 20 MBytes RAM. The Gateway, which also acts as a Controller, shall have the same Analogue/Digital Input and Output points.

The Gateway/Interfacing unit shall have network connection to LAN and field bus.

The amount of data records for the hardware i.e. binary points and analogy points before the memory of the DDC controller is full and start losing data is specified in the Particular Specification.

C5.13 CCMS CENTRAL DATABASE REPOSITORY

A CCMS Central Database Repository shall reside in the CCMS Server.

The database server shall use client/server technology and comply with Microsoft Open Database Connectivity (ODBC) and support ISO/IEC 9075-9:2016.

The central database repository shall maintain an image of the network configuration of every device, controllers, and router on the network. It shall be able to serve installation, maintenance, monitoring and control applications by storing the communication attributes of network variables, messages tags and other system objects.

The central database repository shall support multiple concurrent client read/write access, allowing installation and maintenance to proceed independently at any number of workstations, POTs and controllers distributed around the network.

C5.14 CCMS SOFTWARE - ACCESS CONTROL

The software shall be capable of restricting any operator commands to any point at any specified device.

There shall be a minimum of 200 System Accounts, each individually identifiable and each changeable through keyboard entry.

There shall be a minimum of 3 access levels, defined as: -

(a) User - view all applications and acknowledge alarms, but cannot modify database;

(b) Operator - all privileges except system configuration; and

(c) Administrator - all configuration privileges.

Operator inputs executed under valid system request shall be logged. This record shall contain the operator command and the time and date of input execution.

The system shall automatically terminate all operator-input capability that is previously available by valid system access after a predetermined time from the execution of the last operator's input requiring a valid system access request.

The system shall have a Graphic User Interface for adding, changing or deleting the system user accounts and assigning the access levels for administrator.

C5.15 CCMS SOFTWARE - INPUT PROCESS

The operator shall be able to select applications based upon the password clearance. Those applications not available to the operator by the password clearance shall not be displayed.

The operator shall be able to enter memory changes through a Graphic User Interface. The inputs shall be checked for accuracy by the CCMS and prompted for operator review prior to execution. Operator input assistance shall be provided whenever a command cannot be executed because of operator input errors.

Where the command requires data such as limits, set point, and time, the value shall be entered in the same engineering units as the controlled variable.

A Help Mode (prompting) shall prompt the operator through each step showing the available options.

A Direct Mode shall allow the experienced operator to input, thereby executing the command with a minimum of keystrokes.

The Edit Mode shall be used for data base generation and update. Data base modification and generation shall be done while the system is on-line.

An operator input shall not inhibit change-of-state (COS) reporting.

All edit information shall be permanently stored on central database repository.

The system shall be capable of dumping and loading selected or all data base parameters (such as seasonal limits, programmed start/stop, etc.).

C5.16 CCMS SOFTWARE - INFORMATION ACCESS

The System shall be capable of attaining point status information from any designated output device with a specified access command. The point status shall consist of a point's identification, numerical value (analogy points) and associated engineering units, and individual function labels indicating that the point is locked out/unlocked, on-line/off-line, detected failure of sensor, and is in the alarm (off-normal)/normal condition.

The output following such a command shall contain the status of a single point, or all points grouped under that command.

The output following such a command shall also contain the date and the time of command execution.

C5.17 CCMS SOFTWARE - CHANGE-OF-STATE (COS) AND REPORTING

The CCMS server shall poll the points in all CCMS-Systems and detect any change in each point's status as specified and be able to report this change-of-state to the operator.

All COS outputs shall contain a descriptor, system formatted point identity ID, point data, engineering units, and date and time.

The System shall output an alarm message, minimum 256 characters in length, for each point specified as having an alarm message or maintenance message capability in the point list. The associated message text shall be printed immediately after the standard alarm notification printout for the point.

The alarm messages shall not be restricted by word lists or any other pre-coding method. These messages shall be generated by the operator on-line, using his choice of text. Composition of any one alarm message shall not restrict the composition of any subsequent alarm message of text.

Summaries of message content and points assigned to messages shall be displayed on the operator's terminal or printed on command.

The System shall be able to assign a system application or a user defined application to any point upon a COS detection.

The System shall have the capability of directing the COS output for a point to an operator station.

Change-of-state reporting shall be provided during the output of operator requested logs and summaries.

When multiple change-of-states are received, they shall be output and or printed chronologically.

The administrator shall be able to specify whether a change-of-state requires acknowledgement or not.

The system shall inhibit the reporting of associated analogy COS upon a CCMS Sub-system shutdown. Upon restarting of the Sub-system, the analogy alarm reporting for associated points shall remain inhibited for an operator predetermined time. If any of these points are still in alarm after the time delay, they shall report as specified in the point chart.

C5.18 CCMS SOFTWARE - ALARM PROCESSING AND REPORTING

C5.18.1 Alarm Scanning

The Controllers shall continuously scan all points connected to them and update the Central Database Repository on binary changes of state and significant analogy changes. The degree of significance of an analogy change necessary to require database update shall be assigned from a table in the Central Database Repository through the operator's terminal and downloaded to the appropriate controller. The system shall compare any change of state or analogy update to establish parameters and determine if the point is in an alarm condition. Alarms shall be queued for reporting and under no circumstances shall any alarm go undetected due to multiple alarms. A response time of 3

seconds. (or as otherwise specified shall be provided for the period between alarm detection and reporting for typical and worst case situations)

C5.18.2 Alarm Levels

(a) General

Alarmable points shall be assigned to one of three levels. The levels shall be emergency, critical, and maintenance alarms. The assigning of alarm levels shall be accomplished at point definition and shall be able to be modified on a per-point basis at any time through the operator's terminal.

(b) Emergency Alarm

Emergency alarms shall be printed on the alarm printer and initiate an audible alarm. The alarm shall be muted when the alarm is acknowledged. Emergency alarms shall be reprinted at a selectable time interval until corrected. The reprinting shall not re-start the audible alarm.

(c) Critical Alarm

Critical alarms shall be reported in the same manner as emergency alarms except that the reprinting cycle shall stop on alarm acknowledgement.

(d) Maintenance Alarm

Maintenance alarms shall be printed as described below, but shall not actuate the audible alarm. They shall not be reprinted on a periodic time increment and shall not be required to be acknowledged.

(e) Returns to Normal

On return to normal, the reprinting cycle on emergency alarms shall stop. The return to normal message shall be printed for all three alarm levels.

(f) Alarm Acknowledge

Alarms shall be acknowledged by entering the acknowledge command. Points in critical or emergency alarms shall be displayed in the order of detection. An alarm shall be acknowledged when an affirmative response is received from the operator.

C5.18.3 Alarm Reporting

Each individual point shall be reported on and the condition for reporting shall be determined at the time the point is defined and shall be able to be modified any time thereafter. Conditions for reporting shall be: -

(a) No report under any circumstance;

(b) Reporting of alarms and returns to normal only;

(c) Reporting of all change of state regardless if the state is an alarm;

(d) Alarms shall be printed or displayed in English language including descriptions of the location, system and point, the status or value, and the alarm condition (for example, high, low and so forth). The report shall also include time and date; and

(e) Format of the alarm report shall be configurable through the report generator.

C5.18.4 Alarm Messages

The system shall be able to provide capability to create and assign to any point a message to be printed at the time of alarm similar to the COS alarm message.

C5.18.5 The System shall be able to assign a system application or a user defined application to any point upon an alarm detection.

C5.18.6 Alarm Recording

A minimum of the last 200 alarms or return to normal messages shall be kept in storage and displayed or printed on command. The operator shall be able to select for listing of all alarms, those alarms in a particular location, alarms in a particular system, or the alarm history of a particular point. The operator shall also be able to restrict the summary to those alarms occurring after an operator-selected time and date. The summary shall include the time and date of occurrence, the location, system and point descriptor, value or status at the time of alarm and alarm condition (for example, high, low, return to normal, etc.). The recording of alarms on specific points shall be able to be "enabled" or "disabled" on command. A summary of points disabled for alarm recording shall be provided.

C5.19 CCMS SOFTWARE - EVENT PROCESSING

The system shall provide a Wizard where the operator can define an event algorithm utilising multiple conditions, arithmetic logic, and Boolean logic for a particular event.

The algorithms shall consist of a minimum of up to five-level deep logical statement.

The functions that may be initiated if the conditions are met shall include, but not be limited to, the following: -

- Initiate a binary command;
- Reset an analogy point to a specified value;
- Reset an analogy point by a specified increment or decrement;
- Change the point access control status (for example, enable, disable, lockout, off-line);
- Initiate or cancel a trend;
- Change analogy alarm limits;
- Reassign the alarm reporting device;
- Print a report;
- Print an operator defined message; and
- Initiate a user-written programme.

The operator shall be able to display or print a summary of any event defined.

The operator shall be able to "enable" or "disable" specific event algorithms through the operator's terminal and request a summary of disabled algorithms.

C5.20 CCMS SOFTWARE - SCHEDULING

The system shall automatically initiate equipment or system commands based on a preselected time schedule for those points specified as programmable in the point list. This time schedule shall provide programme times for each day of the week (Monday through Sunday) on a per point basis.

The operator shall be capable of entering, on-line changing or deleting programme times. The programme shall have 1 minute resolution on-line. COS reporting shall not be inhibited while making on-line changes to programme parameters.

The System shall provide time schedules for each time programmable point unless specified otherwise.

Any point not responding to a programme function command shall automatically generate a change-of-state output as herein before defined.

An additional time programme day shall be provided for holidays. The System shall be provided with the capacity to handle a minimum of 366 consecutive holidays.

The start of a holiday programme shall be programmable up to 31 days in advance.

C5.21 CCMS SOFTWARE - GRAPHIC DISPLAY

The system shall provide graphic filter to import AutoCAD drawing, JPEG graphic file, Compuserve GIF graphic file, Corel Draw graphic file, Microsoft Bitmap graphic file, Microsoft PC Paintbrush graphic file, Microsoft Metafile graphic file, Adobe Photoshop graphic file, HP Graphic Language graphic file, Postscript graphic file and other common graphic formats for graphic display.

The system shall provide a series of tools which support the creation, modification, cataloguing, and subsequent display of real-time colour schematics which shall represent a process, equipment, or geographical areas.

Graphics shall be created via mouse and keyboard selection of graphic library stored symbols and system profiles. The system shall provide, in addition, the capability to create custom symbols, system profiles, floor plans, buildings, etc., and to store them in the graphic library.

The schematics shall dynamically present the current state and/or values of operator-selected field or calculated points. These status or values shall be overlaid at the appropriate location on the schematic.

When the operator calls for the colour graphics tools, a tool box shall automatically appear on the screen. The tool box shall allow the operator to select a number of commands. The commands shall include, but not be limited to, the following: -

- Master Schematic Display;
- Schematic Index Display;
- Direct Access to Schematics by Schematic Number;
- Direct Access to Schematics by Point Acronym;
- Add or Change Schematics Titles and Labels;
- Add or Modify Schematics;
- Add or modify Real-Time Data to Schematics;
- Develop New Schematic Symbols; and
- Return to the Operating System.

The operator shall be able to select desired command by the use of the terminal keyboard or mouse.

The displaying of the master schematic shall allow the operator to use a hierarchical method to display areas of increasing scale sequentially. The master schematic shall be an overview of the entire facility. The schematic shall be broken up into zones which represent logical areas for display. The operator shall be able to select a particular zone he wishes to view. The graphic files of the selected zone shall also be able to be broken up into smaller geographical areas of larger scale. The number of hierarchical tiers shall not be limited and the hierarchical selection shall be bi-directional.

Selecting the "index to schematics" command from the tool box shall cause the first page of the schematic index to appear automatically. The index shall consist of the schematic number followed by the schematic title. The operator shall be able to select previewing the schematic in a preview windows. The operator shall be able to select a schematic display, roll to the next page of the index, or exit back to the master index.

The direct access to schematics command shall allow the operator to display a schematic by entering the schematic number or by entering an acronym of a point on a schematic.

The operator shall be able to create new graphic symbols by calling using Graphical drawing tools or imported from other format graphic files.

The operator shall be able to assign real-time data to the schematics. The different types of points shall include, but not be limited to: -

- Start/Stop;
- Start/Stop/Auto;
- Off/High/Low;
- Analogue Inputs;
- Binary Inputs; and
- Calculated Points.

When the schematic is displayed, real-time data shall appear on the screen automatically. The data shall include analogy values with engineering units and binary statuses (on, off, open close, etc.). The status of the point shall be indicated by the colour code. Unless otherwise specified, colour codes shall be as follows: -

- On/Normal – Green;
- Off/Normal – Yellow;
- Disabled or Locked Out – White; and
- Alarm - flashing Red.

Real-time data shall be automatically updated on the screen at least once a minute or as stated in the Particular Specification.

The operator shall be able to issue commands by utilising the keyboard or mouse. Once a schematic is displayed, the operator shall be able to call up an individual point and a menu shall appear on the page indicating the commands available for that point. At the same time, additional information on the point shall appear on the screen. This information shall include the full English language description of the selected point. Commands shall include, but not be limited to, the following:

- Start;
- Stop;
- Auto;

- High;
- Low;
- Change Set point and Alarm Limits;
- Disable;
- Enable;
- Lockout;
- Restore;
- Alarm Message Display;
- Plot graph of totalised or averaged values for the last 24 hour; and
- Initiate Program.

Only those commands applicable to the selected point type shall be displayed in the menu. The results of the command shall be displayed on the screen when updated. Commands that are not within the operator's security range shall not be available to the operator.

The operation of the colour graphics tools shall not interfere in any way with the operation of the rest of the system.

C5.22 CCMS SOFTWARE - ERROR MESSAGES

The system shall report error messages for operator diagnostic and operation assistance.

C5.23 CCMS SOFTWARE - OPERATOR'S MESSAGES

Operators shall be able to transmit messages from one operator's terminal to POT or any future additional operator's terminal. The message shall be up to 70 characters long. The message shall be able to go to all terminals or be restricted to a specific terminal.

C5.24 CCMS SOFTWARE - REPORT GENERATOR

A wizard featuring Microsoft Word processing tools for the creation of custom building reports.

Report can be of any length and shall be able to contain any points for the CCMS Sub-system.

The report generator shall have access to Arithmetic function, Boolean logic, String function, Date time function to perform mathematical calculations inside the body of the report, control the display output of the report, or prompt the operator for additional information for the report.

C5.25 CCMS SOFTWARE - LOCKOUT SUMMARY

A lockout summary shall be provided which contains the point status of all points specified by the operator and in the locked out condition.

The system shall be capable of automatically initiating a lockout summary based on a pre-selected time schedule.
Upon operator request, the System shall output a lockout summary that shall list only those presently in the locked out condition. In addition, all logs and summaries shall display a locked out indicator for those points.

Lockout summaries shall indicate on a per-point basis the lock-unlock status of each point through the use of special characters or flags.

C5.26 CCMS SOFTWARE - ALARM SUMMARY

An alarm summary shall be provided which contains the point status of all points in the alarm condition.

The system shall be capable of automatically initiating an alarm summary based on a pre-selected time schedule.

C5.27 CCMS SOFTWARE - MESSAGE AND GRAPHIC SUMMARY

A summary shall be provided which details the contents of any and all messages within the system.

A summary shall be provided detailing the instruction listing for any and all dynamic colour graphics.

C5.28 CCMS SOFTWARE - POINT INVOLVEMENT SUMMARY

The system shall provide the capability of displaying or printing all of the routines application that a particular point is involved in. The point and display or print selection shall be input by the operator.

C5.29 CCMS SOFTWARE – SIGNAL PRIORITY

Alarm signals shall have break-in priority over all other process that may be in progress. All other processes running shall resume to normal after completion of the alarm signal. Within the alarm level, all signals shall be successive, non-interfering in operation with break-in as defined above. All other routines shall occur on a successive non-interfering basis.

C5.30 CCMS SOFTWARE - SYSTEM LOG

A system log shall be provided which contains the point status of all points associated with each CCMS Sub-system. This system shall not be limited or restricted by any hardware grouping. All systems, therefore, shall be of software groupings only.

The CCMS server shall be capable of automatically initiating system log based on a pre-selected time schedule.
Selection Log - As designated by the operator the system shall be able to printout or display full information on the following: -

- A single specified point;
- All points within a specified group;
- All points within units of a similar type;
- All points within a specified building or zone within a building; and
- All points within a CCMS Sub-system.

Status Log – the system shall be able to indicate full information on a motor or other electro-mechanical or control device in the system: -

- Point indication;
- Contact status of the point - On-Off;
- Alarm - Normal status; and
- Operating Mode.

Trend Log – the system shall be able to provide a means of producing a printout of selected points on a periodic time basis. The operator shall also be able to trend record to a hard disk for later retrieval and print out. Points shall be capable of being added or deleted and time intervals selected through the operator's terminal. Time intervals shall be able to be assigned from 1 minute to 120 minutes as a minimum. The operator shall be able to list a summary of points on trend along with the trend interval and current value or status.

C5.31 CCMS SOFTWARE - HISTORICAL PROFILES

The system shall provide the capability for the operator to build historical profiles through the operator's terminal and initiate the profile immediately, automatically at some future specified time of day and/or automatically on a time increment. Profile shall be displayed on the operator's terminal or printed as selected by the operator. Any averaged or totalised point shall be able to be assigned to a profile. Multiple profiles shall be able to be defined and multiple points assigned to a single profile. Unless otherwise indicated, minimum profile formatting shall be as follows: -

- Last 36 Months, by Month or accounting period;
- Last 30 Days, by Day;
- Last 24 Hours, by Hour;

- Last Hour, by Five Minute Intervals;
- Last Ten Minutes, by Minute;
- Hourly-to-Hour for Today;
- Day-by-Day for Current Accounting Period;
- Total/Average for Today, so far;
- Total/Average for Last Accounting Period;
- Total/Average for Year-to-Date;
- Total/Average for Hour, so far; and
- Total/Average for Last Ten Minutes Only.

The accounting period shall be defined by the operator through the operator's terminal.
The operator shall be able to obtain a summary of defined profiles on the operator's terminal or on the printer as selected by the operator.

C5.32 CCMS SOFTWARE - PREDICTOR GENERATOR

The system shall provide a wizard to extrapolate historical data. The data shall be stored in files in the following format: -

- Last 12 Months, by Month;
- Last 30 Days, by Day;
- Last 24 Hours, by Hour;
- Last Hour, by 5 Minute Increments; and
- Last 10 Minutes, by Minute.

The operator shall be able to obtain extrapolated data up to one-half the time increment of the historical data. For example, if the operator selects historical data composed of the last hour in five minute increments, it shall be possible to extrapolate the data up to one half hour. The operator shall be able to request extrapolated data for any time period within the allowable time increment.

The operator shall also be able to select the degree of curve fit up to degree 4. The data shall be displayed or printed on the printer by operator request.

The data shall include the point descriptor, current value, current time and date, historical values, extrapolated value and in the case of a graphic plot request, the ordinate, abscissa and curve. The curve shall include the historical data and the extrapolated data out to the maximum. The ordinate shall be defined as a value range and the abscissa shall be scaled in proportion to the display data.

C5.33 CCMS SOFTWARE - PREVENTIVE MAINTENANCE

C5.33.1 General

The system shall be provided where required in the Particular Specification. It shall provide a comprehensive preventive maintenance application which shall allow the operator to schedule preventive maintenance on any item regardless of whether the item is monitored by the CCMS.

C5.33.2 Maintenance Point Definition

The system shall allow the operator to define items to be scheduled for preventive maintenance through a graphic user interface. The definition process shall be interactive similar to the definition of monitored points. The operator shall be prompted to input the following data to define a maintenance point: -

- Location of the item to be maintained;
- Item description;
- Task to be performed;
- Maintenance point acronym consisting of building, item description and number, location, trade, service interval;
- Acronym of monitored point accumulating run-time; and
- Maintenance remarks.

C5.33.3 The data shall be displayed for verification before final definition. The operator shall be able to display on the operator's terminal or print on the printer the defined point data. The data shall be able to be modified or deleted through the operator's terminal at any time.

C5.33.4 The maintenance data shall be stored in the CCMS Central Database Repository.

C5.33.5 Maintenance Schedule

The system shall schedule preventive maintenance based on the last date serviced, the service interval accumulated run-time of the equipment (if applicable), and assigned priority. The system shall assign a priority level to the maintenance point when scheduled. The initial priority of the point shall be level four. On the maintenance due date the priority shall change to level three. If the point is not updated after the due date with a new last service date, within the number of days defined as the notification interval, the priority shall change to level two. If not updated by an additional notification interval the priority shall be changed to level one. If a maintenance point has an assigned run-time limit either the point shall be rescheduled on reaching the run-time limit or a choice offered to the operator to decide whether maintenance should take place immediately or on the regular calendar schedule. The option shall be selected by the operator at maintenance point definition.

C5.33.6 Service Update

The system shall provide a command to enter the new date last serviced whenever maintenance of a point is completed. The system shall request the maintenance point acronym and the date serviced. The scheduler shall then calculate a new service date.

C5.33.7 Maintenance Points Summary

The system shall provide a summary of all maintenance points within each trade category. The summary shall be able to be further restricted to building, room, service interval, equipment type, or individual point. The summary shall include all defined parameters.

C5.33.8 Maintenance Worklist

The operator shall be able to obtain on command a printed worklist for all maintenance points or for an individual trade category. The worklist shall be able to be restricted to those points due (or overdue) for maintenance or a listing of all points whether currently due or not. The operator shall also be able to restrict the list to the number of man hours available for each trade category. The available hours shall be input by the operator. The list shall include the acronym, description, current priority level, date last serviced, due date of next service, and number of days service is overdue, if any. The list shall be sorted by priority level. Points within the same area serviced by different trades, due for servicing at the same time shall be summarised separately as congruent points.

C5.34 CONTROLLER SOFTWARE PROGRAMMING STANDARD

The General Purpose Controller shall have a Rapid Application Development (RAD) tool for programming of the controller. The RAD tool shall present a high-level view of the functionality available by creating a graphical or language based programming environment into which the user may place high-level function blocks or program statements and inter-connect them to create the desired system capability. The programming tools shall take this high-level representation, and transform it into application code running on the controller.

C5.35 CONTROLLER SOFTWARE - INPUT/OUTPUT PROCESSING

The system shall provide continuous update of input and output values and conditions. All connected points shall be updated at a minimum of 1 second intervals.

Analogue to digital conversion, scaling and offset, correction of sensor non-linearity, sensing no response or failed sensors, and conversion of values to 32 bit floating point format shall be provided.

The system shall be able to assign proper engineering units and status condition identifiers to all analogy and digital input and outputs.

Proportional Integral Derivative Feedback control for Analogue Input and Output shall also be provided.

C5.36 CONTROLLER SOFTWARE - DIGITAL RUN-TIME TOTALISING

The system shall provide the capability to totalise the number of hours that any binary point in the system is in the "on" condition. The point may be a motor, etc. Every binary point shall be able to be totalised on operator assignment.

The operator shall be able to set limits associated with run-time. The system shall provide capability to have a limit with every binary point. Limits shall be set through the operator's terminal. The system shall print an alarm when the run-time of a point reaches the run-time limit. Run-time totals and limits shall be able to be reset from the operator's terminal on command.

The operator shall be able to list a summary of run-time totals and each associated limit, if any. The summary shall be of all binary points or restricted to a particular location, system or point. The summary shall also be able to be restricted to those points that have reached the run-time limit.

C5.37 CONTROLLER SOFTWARE - ANALOGUE TOTALISING/ AVERAGING

Any analogy or calculated point in the system shall be able to be assigned to the totaliser and/or average programme. The points assigned shall be totalised or averaged a minimum of once a minute. The following totals and averages for each point assigned shall be kept in storage: -

- Last 12 Months, by Month;
- Last 30 Days, by Day;
- Last 24 Hours, by Hour;
- Last Hour, by Five Minute Increment; and
- Last Ten Minutes, by Minutes.

C5.38 CONTROLLER SOFTWARE - TIME BASED CONTROL

Any commendable point in the system shall be able to be assigned a specific command by time of day and day(s) of week through the operator's terminal. The number of commands per point, per day, shall be limited only by the amount of memory available in the respective controller. The following commands shall be available: -

- Start;
- Stop;
- Auto;

- Low;
- High;
- Change set point;
- Change high limit; and
- Change low limit.

Points shall be assigned time frame in which the assigned command is valid. Points shall be able to be assigned different time frame each day of the week plus a holiday schedule. A means of deleting points from the time schedule by day(s) and time frame shall be provided.

The system shall provide a time delay between start and within an individual controller, and the time delay shall be adjustable on per-point basis.

Time schedules shall be able to be down-loaded from CCMS Central Database Repository to the respective controller for implementation. Loss of communication with the central computer shall not affect the operation of downloaded time schedules. Any changes made by a time schedule shall update the Central Database Repository.

The operator shall be able to list summaries of time schedules on the operator's terminal or printer. The summary shall indicate the point and the various time windows assigned for that particular day. The summary shall be able to be restricted to a particular location, system, system type, point type, or point as well as to those days of the week desired.

A means of scheduling holidays 1 year in advance shall be provided. The system shall recognise scheduled holidays and run the holiday schedule for that day or days. The holidays shall be defined through the operator's terminal.

A means shall be provided to extend the time of equipment operation in a particular zone. The extended time shall be initiated from the operator's terminal or from a binary input request from the zone itself. The extension shall be for 1 day only by default and the system shall automatically use the normal schedule the next day. The zone, equipment within the zone (motors, etc.) and the length of the time extension shall be defined through the operator's terminal. A summary of zone parameters and a summary of zones currently operating under extended time shall be provided.

C5.39 CONTROLLER SOFTWARE - AUTOMATIC SEQUENCE

The system shall be a high level tool to define an automatic sequence algorithm based on occurrence of specified changes in the status of any binary, analogy, or calculated point to initiate a controller's command or a user defined programme. The following changes in status shall be able to generate an automatic sequence:

- Change of binary status from 1 to 0 or 0 to 1;
- Reaching run-time limit;
- High analogy alarm;

- Low analogy alarm; and
- Analogue return to normal.

Each input point in the system shall be able to initiate an automatic sequence and any number of points shall be able to initiate the same automatic sequence.

Points initiating user defined programme shall pass a number of parameters to the user defined programme. These parameters shall include the following: -

- Acronym of the point;
- Pointer to the point in the Central Database Repository;
- Current status; and
- Last value.

Automatic sequence shall be assigned to points through the operator's terminal. Assignments shall be able to be modified at any time.

The operator shall be able to request a summary of all automatic sequences with point assignments.

C5.40 CONTROLLER SOFTWARE - GENERAL POLYNOMIAL CURVE FIT

A programme shall be provided for polynomial curve fitting of factors up to the ninth order form with operator-entered curve coordinates. The operator shall be able to enter up to 1000 pairs of coordinates. The programme shall fit the curve defined by the coordinates to a polynomial of the order requested by the operator. The resultant parameters shall be used in polynomials in user written programmes or in the calculation programme.

C5.41 ACMV SUB-SYSTEM CONTROLLER SOFTWARE – ENERGY CALCULATION

C5.41.1 Energy Calculation shall perform the following functions: -

(a) Air Flow Rate

Calculate airflow rate from air flow meter or on differential pressure in supply and return ductwork.

(b) Liquid Flow

Calculate flow rate from differential pressure across an orifice or venturi, or from an annubar sensor or Electro-magnetic flow sensor. Sensor acronym and type shall be input by the operator.

(c) Fluid Energy Rate

Based on flow and differential temperature.

(d) Zone Cooling Energy and Zone Heating Energy

Calculate total cooling or heating energy in a zone based on supply and return air dry bulb and either wet bulb or relative humidity and the volume flow rate of the space.

(e) Electrical Power

Calculate electrical power based on voltage and amperage, or on pulse meter input.

C5.41.2 The operator shall be able to determine the time increment for performing calculations on a resolution of 1 minute.

C5.41.3 Calculated points shall be defined through the operator's terminal in the same manner as for sensed points with additional information requested as required. The calculated point shall appear to the operator as any real point (with a sensor) and the operator shall be able to use the acronym of the calculated point in the same manner as a real point.

C5.42 ACMV SUB-SYSTEM CONTROLLER SOFTWARE - DUTY CYCLE

The operator shall be able to assign through the operator's terminal any controlled load in the system to the duty cycle programme and define associated parameters. Parameters shall be individually assigned per load. Parameters shall be at least as follows: -

(a) Acronym of load start/stop point;

(b) Acronym of Space temperature point that will feedback space conditions to the programme. If no space temperature point exists, this parameter shall not have to be defined;

(c) The minimum on and off times for the load required for equipment protection from damages;

(d) The beginning and ending times of the duty cycle periods. Capability of up to seven unique cycle periods per load shall be provided;

(e) The maximum allowable off time per load individually defined per period;

(f) The time resolution for cycling within each period. The resolution shall be, as a minimum, selectable on 1 minute increments between 1 and 120 minutes;

(g) The percentage "off" time within each time resolution. The percentage shall be selected, as a minimum, on 5% increments between 5 and 95%; and

(h) The commanded status of the load on a high alarm and the commanded status of the load on a low alarm of the space temperature feedback.

The operator shall be able to modify any parameter on an individual basis at any time.

Each load assigned to the duty cycle shall be cycled based on the individual parameters assigned to it. The load shall be "off" for the percentage of time defined for each time resolution, but never for more than the maximum "off" time for any one time. Space temperature alarm shall command the load to its defined status. In no case shall the load ever be put "on" or "off" for less time than the minimum "on" or "off" time defined.

The operator shall be able to display or print all the parameters associated with a load assigned to the duty cycler on request. Summaries shall be able to be requested for all points or restricted to a particular location or load by operator choice.

Loads shall be able to be locked out from or restored to the Duty Cycler by the operator at any time.

C5.43 ACMV SUB-SYSTEM CONTROLLER SOFTWARE – POWER DEMAND MONITORING/LOAD SHEDDING

The operator shall be able to assign through the operator's terminal on-line any controlled load in the system to the load shed programme and define associated parameters. Parameters shall be individually assigned per load. Parameters shall be at least as follows: -

(a) Acronym of the load start/stop point;

(b) Acronym of the space temperature point that will feedback space conditions to the programme. If no space temperature point exists, this parameter shall not have to be defined;

(c) The minimum on and off times for the load required for equipment protection from damage;

(d) The kilowatt rating of the load;

(e) The acronym of the electric meter that the load is associated with; and

(f) The priority level of the load. Providing capability of 16 priority levels.

The operator shall be able to modify any load parameter on an individual basis at any time.

The operator shall be able to display or print all of the parameters associated with a load assigned to the load shedding programme on request. Summaries shall be able to be requested for all points, or restricted to a particular location or load by operator choice.

Demand meters shall be defined by the operator through the operator's terminal. Parameters associated with demand meters are as follows: -

- Acronym of the meter;
- The demand limit to begin shedding loads;
- The demand at which loads shall begin to be restored;
- The number of priority levels associated with the meter; and
- The demand interval length.

The operator shall be able to modify any meter parameters on an individual basis at any time.

The operator shall be able to display or print all parameters associated with a particular demand meter on request.

The power demand programme shall operate on a sliding window basis. Each minute shall be considered to be in the middle of the cycle interval. The demand data shall be gathered each minute. The data from the last N minutes (where N equals one-half the interval length) shall then be used to create a best fit first-degree polynomial curve. The curve shall then be examined at what would be the end of the interval (N minutes ahead). If this value is greater than the shed limit, the power demand programme shall calculate the excess load and initiate load shedding. The shedding shall begin with the lowest priority loads and shall be governed by the point's minimum "on" time, maximum "off" time, point disability, and status of the space temperature point (if one has been defined). If the point has not satisfied (continuously) its minimum "on" time, if the maximum "off" time has already been reached, if the point is disabled, or if the space temperature point is in alarm, the load initially shall not be shed. If the power demand programme finds that it has examined all loads in all priorities and more shedding is still necessary, according to the predicted load, it shall go back to the lowest level and re-examine the points, this time overlooking the maximum "off" time criteria. If the power demand programme finds itself again not able to adequately shed enough load to prevent the predicted power peak, it shall again go through the loads in order of priority and disregard the status of space temperature points. If it is still unable to adequately reduce the load level, the operator shall be informed of the number of kilowatts still needed to be shed. Under no circumstances shall the system shed a load if the points minimum "on" time has not been reached or if the points are disabled.

If at any time after load shedding has been initiated, the system forecasts the end of cycle consumption to be below the restore limit, the power demand programme shall begin starting up the loads in order to bring the system back into the state in which it was operating before the shedding began. Load restoration shall be performed in reverse order from that observed in the shedding process. The first group of points to be restored shall consist of those whose sample area is in alarm. The second group shall be the remainder of the power demand monitored points that are currently "off" and have met their minimum "off" time. Under no circumstances shall the power demand programme restore a point that is either disabled or has not yet satisfied its minimum "off" time. The starts shall be performed in an efficient manner, each being delayed by the amount of time specified by the preceding point within the same controller. When enough load

has been restored so that the forecasted consumption is above the restore limit, the power demand programme shall discontinue the restoration process.

Points that are both duty cycled and power demand monitored may be shed by the power demand programme, but shall only be started up by the duty cycler. If the duty cycler deems it necessary to start such a point, it shall determine whether the point is off due to load shedding or normal cycling. If the point was shed and an entire power demand programme interval has not elapsed since the time of the shed, the duty cycler shall then locate and shed enough other load to allow the original point to be started, without affecting the total system power consumption.

A power demand profile shall be available to the operator upon request. The profile shall be displayed or printed by operator selection. The profile shall include the demand meter description, the time, date, demand limit, restore limit, interval length, current demand, highest demand today and time of occurrence, highest demand yesterday and time of occurrence, highest demand during current building period with time and date of occurrence, and the highest demand for the last 11 billing periods by billing period with time and date of occurrence. Billing periods shall be able to be defined by the operator through the operator's terminal.

C5.44 ACMV SUB-SYSTEM CONTROLLER SOFTWARE - OPTIMUM START TIME

The optimum start programme shall calculate the latest start time for air handling units in each operator-defined zone. The calculations shall consider occupancy time, outdoor temperature, indoor temperature, desired indoor temperature at occupancy, and the capacity of the air handlers.

The programme shall run at a reschedule interval of no more than five minutes before the start-up time for all of the optimum start zones. The programme shall examine each zone at the frequency defined for that zone.

When the programme determines that the optimum start time has been reached, it shall start all of the air handling units included in the zone definition.

At the zone occupancy time, the system shall record the actual zone temperature and any deviation from desired temperature. If any unit within the zone was found to have been off-line between the start-up time and the occupancy time, the data shall be flagged as invalid.

Optimum start zones shall be defined by the operator through the operator's terminal. Parameters shall include as a minimum the following: -

- Occupancy time for each day of the week;
- Desired temperature at occupancy;
- Acronym of outdoor temperature sensor;
- Acronym of indoor temperature sensor;
- Acronyms of air handlers to be started; and
- Acronym of the zone.

The operator shall be able to modify the parameters at any time. A summary of the zone parameters shall be available on command. The summary shall be displayed on the operator's terminal or printed on the printer. The summary shall be of all zones or an individual zone.

An optimum start performance summary shall be available to the operator on request. The summary shall be able to be displayed on the operator's terminal or printed on the printer. This summary shall detail the conditions presented to the optimum start programme as well as the results of the optimum start function for one week. The information, output by zone, shall include the difference between the target temperature and both the inside and outside air temperatures at the zone start time, the difference between the target temperature and the actual room temperature at occupancy time, and the start time measured in minutes before occupancy. Performance summaries shall be able to be requested for individual or multiple zones.

C5.45 ACMV SUB-SYSTEM CONTROLLER SOFTWARE - SUPPLY AIR RESET (SAR)

The SAR programme shall monitor status and adjust the supply air temperature set point, and shall ensure that space temperature conditions are maintained and that the space relative humidity upper limit is not exceeded. The system operator shall be able to define, modify and delete the following parameters: -

- Areas to be enabled/disabled for SAR;
- High and low rest limits; and
- Sampled time interval.

A log shall be provided detailing each parameter associated with supply air reset area.

C5.46 ACMV SUB-SYSTEM CONTROLLER SOFTWARE - CHILLED WATER OPTIMISATION (CHO)

The automation system shall include a software programme to perform chilled water reset, soft loading and chiller sequence. The CHO programme shall optimise the use of chilled water in either one of the two ways - the chilled water supply reset shall be based on either maintaining a constant return temperature or supply sufficient cooling to satisfy zone requirements.

(a) When the CHO programme is based on maintaining a constant chilled water return temperature, the software shall incrementally adjust the supply water set point to achieve the desired space conditions. It shall be possible to individually monitor and control each chilled water loop; or

(b) When the CHO programme is based on supplying sufficient cooling to satisfy zone requirements, the software shall incrementally adjust the chilled water set point upwards until at least one zone is requiring additional cooling.

The system operator shall be able to define, modify and delete the following parameters:-

- Loops to be enabled/disabled for CHO;
- High and low reset limits;
- Incremental adjustment magnitude;
- Sampled time interval; and
- Sequence patterns based on building load in kW.

A log shall be provided detailing each parameter associated with a chilled water optimisation loop.

C5.47 ACMV SUB-SYSTEM CONTROLLERS

Temperature/humidity/pressure controllers shall be of the plug-in proportional type with integrated circuits. Controllers shall be capable of having up to 3 separate outputs. Each shall have separate zero and proportional band adjustments. Indicating lamps shall be provided for each output which will vary in intensity to indicate the amount of output. Controllers shall be available with either 0 to 20V DC proportional output, two-position output, or any combination. Controller shall have internal switches for each output to change the output signal to either direct or reverse. Controller shall be available with integral electronic circuit for absolute high or low limit control.

Air contamination controllers shall be available in one or two stages. Controller shall close its contacts to initiate ventilation system when the air contamination exceeds its set point.

Chilled water reset controller shall have integral reset action to eliminate sustained system offset and be capable of receiving signals from chilled water and outdoor air sensors to control chilled water supply temperature according to an adjustable reset schedule. The controller shall have an adjustable set point for absolute high limit. Controller shall have an indicating lamp that will vary in intensity with the controller output. Controller shall be available with either proportional or 3-point floating output.

Rate/reset controller shall be of the proportional type with adjustable integral and derivative actions. The controller shall be field-adjustable for either direct or reverse action and shall be supplied with a switch to eliminate the integral and derivative functions for calibration purposes. The output of the controller shall be 0-10V DC. An indicating lamp shall be provided which will vary in intensity as the output varies.

Constant temperature controller shall be of the proportional type with integral reset action to eliminate sustained system offset. The controller shall have a switch for selecting long or short integral reset times. Controller shall have an indicating lamp that will vary in intensity with controller output.

C5.48 ACMV SUB-SYSTEM FIELD DEVICE – SMART SENSORS

The smart sensors shall include but not limit to temperature sensors, humidity sensors, absolute humidity (Dew Point) sensors, combined type humidity and temperature sensors, differential pressure sensors; air velocity sensors, contamination, flow sensors, carbon monoxide monitor/alarm sensors, carbon dioxide sensors and nitrogen dioxide sensors, etc.

Data Sharing

The smart sensors shall be able to provide values upon request.

The performance of smart sensors shall be same as specified in Clause C4.4.6 of this General Specification.

C5.49 ACMV SUB-SYSTEM FIELD DEVICE – SMART ACTUATORS

The smart actuators shall include but not limit to control valves, automatic damper as well as actuator and VAV box, etc.

Data Sharing

The smart actuators shall be able to provide values upon request and allow modification of some or all of its control objects by another device.

C5.50 ACMV SUB-SYSTEM FIELD DEVICE - CONTROL VALVES

Valves used in conjunction with a CCMS for control of chilled water shall be of the modulating type with a turn down ratio of at least 50 to 1. Valve bodies shall be cast gunmetal, brass cast iron or as otherwise indicated. Seat and inner valve material shall be brass, stainless steel or as otherwise indicated. Valve sizes 50 mm and smaller shall be screwed and supplied with union fittings. Valve sizes 65 mm and larger shall be flanged. Valves shall be of the straight-through type as required by the sequence or shown on the drawings. Valves actuator shall be equipped with manual opener to allow manual positioning of valve in the absence of control power. Valves shall have authority of at least 0.5 (50%) and shall have suitable actuator to close against full pump head. Valve body shall be rated for differential pressure stroke < 20 mm.

For valves used for fan coil unit, valve body and seat body shall be bronze. The inner valve and stem material shall be stainless steel. The valve shall be of the 2-way type have authority of 0.5 (50%), with body rated for differential pressure, actuator closed against full pump head, and stroke < 5 mm.

Valves shall otherwise comply with Sections B9 & C9 of this General Specification.

Valves schedules for all valves modulations/on-off shall be submitted detailing the maximum allowed and actual pressure drops, authority, turndown ratio, max. pressure the actuator will close against and other valve data.

C5.51 ACMV SUB-SYSTEM FIELD DEVICE - AUTOMATIC DAMPERS

Automatic operated dampers for application in conjunction with a CCMS shall have frames of a minimum of 3.5 mm galvanised steel not less than 50 mm in width and aerodynamically formed blades of not less than 1.5 mm galvanised steel sheet. Dampers shall be adequately braced to form a rigid assembly. No damper shall have blades more than 200 mm wide. Length of blades shall be not more than 1220 mm. Blades shall be secured to 13 mm diameter zinc plated axles by zinc plated bolts and nuts. All blade bearings shall be nylon or bronze. Teflon coated thrust bearings shall be provided at each end of every blade to minimise torque requirements and insure smooth operation. All blade linkage hardware shall be constructed of corrosion resistant, zinc plated steel and brass.

For all dampers incorporated as part of a CCMS controlled systems, the control damper manufacturer shall submit leakage and flow characteristics plus a size schedule for all controlled dampers.

Supply and exhaust dampers for building systems incorporating a CCMS shall be of the low leakage types and shall be generally as described below.

C5.51.1 Standard Applications

Dampers shall be of the parallel or opposed blade design (as selected by the manufacturer's application techniques) with replaceable butyl, spring stainless steel or closed cell neoprene edging. (Reference shall also be made to Section C2 of this General Specification where relevant.)

C5.51.2 Low Leakage Applications (Intake, Exhaust & Recirculation Dampers)

Dampers shall be of the parallel or opposed blade design (as selected by the manufacturer's application techniques). Frames and blades shall be of 3 mm extruded aluminium. Blades shall be of the single unit "Pin- Lock" design, 150 mm wide, with the "Pin-Lock" an integral section within the blade centre axis. Frames shall be of 100 mm extruded aluminium channel and angle, with reinforcing bosses and groove inserts for vinyl seals. Minimum size dampers shall have 50 mm by 15 mm aluminium frames. Pivot rods shall be of 13 mm diameter extruded aluminium, "Pin-Lock" design interlocking into blade section. Bearings shall be of the "Double-Sealed" type with Colcon inner bearing on rod riding in Marlon Polycarbonate outer bearing inserted in frame so that outer bearing cannot rotate (no metal-to-metal or metal-to-bearing riding surfaces). Blade linkage hardware shall be installed out of air stream. All hardware shall be of non-corrosive reinforced material or cadmium plated. Interconnecting linkage shall have separate Colcon bearing to eliminate friction in linkage. Dampers shall be of the overlap design with extruded vinyl

seals in both frames and blades for minimum air leakage. All dampers in excess of 1 m² free area shall have reinforced corners. Curves shall be based on a velocity of 10 m/s. Opposed blade dampers shall have less than 1/2 of 1% leakage at 0.5 kPa static pressure. Parallel blade dampers shall have less than 1% leakage at 0.5 kPa static pressure. Parallel blade dampers shall have less than 1% leakage at 0.5 kPa static pressure.

C5.51.3 Two-Position Control Dampers

Dampers shall be sized for minimum pressure drop at the indicated ductwork size.

C5.51.4 Modulating and Proportioning Dampers

Dampers shall be sized for an effective linear air flow control characteristic within the angle of rotation and maximum pressure drops specified.

C5.51.5 Dampers at Louvres

Dampers located immediately adjacent to intake and exhaust louvres shall be furnished in sizes as indicated because of reduced free area at louvres.

C5.51.6 Isolation Dampers

Dampers shall provide tight shut-off with negligible leakage, and shall withstand the applied pressure, velocities and turbulence in the open position.

C5.51.7 Fire and Smoke Dampers

Fire and Smoke Dampers shall meet all requirements as specified in Section C2. Dampers shall be of the all metal, low leakage construction, with metal-to-metal seals at blades and frame, designed to operate automatically as specified in Section C2.

C5.52 ACMV SUB-SYSTEM FIELD DEVICE - DAMPER ACTUATOR

Actuators shall be of the linear or rotary type for either modulating or two-positioning control. Actuators shall have a manual opener for power failure. Control voltage shall be either 24 V DC or 220 V AC as required by the application, product of clutch, micro-switch shall not be accepted.

C5.53 ACMV CCMS SUB-SYSTEM FIELD DEVICE - VAV BOX CONTROL

C5.53.1 Fan Powered

Unless otherwise specified, a stand-alone control system shall be provided to individually control each fan powered box as a pressure independent system.

C5.53.2 Electronic controls consisting of sensors, microprocessor controller and damper actuator shall be factory mounted. Room sensor shall be field mounted.

C5.53.3 Each box controller shall communicate individually with the central processing unit. Should any part or all of the central energy management system experience downtime, each and all of the boxes shall maintain room control. Set point of room control shall reside within the individual room controller.

C5.53.4 Two-way communication to the CCMS Server shall be provided for setting the following functions: -

(a) Fan operating point - resettable from Server;

(b) Cooling set point - Resettable from central processing unit;

(c) Room Temperature;

(d) Supply ductwork velocity;

(e) Minimum velocity setting - Resettable from Server;

(f) Maximum velocity setting - Resettable from Server;

(g) Night setback command - Resettable from Server; and

(h) Damper position.

C5.53.5 Non-Fan Powered

Similar to above.

C5.54 OTHER CCMS SUB-SYSTEM

The equipment listed below shall be monitored for operation conditions at intervals not to exceed 30 seconds. However, the typical equipment to be supervised and the actual requirements are indicated in the Particular Specification: -

(a) Emergency Generator : On-Off, Fail to Start, Trouble.

(b) Sprinkler Valve : Open-Closed.

(c) Fire Pumps: Unit On-Off, Fail to Start, Trouble.

(d) Domestic Water Pressure : Normal or Low.

(e) Lift or Escalator Failures

C5.55 SCHEDULE OF FUNCTION FOR CCMS

Schedule of Functions monitored and / or controlled by CCMS shall be in accordance with Code of Practice for Energy Efficiency of Building Services Installation (2018 edition) and as follows: -

C5.55.1 Chiller/Heating Water Circuit

(a) Chilled/Heating water supply temperature;

(b) Chilled/Heating water return temperature;

(c) Chilled/Heating water flow rate in each main circuit (normal hour, 24 hrs,);

(d) Chiller/Heating water circuit supply/return pressure;

(e) Building cooling demand (chilled water flow rate, supply temperature, return temperature);

(f) Energy demand of each floor (chilled water flow rate, supply temperature, return temperature);

(g) On/off control/status of all motorised on/off valves;

(h) Valve opening control/status of modulating valves;

(i) External enthalpy/dry bulb/RH; and

(j) Plant efficiency (total electrical power/total cooling load)

C5.55.2 Chiller

(a) On/off status;

(b) On/off control;

(c) Trip/fault status;

(d) Open/close status of on/off control valve;

(e) Operating current

(f) Compressor frequency;

(g) Power input;

(h) Water failure alarm;

(i) Evaporator refrigerant pressure/temperature;

(j) Condenser refrigerant pressure/temperature;

(k) Chilled water inlet/outlet temperature;

(l) Heating water inlet/outlet temperature;

(m) Condenser water flow rate;

(n) Chiller water flow rate;

(o) Chilled water set point;

(p) On/off status of each condenser fan;

(q) Trip/fault alarm of each condenser fan;

(r) Local/CCMS selector status;

(s) Cooling capacity (chilled water flow rate, supply temperature, return temperature);

(t) Heating capacity for heat recovery chillers (heating water flow rate, supply temperature, return temperature);

(u) Chiller efficiency (cooling capacity/power input);

(v) Refrigeration leakage alarms (2 stage); and

(w) All safety alarms.

C5.55.3 Cooling Tower

(a) On/off status;

(b) On/off control;

(c) Trip/fault status;

(d) Open/close status of on/off control valve;

(e) Open/close control of on/off control valve;

(f) Condensing water inlet/outlet temperature;

(g) For fan with frequency inverter: -

- Running status;
- Trip/fault status;
- Inverter speed control/status; and
- Local/CCMS status.

C5.55.4 Primary/Secondary Chilled Water Pump, Sea Water Pump, Heating Water Pump

(a) On/off status;

(b) On/off control;

(c) Trip/fault status;

(d) Supply/return pressure;

(e) flow rate;

(f) Supply/return temperature;

(g) 3-phase operating currents;

(h) Power input (kWh);

(i) Water failure alarm;

(j) Local/CCMS selector status; and

(k) For pump with frequency inverter: -

- Running status;
- Trip/fault status;
- Inverter speed control/status; and

- Local/CCMS status.

C5.55.5 Motor Control Centre (MCC)

(a) 3-phase voltage, 3-phase + N current, p.f., THD and kWh of each incoming cable;

(b) 3-phase voltage, 3-phase + N current and kWh of each outgoing cable to each chiller, chilled water pumps, heating water pumps, control circuit;

(c) ON/OFF and trip status of each incoming or outgoing or interlocking ACB; and

(d) Battery charger failure alarm.

C5.55.6 AHU, PAU

(a) Supply/return air fan on/off status;

(b) Supply/return air fan on/off control;

(c) Trip/fault status;

(d) Local/CCMS status;

(e) Filter clog alarm;

(f) Supply air temperature;

(g) Return air temperature;

(h) Ductwork static pressure for control of fan speed;

(i) Fresh air flow rate;

(j) Outdoor temperature/Enthalpy;

(k) Chilled water valve control;

(l) Chilled water valve position;

(m) Heating water valve control;

(n) Heating water valve position;

(o) Return air damper control;

(p) Return air damper position;

(q) Fresh air damper control;

(r) Fresh air damper position;

(s) Loss of air flow alarm;

(t) Fire trip alarm;

(u) Power input;

(v) CO_2 concentration for demand control; and

(w) For AHU/PAU with frequency inverter: -

- Running status;

- Trip/fault status;

- Inverter speed control/status; and
- Local/CCMS status.

C5.55.7 Ventilation fan

(a) Fan On/off status;
(b) Fan Trip/fault status;
(c) Local/CCMS status;
(d) Damper control;
(e) Damper position;
(f) Filter clog (if any);
(g) CO level (for carpark exhaust);
(h) Loss of air flow alarm;
(i) Fire trip alarm;
(j) Power input; and
(k) For fan with frequency inverter: -
- Running status;
- Trip/fault status;
- Inverter speed control/status; and
- Local/CCMS status.

C5.55.8 VAV/CAV boxes

(a) Room temperature;
(b) Room temperature set point;
(c) PIR sensor;
(d) Air flow rate;
(e) Heating water valve (if any) modulating control;
(f) Damper position control/monitoring; and
(g) Time schedule by real-time clock w/battery.

C5.55.9 FCU

(a) On/off control of each FCU;
(b) Room temperature;
(c) Room temperature set point;
(d) Chilled water valve modulating control;
(e) Heating water valve (if any) modulating control;
(f) Ductwork heater (if any) stage control;
(g) 3-position fan speed;

(h) filter clog alarm; and

(i) Power input of group of FCU (department basis).

C5.55.10 Computer Room Air Conditioner

(a) On/off control and status;

(b) Trip/fault status;

(c) Local/CCMS status;

(d) Room temperature;

(e) Room humidity;

(f) Room temperature set point;

(g) Room humidity set point;

(h) Chilled water valve modulating control/status;

(i) Heating water valve (if any) modulating control/status;

(j) Ductwork heater (if any) stage control;

(k) Humidifier (if any) on/off control/status;

(l) filter clog alarm;

(m) Loss of air flow alarm;

(n) Fire trip alarm; and

(o) Power input.

C5.55.11 Gas Tight Damper, Fire Damper, Smoke/Fire Damper

(a) Closure alarm.

C5.55.12 Chilled Water/Heating Water F&E (closed type)

(a) High level alarm;

(b) Low level alarm; and

(c) Pump fault/trip status.

C5.55.13 Water Treatment

(a) On/off status;

(b) Trip/fault status;

(c) Conductivity sensor reading/set point;

(d) Bleed off valve position/control; and

(e) Bleed off flowrate.

C5.55.14 Room Condition Monitoring for Critical Rooms, such as Computer Room, Network Room, PBX Room, etc.

(a) High temperature alarm;

(b) High humidity alarm;

(c) Room temperature; and

(d) Room humidity.

C5.55.15 Cooling Energy Monitoring

(a) Energy meters reading. The energy meters shall be located at the main tee-off at each floor for both normal and 24-hours CHW system.

SECTION C6

CENTRAL REFRIGERATION MACHINE, DIRECT EXPANSION EVAPORATOR AND HEAT REJECTION PLANT

C6.1 GENERAL

In this section, refrigeration machine may refer to chiller or heat pump.

The refrigeration plant for air conditioning purposes shall generally be of the mechanical, vapour compression type.

The refrigeration machine shall be factory assembled and tested complete "packaged" units which may have reciprocating, centrifugal, screw or scroll type compressors and as specified in the Particular Specification. The testing of the cooling/heating capacity of the refrigeration machine shall be carried out in accordance with AHRI Standard 550/590(I-P/2018), BS EN 14511-1:2018 to BS EN 14511-4:2018 or other international recognised standards.

The plant shall include any accessories necessary to ensure continuous and reliable automatic operation and remote monitoring and control. Power supply voltage-dip ride-through devices shall be provided to delay the protective shut down of refrigeration machine. Fast restart to allow the refrigerant machine to restart and going to a postlude operational mode shall be required for minimising downtime.

Each unit shall be capable of running continuously at the lowest step of cooling or heating capacity provided without any adverse effect.

Compressor and motor speeds shall not exceed 50 revolutions per second for reciprocating type and for screw type. For non-oil-free centrifugal type, the motor speed shall not exceed 50 revolutions per second and the compressor speed shall not exceed 250 revolutions per second. For oil-free centrifugal type, both motor and compressor speed shall not exceed 800 revolutions per second. Energy efficient motor to optimise the system coefficient of performance shall be required. The noise level of the refrigeration machine shall comply with the requirements as specified in the Particular Specification or the relevant environmental protection ordinances whichever is more stringent. If acoustic silencer is required in order to achieve the required noise level, it shall be factory-built and shall not de-rate the machine efficiency and capacity as specified in the Particular Specification.

For non-oil-free chiller, each compressor shall form a separate oil circuit with its own oil separator, oil filter and positive lubrication oil safety control circuit equipped to ensure proper functioning of each compressor and accessories.

All units shall comply, where applicable, with the following codes: ISO 5149:2014, ASHRAE Standard 90.1: 2016, ASHRAE Standard 189.1-2017, ANSI/ASHRAE 15-2016 and ANSI/ASHRAE 34-2016; AHRI Standard 550/590(I-P/2018) Testing and Ratings; BS EN 14511-1:2018 to BS EN 14511-4:2018 Testing and Ratings and Code of Practice for Electricity (Wiring)

Regulations and Code of Practice for Energy Efficiency of Building Services Installation.

Refrigerants adoption for refrigeration and air-conditioning system in government building projects shall comply with flammability safety classification in accordance with Clause B6.1 of this General Specification.

Characteristic curves shall show the energy consumption in kilowatts, pressure drop through the evaporator, chilled or hot water flow rates and temperatures, condenser fan speeds, etc., for each unit at 25%, 50%, 75% and 100% of full capacity.

Performance characteristics, Integrated Part Load Value (IPLV) and Non-standard Part Load Value (NPLV), to shown the performance rating of refrigeration system while operating at various capacities shall be measured in accordance with the latest edition of AHRI Standard 550/590(I-P/2018).

Sound pressure level characteristic curves shall be in dB measured in accordance with ANSI/AHRI standard 575:2017 for 25%, 50%, 75% and 100% of full capacity.

The testing of the cooling/heating capacity of the refrigeration machine shall be carried out in accordance with AHRI Standard 560:2000, BS EN 14511-1:2018 to BS EN 14511-4:2018 or other international recognised standards.

C6.2 ABSORPTION UNITS

Absorption refrigeration units if required will be fully specified in the Particular Specification. They are not commonly used for general refrigeration applications in place of conventional reciprocating, centrifugal or screw types in Hong Kong due to its less favourable energy performance.

C6.3 COLD STORAGE REFRIGERATION

Independent refrigeration circuits shall be supplied and installed at the cold storage room and shall comprise an air-cooled refrigeration system with semi-hermetic reciprocating compressor connected to each room unit cooler. The unit cooler shall be of the ceiling type, drawn through direct expansion with distributor, heat exchanger for better efficiency, and electric defrost heaters. Requirements for cold storage facilities will be fully detailed in the Particular Specification for specific application. The cold storage refrigeration shall be factory assembled and tested in accordance with BS 2502:1979, ASHRAE 62.1-2016 and requirements of the International Association for Cold Storage Construction (IACSC) and the International Association of Refrigerated Warehouses.

C6.4 COMPRESSORS, RECIPROCATING TYPE

C6.4.1 Hermetic compressors will be acceptable where either: -

(a) The entire refrigeration system is completed and charged with refrigerant at the manufacturer's works; or

(b) The condensing unit incorporating the hermetic compressor has a hold charge of refrigerant or inert gas on arrival at Site.

C6.4.2 Crankshafts or eccentric shafts of all open or semi-hermetic compressors shall be balanced and, if having an input power greater than 2.25 kW, run in replaceable bearings.

C6.4.3 Pistons greater than 50 mm diameter shall be fitted with either: -

(a) Compression and/or oil control rings; or

(b) A combination of compression rings and a piston ring specially shaped to act as an oil scraper.

C6.4.4 All open and semi-hermetic compressors having an input power in excess of 350 kW shall have: -

(a) Removable cylinder liners; and

(b) Side or end covers which will enable servicing or repair of the unit to be carried out "in-situ".

C6.4.5 Open type compressors shall have a rotary mechanical seal fitted to the driving shaft which effectively prevents leakage of refrigerant or oil. Direct coupled type units shall be driven through flexible coupling units. Compressors with an input power greater than 25.0 kW shall be of a type which will enable the shaft seal to be removed without moving compressor or motor.

C6.4.6 Open and semi-hermetic compressors of 6.0 kW input power and above shall have: -

(a) A crankshaft driven oil pump used to force feed lubricant via a strainer to the main and big end bearings and the shaft seal;

(b) An oil pressure relief valve or bleed device provided between the oil pump discharge and the crankcase;

(c) Provision for draining oil from the suction manifold into the crankcase and for venting refrigerant gas (but not oil) in the opposite direction; and

(d) A crankcase heater arranged to operate while the compressor is at rest.

C6.4.7 All types of compressor, with the exception of hermetic units or factory sealed systems, shall have the following fittings provided and connected: -

(a) Stop valves on refrigerant suction and discharge connections;

(b) Refrigerant pressure gauges, not less than 75 mm diameter and fitted with means of isolation, on suction and discharge. Gauges shall have pressure and saturation temperature scales for the refrigerant being used. Alternatively, gauges with pressure scale only may be used in conjunction with a pressure/saturation temperature conversion table fixed nearby;

(c) Refrigerant monitor to display the concentration level of refrigerant;

(d) Oil pressure gauge, not less than 75 mm diameter, with means of isolation (compressors with oil pump only);

(e) Crankcase oil level sight glass;

(f) High and low refrigerant pressure safety cut-outs with adjustable differential pressure set point. Protection settings shall be pre-set in accordance with manufacturer's recommendations;

(g) Low oil pressure safety cut-out with hand reset (compressors with oil pump only);

(h) Suction refrigerant strainer; and

(i) All instruments shall be mounted in a neat instrument panel mounted on the package unit or on a varnished teak frame mounted panel near to the machine being served and to a design acceptable to the Supervising Officer.

Alternatively, pressure measurements read from the display panel of the chiller is acceptable to the Supervising Officer

C6.4.8 All compressors having a refrigeration duty in excess of 35 kW shall have capacity control by means of cylinder unloading. Compressors shall be arranged so that they start unloaded.

The hot gas by-pass or injection system of capacity control will not be accepted.

C6.4.9 All compressors shall be mounted on vibration isolators.

C6.5 COMPRESSORS, CENTRIFUGAL TYPE

C6.5.1 For non-oil-free type centrifugal compressor, the following features shall be equipped: -

(a) Open type centrifugal compressors shall have a rotary seal fitted to the driving shaft which effectively prevents leakage of

refrigerant or oil. Open compressors shall be driven through a flexible coupling of a type which enables the shaft seal to be removed without moving the compressor or motor.

(b) The lubrication system shall be arranged with an interlock to ensure adequate oil pressure at all bearings before the compressor starts and during the "coast down" period. A replaceable or cleanable filter shall be positioned in the oil delivery pipe. Where an oil cooler is used, it shall be thermostatically controlled. A hand reset pressure or flow switch shall stop the compressor on a lubrication system failure. The oil sump shall have a thermostatically controlled electric heater which operates while the compressor is at rest.

(c) The compressor shall have automatic capacity regulation which will control at any point from 25 to 100% of full duty by inlet guide vane (for constant motor speed) or inlet guide vane and variable speed control (for variable motor speed) without inducing a surge condition. The compressor shall always start in the unloaded condition.

The hot gas by-pass or injection system of capacity control will not be accepted.

(d) The motor of a semi-hermetic compressor which is refrigerant gas cooled shall have in-built protection against inadequate cooling.

(e) The compressor shall have lubrication oil management system which will ensure appropriate and sufficient lubrication to the bearings during the compressor operation and to minimise refrigerant dilution in the oil. The lubrication oil management system shall comprise differential oil switch and oil temperature sensors to perform safety checks and manage the operation of oil pump and oil heater.

(f) The following fittings shall be provided and connected: -

(i) Refrigerant pressure gauges as Clause C6.4.7(b);

(ii) Oil pressure gauge as Clause C6.4.7(d);

(iii) Oil sump or reserve level sight glass;

(iv) Pressure safety cut-outs as Clause C6.4.7(f);
(v) Low oil pressure or flow switch with manual reset;

(vi) High oil temperature cut-out with reset;

(vii) Instrument mounting as Clause C6.4.7(i); and

(viii) Stop valve on refrigerant discharge and suction.

Alternatively, pressure measurements read from the display panel of the chiller is acceptable.

C6.5.2 For oil-free type centrifugal compressor, the following features shall be equipped.

(a) The compressor shall be of semi-hermetic type and directly driven and powered by pulse width modulating voltage supply. The motor shall be compatible with high-speed variable frequency operation that affords high speed efficiency, compactness and soft start capability. The motor shall have a thermistor integrated into the windings providing real time feedback of core motor temperature allowing accurate control of liquid motor cooling. The motor cooling shall be provided by an integrated liquid refrigerant injection system with individual refrigerant stop valves at suction and discharge line.

(b) The rotor shaft of the compressor shall be supported by oil-free magnetic bearings. The rotor shaft and the impellers of the compressor shall levitate during rotation and float on a magnetic cushion. The rotor shaft of the compressor shall be self-corrected and maintained at centred rotation during operation constantly. Bearing sensors shall be provided to ensure real-time feedback on the orbit of the shaft and to control the magnetic bearings. When the compressor is not under operation (not rotating), the rotor shall be supported by touchdown bearings made from durable materials.

(c) Adequate radial and axial magnetic bearings shall be provided to withstand the radial and axial force so created during compression.

(d) Each compressor shall have a bank of capacitors used for energy storage and filtering DC voltage fluctuations. In case of power failure, the capacitors shall continue to provide power to the bearings to keep them levitated, allowing the motor to turn into a generator and to power itself down to a stop.

(e) The compressor motor shall be a permanent magnet synchronous motor, with its completely integrated variable speed drive, which shall provide efficiency not less than 96% at full load.

The compressor motor speed shall be regulated by a variable frequency drive according to the load condition. The variable speed drive shall have suitable rating to operate the unit at any loading by proportionately increasing or decreasing the motor speed without surging.

(f) The motor shall be suitable for 380V, 3 phase, 50 Hz and 24 hours continuous operation. Otherwise, transformer shall be

provided for rated voltage and frequency by the compressor manufacturer and factory assembled. The isolation transformer shall comply with IEC 60076-1:2011 with copper primary and secondary wings. The transformer shall be designed to operate at 50Hz and capacities at least 20% higher than the required power rating of the chiller and its components. Efficiency shall be over 98% at full load and isolation class shall be minimum Class H. Each transformer shall be housed in a metal enclosure with minimum IP55 rating. Protective devices for overcurrent and earth fault shall be provided. Properly rated fast-acting fuses shall be installed in the line before each compressor's AC input terminals. UL-approved EMI/EMC filter device shall be provided on the input power line. Each compressor shall equip with built-in current limiting device to restrict the start-up current.

(g) The compressor shall be provided with Electromagnetic Interface and Electromagnetic Compatibility EMI/EMC filter upstream of the compressor power input. The EMI/EMC filter shall be approved to UL 1283 and comply BS EN 60939-2:2005 or CSA C22.2 No. 8. The rated voltage shall be up to 480V AC 50 Hz as minimum. A short, heavy, stranded conductor from the filter chassis to the main ground of the chiller unit shall be provided for grounding.

Each compressor shall provide with surge suppression device parallel to power input line for protect against electrical surge by the manufacturer. The surge protection device for chiller shall be cabled to performance under a standard test wave of 20 kV 1.5/50 μs voltage impulse and 10kA 8/20μs current impulse.

Built-in voltage dip protection device shall provide for whole system, sensing instrument and devices of the chiller unit and shall be factory assembled in compliance with IEC61000-4-11:2004/A1:2017 and IEC61000-4-34:2007+A1:2009.

Each compressor circuit shall equip with a line reactor to protect against incoming power surges and reduce harmonic distortion. The line reactor shall comply with the following requirements:

- Sustain up to at least 600V 3 Phase 50 Hz,
- UL Standard 58 with dielectric strength tests at 2.2kVAC for 1 minute,
- CSA certified and CE marked or equivalent, and
- National Electrical Manufacturers Associated Insulation Class H or better.

(h) Cabinet shall be made of galvanised steel sheet and painted to provide a high resistance to corrosion.

(i) The compressor motor speed shall be regulated by a variable frequency drive according to the load condition. The variable speed drive shall have suitable rating to operate the unit at any loading by proportionately increasing or decreasing the motor speed without surging. The capacity of the compressor shall be controlled by the variable speed drive and the inlet guide vanes at any point from 25% capacity to full capacity. The compressor shall start unload and current inrush less than 5 amps.

(j) The compressor shall equip with discharge and suction shutoff or isolating valves. Check valve shall be fitted in the discharge line of each compressor to protect against refrigerant backflow. Integrated valves to achieve the requirements are acceptable.

(k) The compressor speed shall reduce as condensing temperature and/or heat load reduces optimising energy performance through the entire range from 100% to 25% below of full load capacity of teach compressor given AHRI unloading condition.

(l) Inlet guide vanes shall be built-in to further trim the compressor capacity in conjunction with the variable speed control to optimise compressor performance at low load.

(m) The compressor shall include a microprocessor controller capable of controlling magnetic bearings, inlet guide vanes, and speed control. The controller shall be capable for providing commissioning assistance, energy outputs, operation trends, and fault codes via a high level interface.

The compressors shall be controlled by staged one-by-one by staging the compressors depending on the system load and demand. The lead compressor should start and load up close to its full capacity before the next compressor is brought on line. Prior to energising any lap compressor, the lead compressor should run in a stable condition for a few minutes and demand should be checked to see if there is still enough load to justify staging an additional compressor. The load must be high enough to ensure that the compressor(s) online plus the compressor being added shall not over shoot and/or surge. During the staging operation, the compressors shall in full vane away from surge and choke lines as far as possible. If additional compressors need to be brought online after going through the above process, the operating compressor(s) must be unloaded (slowed down) to decrease the discharge pressure and increase the suction pressure. Continue to reduce the pressure ratio to less than 2.4, then start the next compressor. Operate all energised compressors in parallel and load them equally. A staging valve shall be provided to minimise the influence of the check valve and facilitate the smooth staging process.

The service valves shall be equipped at the inlet and outlet of each compressor and condenser. Service valves shall be accessible whilst the chiller is in operation.

Compressor(s) shall be mounted directly on the base frame of the chiller. Each compressor shall be able to field isolated and removed from both refrigerant and electrical circuits for maintenance without interrupting the chiller operation. The removal of compressor shall not require any soldering, welding or cutting woks on the chiller.

(n) Each compressor shall have one refrigerant circuit including:

- 1 or 2 compressors
- Electronic expansion valve
- Evaporator
- 1 or 2 (1 for each compressor) safety valve(s) on suction side
- Manometers on evaporator and condenser
- Condenser
- Safety valve on evaporator and condenser
- Water pressure differential switch on evaporator and condenser
- Refrigerant pressure gauges (not less than 75mm diameter and fitted with means of isolation, on suction and discharge. Gauges shall have pressure and saturation temperature scales for the refrigerant being used. Alternatively, gauge with pressure scale only may be used in conjunction with a pressure/saturation temperature conversion table fixed nearby)
- Pressure safety cut-outs (high and low refrigerant pressure safety cut-outs with adjustable differential set point. Settings of the protection shall be pre-set at the manufacturer's recommended settings by the manufacturer at factory)
- Instrument mounting (all instruments shall be mounted in a neat instrument panel mounted on the package unit or on a varnished teak frame mounted panel near to the machine being served and to be design acceptable to the Supervising Officer.)
- Soft-start controller board
- EMI filter for compressor
- Silicon controlled rectifier module
- DC-link Capacitor Board
- DC/C converter

- IGBT Inverter
- Bearing Motor Compressor Controller
- Driver module
- Compressor I/O Board
- Fast acting fuse

(o) Automatic correction action to reduce unnecessary cycling shall be provided through pre-emptive control of low evaporator or high discharge pressure conditions to keep the chiller operating through abnormal transient conditions. The chiller shall allow +25% and -50% of chiller water flow rate.

(p) The oil free centrifugal chiller unit shall be factory assembled and tested in the manner completed whole unit. The testing of cooling capacity, coefficient of performance (COP) and Integrated Part Load Valve (IPLV) of the chiller unit shall be carried out in accordance with BS EN 14511-1:2018 to BS EN14511-4:2013, AHRI 550/590:2012, or other international recognised standards as considered acceptable to the Supervising Officer. The characteristic curves shall show the energy consumption in kilowatts, pressure drop through the evaporator, chilled or hot water flow rates and temperatures, condenser fan speeds, etc., for each unit at 25%, 50%, 75% and 100% of full capacity.

(q) Built-in or standalone active harmonic filter shall be assembled and tested in the factory for the whole unit.

(r) Control panel

Microprocessor-based control panel shall be provided consist of touch-screen operator interface and a unit controller. Power and control shall locate in two sections of the main panel to ensure protection against all weather conditions. The control panel shall be IP54 and internally protected with panel against possible accidental contract with electrical component IP20. The main panel shall be fitted with a main switch interlocked door.

(s) The control system shall be touched screen panel to provide clear, real time and adaptive type, and concise information on the chiller status, alarms, trends, and set point adjustment. The compressor controllers shall continue uninterrupted operation of the chiller whilst the touch screen become inoperable. The touch-screen shall display the chiller operating parameters, set point changes with multi-level password protected, and can be capable of resetting faults and alarms. The control system shall be capable to quick re-start the chiller automatically after power failure within 30 seconds. The following parameters, but not

limited, shall be displayed on the home screen and trend curves on the trend screen.

- Entering and leaving chilled water temperatures, chilled water supply temperature reset point, ambient air temperature, time, date, operating hours, system demand, chiller status, alarm, fault, etc.
- Compressor information including compressor maximum speed, actual speed, percent of full speed per compressor, compressor demand, alarm, fault, suction pressure, discharge pressure, pressure ration, power demand, actual power input, 3-phase current, voltage, surge RPM, choke RPM, liquid line temperature etc.
- Entering and leaving condenser water temperatures, Condenser saturated refrigerant pressure, condenser water in and out temperatures, refrigerant pressure and temperature, etc.
- Evaporator water in and out temperatures, refrigerant pressure and temperature, liquid line temperature, etc.
- Trending log data Including entering and leaving chilled water temperatures, ambient air temperature, actual power input, number of compressor operating, etc. all data shall have time stamp for analysis

(t) Each chiller shall have control panel, interface port, and interface cable. The control panel shall contain USB port(s) for downloading the unit's history, major parameter trends, alarms, fault history, and unit operating manual that is stored in the microprocessor. The fault history shall be displayed with date and time stamped. The alarm and fault history shall be downloadable from the chiller's USB port(s).

(u) The control panel shall connect to the Central Control and Monitoring System. The chiller manufacturer shall provide all required hand-held tools with licensed software for the interfacing to chiller and chiller control system. Access code at client level shall be provided for the proprietary monitoring software.

(v) The following fittings shall be provided and connected: -

(i) Refrigerant pressure gauges as Clause C6.4.7(b);

(ii) Pressure safety cut-outs as Clause C6.4.7(f);

(iii) Instrument mounting as Clause C6.4.7(i); and

(iv) Stop valve on refrigerant discharge and suction.

Alternatively, pressure measurements read from the display panel of the chiller is acceptable.

C6.6 COMPRESSORS, SCREW TYPE

C6.6.1 Screw compressors shall have quiet operation with oil injection lubrication system. Open compressors shall have a rotary seal fitted to the driving shaft which effectively prevents leakage of refrigerant or oil. Open compressors shall be driven through a flexible coupling of a type which enables the shaft seal to be removed without moving compressor or motor.

C6.6.2 A device shall be fitted to prevent the pressure differential across the compressor causing backward rotation at a normal or emergency stop.

C6.6.3 The lubrication system shall be arranged with an interlock to ensure adequate oil pressure at all bearings before the compressor starts. A hand reset pressure or flow switch for stopping the compressor shall be fitted at an appropriate location from the oil pump delivery pipe to the oil sump. A replaceable or thermostatically controlled oil cooler shall be used to remove the heat gained by the oil in the rotor chamber or the chiller manufacturer shall select and confirm that the lubrication oil used can be operated at a temperature higher than the rotor chamber. The oil sump shall have a thermostatically controlled electric heater which operates while the compressor is at rest.

C6.6.4 The compressor shall have automatic capacity control equipment which will control at any point between 25% and 100% of full duty via control of the compressor speed by variable speed drive or slide valve. For compressor with stepped capacity loader control, each chiller shall have capacity control steps as specified in Particular Specification and the minimum step capacity shall be maximum 25% of full load. The compressor shall be fitted with a device which ensures that it cannot start unless in the fully unloaded condition.

The hot gas by-pass or injection system of capacity control will not be accepted.

The motor of a semi-hermetic compressor which is refrigerant gas cooled shall have in-built protection against inadequate cooling.

The following fittings shall be provided and connected: -

(a) Stop valves on refrigerant discharge and suction;

(b) Refrigerant pressure gauges as Clause C6.4.7(b);

(c) Oil pressure gauge as Clause C6.4.7 (d);

(d) Oil sum or reservoir level sight glass;

(e) Pressure safety cut-outs as Clause C6.4.7(f);

(f) Low oil pressure or flow switch with manual reset;

(g) High oil temperature cut-out with manual reset; and

(h) Instrument mounting as Clause C6.4.7(i).

Alternatively, pressure measurements read form the display of the chiller is acceptable.

C6.6.5 Screw compressor for ammonia chiller

(a) The casing of screw compressor for ammonia chiller shall be designed to maximise strength to weight ratio and properly gasket to prevent leakage. The compressor shall be designed for a maximum allowable working pressure higher than 2600 kPa. Suction filter and oil filter shall be provided. A check valve shall be provided at the suction side to prevent the counter rotation due to pressure equalisation.

(b) The screw compressor unit shall be completed with a variable volume ratio pressure equalisation device to maintain the highest efficiency under all working conditions on both the evaporator load side and the condenser cooling medium side. Control shall take place in two stages high and low volume ratio. The device shall consist of one control and one regulating piston. The unit is connected to the compressor high, intermediate and low pressure systems. These pressures act on different surfaces of the control piston and according to the internal ratio between the pressures the piston will open or close the flow of high pressure oil to the regulating piston. When the high pressure oil acts on this piston, it partly closes the compressor discharge port, which produces a high volume ratio. When the high pressure oil is drained, the reverse actions apply and the regulating piston opens part of the discharge port, giving a low volume ratio.

C6.7 COMPRESSORS, SCROLL TYPE

C6.7.1 Scroll compressor shall be fully hermetic, directly driven by suction gas-cooled electric motor of speed not exceeding 50 revolutions per second. Each compressor shall be complete with internal motor protection against overloads, positive lubrication, mufflers, crankcase heater and vibration isolation.

C6.7.2 The following fittings shall be provided and connected: -

(a) Stop valves on refrigerant discharge and suction;

(b) Refrigerant pressure gauges as Clause C6.4.7(b);

(c) High and low pressure safety cut-outs as Clause C6.4.7(f);

(d) Filter dryer; and

(e) Instrument mounting as Clause C6.4.7(i).

Alternatively, pressure measurements read from the display panel of the chiller is acceptable.

C6.8 CONDENSERS, SHELL AND TUBE (FRESH COOLING WATER APPLICATION)

C6.8.1 Condensers shall be of the manually cleanable type capable of being re-tubed "in-situ".

C6.8.2 For fresh water condenser cooling applications, the condenser shall be of steel and the water boxes/end covers shall be of steel or cast iron.

C6.8.3 The tubes shall be of copper, aluminium brass, cupro-nickel, AISI 316 stainless steel or as otherwise indicated in the Particular Specification. The tube plates may be of the same alloys of the tubes or alternatively made in mild steel.

C6.8.4 Internal baffles and other fittings in either water or refrigerant circuits shall be made of material such that they will not corrode or set up corrosion or permit electro-chemical action with the liquids and/or other materials used in the condensers.

C6.8.5 End water boxes shall be designed to provide adequate space for water movement such that there is no erosion of the tube ends. The water boxes shall be epoxy resin coated internally to prevent corrosion.

C6.8.6 End box covers shall be removable, and allow easy access for cleaning the tubes. Means shall be provided for venting and draining of the water side of the unit.

C6.8.7 The design fouling factor on the water side of the tubes shall be 0.000044 m^2 $^oC/W$ for cooling tower fresh water.

C6.9 CONDENSERS, SHELL AND TUBE (SEA OR BRACKISH COOLING WATER APPLICATION)

C6.9.1 Condensers shall be of the manually cleanable type capable of being re-tubed "in-situ".

C6.9.2 For sea water or brackish water condenser cooling applications, the condenser shell shall be of steel and the water box/end covers shall be of steel or cast iron.

C6.9.3 The tubes shall be of titanium and the tube plate shall be of titanium clad steel.

C6.9.4 Ditto as Clause C6.8.4.

C6.9.5 Ditto as Clause C6.8.5 In addition the water boxes shall be provided internally with a sacrificial zinc anode at both ends.

C6.9.6 Ditto as Clause C6.8.6.

C6.9.7 Ditto as Clause C6.8.7 except that the design fouling factor shall be 0.000088 m^2 $^oC/W$.

C6.10 CONDENSERS, SHELL AND TUBE-GENERAL REQUIREMENT

C6.10.1 The positioning of the condenser shall be such that removal or maintenance of the tubes is not obstructed by walls, pipework, valves, etc.

C6.10.2 Means shall be provided for the controlled venting of non-condensable from the refrigerant side of the condenser. For machine using R-134a, this may be manually controlled.

C6.10.3 Automatic control of the condensing pressure shall be incorporated.

C6.10.4 The refrigerant and water systems shall be pressure tested at the manufacturer's work in accordance with Part H.

C6.11 CONDENSERS, AIR-COOLED

C6.11.1 Air cooled condensers shall have tube-and-fin or micro-channel configuration as approved by the Supervising Officer.

For tube-and-fin design, the condenser shall have copper tubes with:

-Aluminium fin coated with corrosion protection coating;

-Electro-tinned copper fins;

- Copper fin; or

-Type of fin as otherwise indicated in the Particular Specification.

Corrosion protection coating of the condenser fins shall be applied in factory by the chiller manufacturer. Fins with minor damage shall be combed straight. Units with extensive damage to fins will not be accepted. Provision shall be made for the purging of non-condensable from the condenser.

For micro-channel design, the condenser shall have overall aluminium structure in construction with corrosion protection coating which shall be applied in factory by the chiller manufacturer.

C6.11.2 Air cooled condensers mounted outside buildings shall have weather-proof fan motors. The units shall discharge air vertically upwards.

C6.11.3 Automatic control of the condensing pressure shall be incorporated. Modulation of air flow shall be by staging of condenser fans or by variable speed devices and the fan motor shall be selected for this application and de-energised when necessary.

C6.11.4 Fans shall comply with limitations on permitted noise levels where indicated in the Particular Specification. Fans shall have sufficient static pressure to cater for the additional acoustic treatment such as silencer, if any, in order to meet the noise requirements, set out in Section C8 and the Particular Specification.

C6.11.5 The complete condenser coil shall be pressure tested at the manufacturer's work in accordance with Part H.

C6.12 CONDENSERS, EVAPORATIVE

These are not normally used in Hong Kong. Should such equipment be required, it will be fully detailed in the Particular Specification.

C6.13 COOLING TOWER

C6.13.1 Cooling towers shall be of the type with induced or forced draught fans as indicated. The entering and leaving water temperatures and the water flow rate shall be suitable for peak heat rejection rate at the maximum ambient wet bulb temperature indicated in the Particular Specification. The performance of the cooling towers shall be certified by the Cooling Tower Institute (CTI) in accordance with CTI STD-201 RS:2017.

C6.13.2 Casings shall be of glass reinforced plastics (GRP), or as indicated. The casing shall have a treatment to minimise corrosion or decay and suitable for the casing material used. The casing and structure shall withstand extreme typhoon gale force winds from any direction. All hardware with the exception of the supporting grillage shall be fabricated of AISI 316 stainless steel. This shall include the mechanical equipment support structure, fan guards and all bolts, nuts and fasteners used in the construction of the tower.

C6.13.3 The water distribution system shall be easily cleanable to minimise collection of deposits and growth of algae which might encourage the growth of "legionella pneumophila" bacteria, and also be protected by

a strainer. Open distribution pans or troughs shall be fitted with coarse mesh grids to exclude debris.

C6.13.4 Fill shall be of the film-type and vacu-formed PVC, with louvres and drift eliminators formed as part of the fill sheets. The PVC fill shall be self-extinguishing for fire resistance with a flame spread of less than 25 per ASTM E84-18b. Fill sheets shall be individually suspended from stainless steel structural tubing, or by other suitable methods, supported by the tower columns and intermediate stainless steel panels, and shall be elevated above the floor of the cold water basin to facilitate cleaning. Air inlet faces of the tower shall be free of water splash-out, and guaranteed drift losses shall not exceed 0.005% of the design water flow. All packing shall be resistant to corrosive attack by algae, fungal growth, the type of condenser water used or the chemicals used to treat the condenser water.

C6.13.5 Where the tower is to circulate sea water, treated wastewater effluents or brackish well water, all components must be capable of withstanding the corrosive effects of these liquids. All metal parts shall be of zinc free bronze or suitable grades of stainless steel coated after installation by heavy bituminous or suitable epoxy resin coatings. Measures shall also be taken against insect and fungus attack. The packing material shall not distort in any manner which would obstruct the air or water flow.

C6.13.6 The cooling tower "basin" shall be provided in reinforced concrete to a specified standard by the Building Contract. Alternatively, if specified to be provided in the Specialist Services Contract, it shall be of AISI 316 stainless steel, GRP or as otherwise indicated. Sheet mild steel basins if specified (for fresh water applications only) shall be hot dipped galvanised after manufacture and have two coats of an approved anti-corrosion paint applied.

C6.13.7 The AISI 316 stainless steel or GRP as specified hot water distribution basin shall be equipped with metering orifice-type nozzles to deliver incoming water by gravity to the fill. Nozzles shall be easily removable and replaceable.

C6.13.8 The GRP cold water basin shall be sealed watertight, and shall include a float-operated mechanical make-up valve, a 100 mm diameter overflow connection and a depressed GRP sump completed with a debris screen made of stainless steel or other suitable corrosion resistant material. The assembly shall be hot-dip galvanised after fabrication and painted.

C6.13.9 The capacity of the basin shall be sufficient to prevent overflow when the tower is at rest. There shall be adequate and easy access for cleaning out the basin.

C6.13.10 Fans shall be of the axial type mounted to provide a vertical upwards air discharge. In circumstances where centrifugal units are required, these will be fully specified in the Particular Specification.

Particular attention must be given to the limitations on permitted noise levels, where indicated. However, where not indicated, noise levels must be restricted and must be stated with the plant offered. Plant likely to generate unacceptable noise will not be accepted.

Fan casings and impellers shall either be made of corrosion resistant material or proofed against corrosion after manufacture. Fan motors shall be totally enclosed and weatherproofed, TEFC, 1.15 service factor, mounted outside the humid interior of tower. Fan motors on induced draught units shall have suitable protective treatment as they will be mounted in the moist air stream.

Belt or gear drives shall be readily accessible but fully protected against the weather and personnel. Anti-vibration "cut-out" devices shall be provided to protect the fans drive, etc. Warning of a "cut-out" shall be wired back to the plant room in order to draw attention to any such problem.

The energy efficiency performance of cooling tower fan shall comply with Code of Practice for Energy Efficiency of Building Services Installation (2018 Edition).

C6.13.11 A bleed-off pipe with stop valve and flow regulating device shall be provided on each cooling tower. The bleed-off water shall be re-used after treatment free from bacteria for buildings flushing water connection.

C6.13.12 Where indicated, chemical treatment equipment for maintenance of cooling water quality shall be provided generally in accordance with Part F.

C6.14 EVAPORATORS, SHELL AND TUBE WATER CHILLING

C6.14.1 Evaporators shall be of the shell and tube type, capable of being re-tubed "in-situ". Where an evaporator which cannot be re-tubed "in-situ" is required, it shall have the refrigerant and water connections flanged and be mounted on the packaged unit in a manner which permits easy removal. The design fouling factor on the closed circulation water side of the tubes shall be 0.000018 m2 ^{o}C/W.

C6.14.2 For flooded type evaporator, the evaporator shell and tube plates shall be of steel and the water boxes/end covers shall be of steel or cast iron. The tubes shall be of copper, aluminium brass, cupro-nickel, AISI 316 stainless steel or as otherwise indicated in the Particular Specification. The water box/end covers shall be removable and the plant components arranged such that the space for tube removal is not obstructed.

C6.14.3 The flow of refrigerant to a multiple circuit dry expansion evaporator shall be controlled by an externally equalised thermostatic or electronic expansion valve which shall not "hunt" at any step of compressor unloading. The design of the refrigerant passages in direct expansion

type evaporators shall be such that any oil present is always carried back to the compressor at the lowest stage of capacity reduction.

C6.14.4 Where a fixed orifice expansion system is used with a semi-flooded evaporator, a durable nameplate shall be permanently fixed adjacent to the sight glass, in the refrigerant liquid pipe feeding the orifice, with wording as follows: -

"Bubbles" do not always indicate refrigerant undercharge. The A/C Contractor shall refer to special charging instructions by the manufacturer for refrigerant changing.

C6.14.5 Provision shall be made on flooded and semi-flooded evaporators for returning oil from the evaporator to the compressor. If the system uses and passes oil-rich refrigerant into the compressor suction pipe it shall not damage the compressor or cause foaming of the oil in the sump.

C6.14.6 The refrigerant and water systems shall be pressure tested at the manufacturer's works in accordance with Part H.

C6.15 EVAPORATORS, AIR COOLING

C6.15.1 Air coolers using direct expansion of primary refrigerant shall be provided with refrigerant distributors. Connections to the tubes shall be designed to ensure equal flow of refrigerant to each tube.

C6.15.2 The flow of refrigerant to a multiple circuit with dry expansion evaporator shall be controlled by an externally equalised thermostatic or electronic expansion valve which shall not "hunt" at any step of compressor unloading.

C6.15.3 The design of the refrigerant passages in direct expansion type evaporation shall ensure that the return (or suction) connections are arranged such that any oil present is always carried back to the compressor even at the lowest stage of capacity reduction.

C6.16 PLATE TYPE HEAT EXCHANGER

C6.16.1 Heat exchangers shall consist of most energy efficient metal plates pressed into a corrugated pattern and securely clamped between nitrile rubber gaskets by the pressure end plates of the mild steel framework. Plates shall be stainless steel 316 for fresh water or titanium for sea/well water. The plates shall be suspended from the top bar of the framework and located on the bottom guide bar. No part of the mild steel framework shall be in contact with the heat transfer fluids.

C6.16.2 Heat transfer plates shall be clamped by lateral bolts between a stationary frame plate and a movable pressure plate such that opening of the plate heat exchangers can be done without removing any connecting pipes.

C6.16.3 Heat exchanger shall be designed to give a high heat transfer efficiency to achieve close approach temperatures as low as 3ºC.

C6.16.4 Heat exchanger frame shall be of mild steel and shall be suitable for bolting to a horizontal deck. The frames shall be arranged such that when the tie bars are loosened, full access to all plate surfaces is provided for cleaning and maintenance. The entire framework and all parts of the units shall be factory treated to prevent corrosion such that the heat exchanger shall be capable of corrosive environment. All holding down bolts shall be of high tensile carbon steel with plastic tube protection. Each shall be equipped with bearing boxes and a locking washer enables the bolts to be opened from the fixed cover. No welded parts are allowed.

C6.16.5 Inlet and outlet ports shall be metal lined constructed on the fixed frame plate only. Metal lining shall be of the same material as the plates.

C6.16.6 The heat transfer plates for fresh water application shall be of stainless steel and in a corrugated pattern with thickness of 0.6 mm minimum, and pressing depth of about 3.20 mm with pressure rating a minimum of 1000 kPa or other rating to suit system design as specified. Maximum plate pack length shall not exceed 45% of the total framework length. Double gaskets shall be provided around the bypass port on each plate, with a drain hole between the gaskets to facilitate leak detection.

C6.16.7 Distribution area shall be with regular pattern and the flow pattern shall be "counter flow". Gasket shall be on every plate to eliminate inter leakage between media.

C6.16.8 The heat exchanger units shall be pressure tested in the factory prior to delivery. The plate heat exchanger shall have a working pressure not less than 1000 kPa and shall be tested with a minimum pressure of 1.5 times the working pressure for 24 hours suitable to the system design application as specified. The manufacturer shall guarantee the heat exchanger free from leakage for 5 years.

C6.16.9 The heat exchanger for chilled or hot water application shall be properly insulated with optimum efficiency and robust insulation against heat loss. The insulation panels shall be of the double skin aluminium/stainless steel cladded type with handles suitable for easy removable for plates access for inspection and maintenance. An insulated stainless steel drip tray shall also be equipped for chilled water application.

C6.17 LIQUID RECEIVERS (REFRIGERANT RECOVERY UNIT)

C6.17.1 A separate refrigerant recovery unit (RRU) shall be provided for chiller units. Combination of condenser / receiver is not acceptable. At least one RRU shall be provided for the largest size of chiller unit for each

chiller plant room. The RRU shall be complete with a compressor, condenser, liquid/gas transfer valve, pressure relief valve and all other necessary fittings and accessories.

C6.17.2 The RRU shall have a capacity of not less than 1.2 times the refrigerant charge of the largest chiller unit. A factory test certificate for the pressure vessel safety operation issued by the manufacturer shall be provided.

C6.18 PRESSURE TESTING

C6.18.1 The units previously mentioned shall have a strength and leakage pressure test after manufacture. The pressure applied on the refrigerant side shall be as indicated in the table in Part H.

C6.18.2 A pressure test equal to the low side test pressure quoted in Clause C6.18.1 mentioned above for the refrigerant being used, shall be applied to the field-erected refrigerant system after all piping has been fitted. This test shall be in addition to the pressure test on each unit at completion of manufacture.

C6.18.3 Pressure tests for condenser water circuits from and to cooling towers or other sources shall be in accordance with Part H of this General Specification.

C6.19 PUMP DOWN OF SYSTEM

C6.19.1 The control system for reciprocating compressors in direct expansion systems shall be so arranged that, on the compressor stop circuit being actuated, the compressor will automatically pump down the system before it stops running. The following features shall therefore be incorporated: -

(a) A discharge line check valve; and

(b) The low pressure cut-out shall be set at the pressure corresponding to the following temperatures for air conditioning applications: -

Table C6.19.1(b) Cut In/Out Temperature

	Cut out	Cut in
R134a	-15°C	-3.9°C
R407c	-2°C	0.2°C
Ammonia	-2.2°C	0.2°C

C6.19.2 Pump down will not be required: -

(a) Where the compressor is stopped by a safety cut-out when its driving power will be immediately terminated; or

(b) On fully manually operated systems.

C6.20 REFRIGERANT PIPEWORK

C6.20.1 Pipework for refrigerant systems shall be of copper or steel, which shall be internally degreased and cleaned.

C6.20.2 For all chloro-fluoro-methane or ethane compounds: -

(a) All pipes from up to 108 mm OD shall be of copper complying with BS EN 12735-1:2016and BS EN 12735-2:2016 or another international recognised standard.

(b) All pipes over 108 mm OD shall be of black extra heavy seamless steel pipe to BS EN 10216-1:2013 grade 1.0255 or another international recognised standard.

(c) On fully packaged refrigeration machine, pipework other than copper, i.e. steel fitted and tested in the factory as standard production for the units, will be acceptable subject to notification and written approval by the Supervising Officer.

C6.20.3 For ammonia system: -

Steel - whatever size is technically necessary or as specified in the Particular Specification.

All materials used in the refrigerant circuit shall be suitable for use in the presence of ammonia refrigerant or lubricating oil, or a combination of both, and comply with ANSI/IIAR Standard 2-2014 ANSI / ASME Code B31.5:2016 or 2017 ASME Boiler and Pressure Vessel Code , and meet with system pressure-temperature requirement so that they will not corrode or cause corrosion when in contact with the fluids conveyed.

C6.20.4 Size of Refrigerant Piping: -

Refrigerant piping shall be sized to avoid excessive pressure drop of the fluids or gases they carry. The recommendations of the CIBSE and/or ASHRAE /or other reputable/factory standards approved by the Supervising Officer on the sizing of refrigerant piping shall be complied with.

C6.21 REFRIGERATION PLANT ACCESSORIES AND CONTROLS

C6.21.1 Every refrigeration system shall be protected by a pressure relief device unless it is so constructed that pressure due to fire conditions would be safely relieved. The equipment provided shall comply with ANSI/ASHRAE 15-2016 and ANSI/ASHRAE 34-2016 or BS EN 378-2:2016 as appropriate and the outlet piped to discharge outside the building.

C6.21.2 Systems using a thermostatic expansion valve shall have the following items preceding it in the refrigerant liquid pipe: -

- A solenoid valve;
- A sight glass;
- A refrigerant drier (replaceable);
- A refrigerant strainer; and
- A capped refrigerant charging valve.

C6.21.3 An evaporator pressure regulating valve where fitted shall be protected by a strainer, and an evaporator pressure gauge shall be provided, up-stream of the valve, fitted with means of isolation.

C6.21.4 Units having a direct expansion evaporator at a higher level than the compressor shall operate on a pump down cycle. On water chilling installation, the chilled water pump shall be kept running during this process.

C6.21.5 Refrigerant stop valves which incorporate a spindle gland shall be of the back seat type. The spindle gland shall be serviceable with the valve "in-situ".

C6.21.6 A flow switch shall be provided in the chilled water pipeline to each shell and tube evaporator to prevent the compressor starting or continuing to run if the water flow is below the minimum stipulated by the evaporator manufacturer.

C6.21.7 A low temperature thermostat with alarm and manual reset shall be provided for each shell and tube evaporator to stop the compressor(s) if the chilled water flow temperature falls below +3 ^{o}C. For other settings as recommended by the manufacturer shall be submitted for approval.

C6.21.8 Full flow driers with strainers shall be supplied for all refrigerant liquid lines and shall be completed with isolating valves and bypass arrangements. Driers shall be of the renewable cartridge type.

A suitable sight glass shall be provided, either built-in to the drier, or as a separate component installed adjacent to the drier to show through a suitable glass eye whether the moisture content of the refrigerant is within permissible limits.

C6.21.9 Strainers shall be provided before all expansion valves, float valves, solenoid valves, etc. Except where the expansion valve is fitted just downstream of a solenoid valve, only one strainer needs to be fitted.

C6.21.10 Full flow strainers of the cleanable and renewable type shall be fitted at the suction of all compressors.

All strainers and driers shall be easily and readily accessible for cleaning or replacement of cartridges.

C6.21.11 Full flow oil filters shall be incorporated in all force-feed lubricating system.

C6.21.12 Where oil separation equipment is to be provided, it shall be completed with traps, strainers, floats, receivers and gauges.

The oil separator shall be a fabricated steel shell with dished steel endplates and ample and accessible cleaning handholes. The oil return control floats shall not be fitted inside the shell. No pipes shall be fitted inside the shell. No pipes shall be connected through the lids of cleaning or access holes. Adequate provision shall be made for purifying and flushing the system.

C6.21.13 Energy meters shall be provided for chilled (or hot) water system for energy audit purposes. The specification/requirement of the energy meters shall be as described in Section C10.

C6.22 ROOF MOUNTED PACKAGED WATER CHILLER / HEAT PUMP PLANTS

C6.22.1 The Units shall include the number and type of compressors indicated in the Particular Specification, with air cooled condenser coils, condenser fans and motors, shell and tube direct expansion evaporator water chiller/heat pump.

C6.22.2 Expansion valves controls and safety devices shall all be housed in a substantial weatherproofed casing.

C6.22.3 Where specified in the Particular Specification, units shall have full noise suppression treatment with outlet silencers generally as covered in Sections B8 and C8.

C6.22.4 Unitary package chiller/ heat pump units shall conform to and shall have rated and tested capacity to the requirements of AHRI 210/240:2017 or other equal Internationally Recognised Standard accepted by the Supervising Officer.

C6.23 HEAT RECOVERY CHILLER

C6.23.1 Heat recovery chiller unit shall be completed with a heat recovery condenser and condensing unit, three-way valve, receivers, etc. The exact configuration of these devices shall follow the details recommended by the chiller manufacturer. The heat which is normally rejected to the air-cooled or water-cooled condenser shall be reclaimed and made available through the heat recovery condenser and other provisions as specified, for a variety of uses aiming to optimise the building energy performance.

C6.23.2 Waste heat shall be reclaimed by adding a heat recovery condenser, refrigerant control valve, liquid line receiver and controls to the standard air-cooled or water-cooled chiller, making it as a heat recovery chiller. The heat recovery chiller shall have only one refrigerant control valve which makes its operation reliable, simple to control and easy to maintain.

C6.23.3 During operation in the cooling mode, the hot refrigerant gas shall be condensed only in the normal air-cooled or water-cooled condenser, the system cooling load heat and the heat of compression shall be rejected to the atmosphere via this condenser. The system shall sub-cool the liquid refrigerant which shall increase the capacity of the machine by up to 12 percent without increasing power consumption. The condenser fans shall operate in a cycle according to the outside temperature. Suitable air dampers/head pressure control devices shall be equipped to maximise the machine heating or cooling output efficiency.

C6.23.4 Under heat recovery mode, the refrigerant gas shall condense in the shell-and-tube or plate type heat recovery condenser. The high pressure and temperature refrigerant gas shall flow into the heat recovery condenser and the heat released from the cooling load and heat of compression shall be rejected to the heating water circuit.

C6.23.5 The flow modulation device shall control refrigerant flow or condensing water flow through the heat recovery unit and normal air-cooled or water-cooled condensers. It shall be controlled by the system heating requirements. The unit shall operate with 0 to 100 percent heat recovery, so that part of the heat shall be rejected and part recovered for system water heating or room relative humidity (RH) control application.

C6.23.6 The heat reclaim condenser shell shall be of carbon steel. For shell and tube type design, water boxes at a minimum of 1050 kPa or to suit system design shall be provided which shall have steel pipe stub connections grooved for couplings.

C6.23.7 The heat exchanger tubes shall be of seamless copper tubing rolled into tube header sheets. Other energy efficient heat exchange equipment/devices may be accepted subject to the approval of the Supervising Officer.

C6.24 HEAT PUMP

C6.24.1 Heat pump shall be of the air-to-water or water-to-water type as specified in the Particular Specification.

C6.24.2 Air-to-water heat pump shall be operating in reverse refrigeration cycle whilst water-to-water heat pump makes use of the building cooling load as a heat source for water heating. Each heat pump shall include compressor, compressor motor, evaporator, condenser, lubrication system, capacity control, solid state control centre and indication accessories. Relevant content of Section C6 concerning various components of a normal packaged chiller shall also be applied where applicable.

C6.24.3 The refrigerant circuit shall be leak tested at factory, evacuated and pumped up with a holding charge of refrigerant under positive pressure prior to the delivery of the unit. If this holding charge is lost on arrival, the system will not be accepted.

C6.24.4 The unit shall consist of factory assembled, charged, wired, insulated and tested system using an environmental friendly refrigerant.

C6.24.5 The capacity control of the heat pump shall be based on the leaving hot water temperature sensing in order to maintain constant leaving water temperature.

C6.24.6 A water flow switch shall be installed in the water piping line to prevent the unit from starting when water is not circulation through the evaporator.

C6.25 ENERGY EFFICIENCY PERFORMANCE

The refrigeration plant shall be accepted with a minimum coefficient of performance as specified in the following Tables and comply with the requirements stipulated in Code of Practice for Energy Efficiency of Building Services Installation. The values of minimum coefficient of performance shall comply with Code of Practice for Energy Efficiency of Building Services Installation (2018 edition).

For heat pump and heat recovery equipment/applications, the equipment/system coefficient of performance shall comply with Code of Practice for Energy Efficiency of building Services Installation (2018 edition).

Details of energy efficiency assessments shall be submitted before the equipment is accepted. Factory test and field test reports shall be provided to substantiate the equipment design and performance.

Ample time approved by the Supervising Officer shall be allowed for the submission in order to meet with the installation programme.

C6.26 TOTAL ENERGY HEAT PUMP

C6.26.1 The total energy heat pump unit shall serve as a normal chiller unit and hot water plant, and capable to produce chilled water and hot water to meet both the cooling and heating demand simultaneously for the air-conditioning system. The unit shall be either a proprietary product, or specially developed and manufactured by a manufacturer which have sound experiences in developing such system /equipment in the past. The A/C Contractor shall submit all relevant information, including but not limited to, the schematic design, components sizing, components selections, technical calculations, materials uses, operation features, system performances under full load and part load conditions, etc. to the Supervising Officer for approval prior to ordering.

C6.26.2 Each unit shall be factory built, assembled, piped, wired, refrigerant charged and fully tested before shipment as complete sets supplied from a single manufacturer. The only field connections required on site shall comprise only external control circuitry, system water piping and electrical power supply. Facilities for connection and working under the control of the CCMS system shall be provided.

C6.26.3 The total energy heat pump shall be manufactured to cater for using ambient air as media for residual cooling /heating energy dissipation and suitable for operating with ambient temperature down to 4°C and higher than 40°C.

C6.26.4 The total energy heat pump shall be designed to cool chilled water from 12.5°C to 7°C and to heat hot water from minimum 40°C to 45°C simultaneously with dual setting for both chilled and hot water temperature available in order to suit the varying cooling and heating demand. The minimum chilled water-out temperature shall be 5°C at cooling mode and the maximum hot water-out temperature shall be 60°C at heating mode.

C6.26.5 The total energy heat pump unit shall consist of compressors, air-cooled heat exchanger (condenser coil), two nos. of water-side heat exchangers for chilled water and hot water respectively, necessary numbers of electronic expansion valves and 3-way electronic refrigerant flow control valves and all necessary accessories.

C6.26.6 Depending on the demand and priority on cooling and heating loads, the total energy heat pump shall be switched among the following five operating modes freely during system operation by varying the refrigerant flow path: -

(a) Heating Mode

The refrigeration circuit shall be arranged to operate as an air-cooled heat pump when there is no cooling requirement. The air-cooled heat exchanger (acting as evaporator) shall absorb heat energy from the ambient air. The system heat energy shall be recovered by the heat exchanger at hot-water side so as to

provide hot water source for the connected hot water system. In this mode, the heat exchanger at chilled-water side is isolated from the refrigerant circuit.

(b) Heat Recovery Mode

The refrigerant circuit shall be arranged to provide chilled water as well as uncontrolled hot water simultaneously. The heat exchanger at chilled water side (acting as evaporator) absorbs building heat energy (to provide cooling to the building) and the system heat energy shall be recovered by the heat exchanger at hot-water side (act as heat recovery condenser) so as to provide uncontrolled hot water for heating purposes. In this mode, the air-cooled heat exchanger is isolated from the refrigerant circuit.

(c) Cooling Mode

The refrigerant circuit shall be arranged to operate as a normal air-cooled package chiller when there is no heating requirement. The refrigeration circuit shall be arranged to absorb the building's heat energy (i.e. to provide cooling to the building) by the heat exchanger at chilled-water side (acting as evaporator) and to reject the heat energy by the air-cooled heat exchanger (act as condenser) to the atmosphere through the refrigeration process.

(d) High Cooling and Small Heating Mode

The refrigeration circuit shall be arranged to operate such that the heat exchanger at chilled-water side (acting as evaporator) absorbs the building's heat energy (i.e. to provide cooling to building). The system heat energy shall be partially recovered by the heat exchanger at hot-water side to provide hot water source for the connected hot water system. The surplus heat energy shall be rejected to the atmosphere via the air-cooled heat exchanger (acting as condenser) at the same time.

(e) Small Cooling and High Heating Mode

The refrigeration circuit shall be arranged to operate such that the heat exchanger at chilled-water side (acting as evaporator) absorbs the building's heat energy (i.e. provide cooling to the building) and, at the same time, the air-cooled heat exchanger absorbs the heat energy from the ambient air in order to meet the total heat load. The system heat energy shall be recovered by the heat exchanger at hot-water side to provide the required heating load.

The operation of the 3-way electronic valves and other refrigerant flow control valves shall be arranged to achieve the above five operating modes.

C6.27 AUTOMATIC CONDENSER TUBE CLEANING SYSTEM

C6.27.1 Automatic condenser tube cleaning system shall be provided for each water-cooled condenser of the refrigeration machine as specified and indicated on the drawings and particular specification. The system shall comprise of rubber sponge balls, ball injector, ball strainer/collector, programmable control panel, inspection chamber, control valves, associated pipework and all necessary accessories to form a complete fully automatic condenser tube cleaning system. The A/C Contractor shall ensure the refrigeration plant arrangement shall accommodate the automatic condenser tube cleaning system installation.

C6.27.2 The sponge balls shall be injected to into the condenser inlet pipe by the ball injector. The balls shall then flow through the condenser tubes in a random distribution manner within the stream to wipe away any fouling deposits that are present so as to maintain at or near the peak design heat transfer coefficient of the condenser. After passing through the condenser tubes, the sponge balls will be collected at the ball collector and ready to be injected to the condenser in the next cleaning cycle. The cleaning cycle shall be programmable from 30 to 120 minutes. The system shall be operated on-line and shall not disrupt the normal operation of the refrigeration machine.

C6.27.3 The sponge balls shall have a certain oversize compared to the inner condenser tube diameter. The density of the sponge balls shall be equivalent to the density of the condenser water and the material, size and quantity of the balls shall be selected as per manufacturer's recommendation and shall be approved by the Supervising Officer.

C6.27.4 The control system shall be connected to the CCMS via appropriate interface to monitor the operation of the system and to make adjustment to the parameters.

C6.28 SOLAR HEATING SYSTEM

C6.28.1 General

The Solar Heating system shall include solar collector system, water pipework system, automatic controls, water treatment system, brackets/support, access walkway system, thermal insulation, hot water storage calorifier, water circulation pumps, valves and accessories. All the components and parts shall be compatible to each other to provide best performance.

Individual components forming part of the solar heating system shall, in addition to this section, comply with the appropriate sections contained elsewhere in this General Specification. The A/C Contractor shall submit information on the make and type of each unit together with the test certificate of solar collector panels complying with BS EN

ISO 9806:2017or approved equivalent for the Supervising Officer's approval.

C6.28.2 Overall Performance

The solar heating system shall include solar collector panels, hot water storage calorifier, circulation pumps, pipework & valves, accessories, water treatment plant, automatic controls and accessories, etc. The solar heating system shall be capable to withstand potable water with temperature up to 99^{o}C during stagnation. Solar collector panel shall have a minimum efficiency as specified in the Clause C6.28.3.

C6.28.3 Construction of Solar Collector

Solar collector shall be either flat plate design or evacuated-tube design.

(a) Flat Plate Type Solar Collector Panel:

The solar collector panel shall be of flat plate design. Solar collector panels shall be connected in series and/or parallel and installed on appropriate supporting framework with sufficient maintenance access facilities as recommended by the manufacturer.

A copper tube matrix that contains potable water shall be mechanically bonded to a 0.8 mm thick aluminium absorber plate or 0.2 mm thick copper absorber plate and sealed with high transference thermal paste or soldered copper to copper. The absorber plate shall be coated in black carbon surface or approved equivalent offering up to 35% absorption. The minimum solar absorptance at normal incidence shall be 0.93 where the emittance of coating at normal incidence shall ±0.03. The solar collector panel system shall be designed and manufactured to BS EN 12975-1:2006+A1:2010 & BS EN ISO 9806:2017, BS EN 12976-1:2017 & BS EN 12976-2:2017, AS/NZS 2712:2007 Amd 3:2014 or approved equivalent.

Each collector shall have an insulated casing that houses a copper tube matrix for transporting the collector fluid. A copper or aluminium absorber plate with appropriate coating shall be mechanically bonded or soldered to the headers. The top of the collector shall be glazed with a glass cover to prevent heat losses and protect from the adverse weather conditions.

Tempered solar glass glazing shall be used to seal the top of the collector and a high strength black casing protecting all the components. The glazing shall be minimum 3 mm thick, with glazing transmittance of 0.88 minimum and with appropriate strength to withstand high wind load and hail. The casing shall be constructed of metal with oven baked paint finish for protection against the weather and with high outdoor durability. Panel efficiency shall be minimum 65% at 30K temperature

difference between average fluid temperature and ambient temperature with solar irradiation 1000W/m^2 based on aperture area.

Thermal insulation of appropriate thickness shall be provided under and around the side of the absorber plate, to prevent solar panel heat loss.

The solar collector system shall be designed for either potable water or treated water to temperature up to 99 ^oC under normal operating conditions. Solar collector panels shall be mounted at a tilt angle to the horizontal to achieve maximum solar gain for the application. Each solar collector panel shall produce minimum 650 W per sq. metre based on 1000 W per sq. metre irradiation and difference of average fluid temperature and ambient temperature (i.e. tm-ta = 30K) of 30K without wind. The solar collector panel shall give a yield of 2.3 kWh per sq. metre of solar collector aperture area per day calculated on a yearly average for the region.

(b) Solar Evacuated-Tube Collector Panel:

Solar Evacuated-Tube Collector Panel should consist of single tubes which are connected to a header pipe. All evacuated collector tubes shall either have tubes with flow of heat transfer fluid through the absorber or tubes with heat transfer between the absorber and heat transfer fluid of the collector cycle using the heat-pipe principle. The absorber surface should be contained inside a glass tube. The glass tube enclosing the absorber surface and heat transfer tubes shall be evacuated and permanently sealed off. The glass tube should be tempered glass and designed to withstand the pressure difference between the atmospheric pressure and the internal vacuum. The absorber of the collector should be coated with appropriate selective coating.

Solar collector panels shall be connected in series and/or parallel and installed on appropriate supporting framework with sufficient maintenance access facilities as recommended by the manufacturer. Each solar collector panel shall produce minimum 700 W per sq. metre, i.e. 70% efficiency at 30K temperature different between average fluid temperature and ambient temperature with solar irradiation = 1000 W/m^2 based on aperture area. The transmittance of glass tube shall be minimum 0.91 and solar absorptivity of absorber shall be minimum 0.93. The emissivity (at 80°C) of absorber material shall not exceed 0.06. The solar collector panel shall give a yield of 2.4 kWh per sq. metre of solar collector aperture area per day calculated on a yearly average for the region.
The solar collector panel shall have an impact resistance and cyclone resistant as approved by the Supervising Officer.

C6.28.4 Thermal Storage Hot Water Calorifier

The thermal storage hot water calorifier (calorifier) shall be used to store up the thermal energy delivered by the solar panels. The calorifier could be provided either with electric or gas fired auxiliary heater or hooked up with heat pump system. The calorifier shall be constructed of mild steel with appropriate coating or stainless steel. The venting requirements of the calorifier shall comply with the requirements of local Water Supplies Regulations. The calorifier shall be fitted with closed circuit flow and return lines capable of receiving thermal energy from solar collectors hot water flow. The calorifier (unless open vented type) shall be fitted with pressure and temperature relief valve and in accordance with local regulations. Calorifier with immersed auxiliary heaters shall be fitted with a manual reset over temperature thermostat that is adjustable between 40-99 ^{o}C. The calorifier shall be completed with insulation of minimum 50 mm thickness mineral wool insulation or appropriate insulation as recommended by the manufacturer. The calorifier shall be completed with temperature gauge, temperature sensors, drain pipe, heating circuit in/outlet, utility circuit in/outlet, copper coil and etc.

The calorifier shall be factory designed & manufactured to comply with PD 5500:2018+A1:2018 or AS 3498:2009 or approved equivalent. Copper coil shall be designed with a maximum pressure of 10 Bars and a temperature of 200 ^{o}C. Temperature sensor shall be provided for electronic controller of the solar collector system for automatic control. Manufacturer working and test pressure certificate shall be submitted for approval.

C6.28.5 Circulation Pump

Circulation pump shall be of canned rotor type, i.e. pump and motor for an integral unit without shaft seal and with only 2 gaskets for sealing. The bearings are lubricated by the pumped fluids. The materials of rotor, shaft and casing shall comply with Section C13-Water Handling Equipment of the A/C General Specification.

C6.28.6 Automatic Control and Monitoring

The solar collector system shall be provided with a temperature monitoring system built into a differential controller, which will give temperature at different points in the circuit. Moreover, the solar collector system shall be provided with measurement and measurement devices suitable for remote monitoring and control by DDC controller/Programmable Logic Controller to

(a) Monitor operating status, alarm, flowrate, temperature and energy level; and
(b) Control the operating set points of the system.

The solar heating system shall be provided with a data logging system for automatic generation of the following information: -

(a) Monthly mean in-plane solar irradiation (MJ/sq.m/month);

(b) Monthly mean solar energy absorbed by system (MJ/month); and

(c) Monthly electrical energy consumption of circulating pump (kWh/month).

The system shall also be provided with a data logging system to record the temperature and energy performance of the system. Interfacing devices shall also be provided for connection to the CCMS system.

SECTION C7

ELECTRIC MOTORS AND ELECTRICAL EQUIPMENT

C7.1 LOW VOLTAGE - GENERAL

The mains for the low voltage electrical motors and equipment shall be suitable for a supply as specified in Clause A3.12.

Unless otherwise indicated, all electrical equipment shall be tropicalised and suitable for use in service conditions as specified in Clause A3.11. Equipment shall be protected against atmospheric corrosion, including that caused by salt-laden air. Materials used shall not be susceptible to mould growth or attack by vermin.

Cables for power circuits shall not be less than 2.5 mm^2 copper conductors and cables for control circuit shall not be less than 1.5 mm^2 copper conductors.

C7.2 LOW VOLTAGE - WIRING FOR REFRIGERATED SITUATIONS

All electric wiring to be installed into refrigerated situations where the temperature is to be maintained at or below 0 ^oC shall be either MICS or elastomeric cables that are applicable for the designed operating environment.

C7.3 LOW VOLTAGE - ELECTRIC EQUIPMENT

The low voltage electric equipment shall comply with the relevant sections of the Electrical General Specification.

Equipment	Electrical General Specification
Electric motor	Clause C5.25
Variable speed drives	Clause C5.19
Motor switchgear, starter and control Panels	Clauses C5.18 and C5.26
Automatic power factor correction Capacitors	Clause C5.22

C7.4 HIGH VOLTAGE - ELECTRIC EQUIPMENT

The high voltage electric equipment shall comply with the relevant sections of the Electrical General Specification.

Equipment	Electrical General Specification
High Voltage - General	Clause C13.1
High Voltage - Electric motor	Clause C13.3

High Voltage - Motor control switchboards	Clause C13.4
High Voltage - Auto-transformers	Clause C13.5
High Voltage - Power factor correction capacitors	Clause C13.5
High Voltage - Power cables	Clause C13.7

SECTION C8

NOISE AND VIBRATION CONTROL

C8.1 GENERAL

This section of the Specification intends to direct the A/C Contractor to select the appropriate and sufficient noise and vibration control measures on the plant/equipment, the interconnected piping, ductwork and conduit so that when the installed plant/equipment are put into operation, the resulting noise and vibration levels at locations within the building and at the adjacent or nearby buildings shall not exceed the acceptable limits as promulgated by the statutory requirements of the Environmental Protection Department.

The Corrected Noise Level at potential Noise Sensitive Receiver in the adjacent or nearby building, if so identified in the Particular Specification and/or Drawings, shall not exceed the Acceptable Noise Level stipulated in the Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites issued by the Environmental Protection Department when the plant/equipment installed by the A/C Contractor are put into operation.

The noise assessment shall be carried out for air-cooled chillers / condensing units / condensers and/or water-cooled chillers / cooling towers and chilled water / condensing water pumps or external ventilating fan intakes/outlets to ensure compliance with the statutory requirements of the Environmental Protection Department.

C8.2 EQUIPMENT BASES

C8.2.1 General

Floor mounted equipment shall be installed on 100 mm high concrete housekeeping pads provided by the Building Contractor covering the whole floor area requirements of the equipment bases plus a minimum of 150 mm further on each side or on inverted beams at the roof. Vibration isolators shall be mounted on this concrete pad or inverted beams.

C8.2.2 Welded Structural Steel Bases

Bases shall be constructed of adequate "I" or channel hot dipped galvanised steel members reinforced as required to prevent the bases from flexing at start-up and from misalignment of drive and driven units.

All perimeter members shall be of steel sections with a minimum depth equal to 1/10th of the longest dimension of the base but need not exceed 350 mm provided that the deflection and misalignment are kept within acceptable limits as determined by the equipment manufacturer.

Height saving brackets shall be employed in all mounting locations to provide a base clearance of 50 mm.

C8.2.3 Concrete Inertia Bases

Concrete inertia bases shall be formed within a structural steel beam or channel frame reinforced as required to prevent flexing, misalignment of the drive and driven units or transferral of stresses into equipment. The base shall be completed with height saving brackets, concrete reinforcement and equipment bolting down provisions.

In general, the thickness of concrete inertia bases shall be of a minimum of 1/12th of the longest dimension of the base but never be less than 150 mm. The base depth needs not exceed 300 mm unless specifically required.

As an indication of the standards required, minimum thickness of the inertia base shall generally comply with the following table or be 1/12th of the longest dimension of the base, whichever is the larger: -

Table C.8.2.3 Minimum Thickness of Inertia Base

Motor Size (kW)	Minimum Thickness
3.7 - 11	150 mm
15 - 37	200 mm
45 - 55	250 mm
75 - 185	300 mm

Base forms shall include minimum concrete reinforcement consisting of 13 mm bars or angles welded in place on 150 mm centres running both ways in a layer of 40 mm above the bottom, or additional steel as is required by the structural conditions.

Unless otherwise specified, concrete inertia bases shall weigh from 2 to 3 times the combined weight of the equipment/plant to be installed thereon.

Base forms shall be furnished with drilled steel members and with anchor-bolt sleeves welded below the holes where the anchor bolts fall in concrete locations.

Height saving brackets shall be provided in all mounting locations to maintain a base clearance of 50 mm.

C8.3 VIBRATION ISOLATORS

The following types of vibration isolation mountings or suspensions are not exhaustive but serve to cover the main types that shall be applied as appropriate unless otherwise stated in the Particular Specifications.

C8.3.1 Type "A" - Free Standing Spring Mounts

These shall be free standing and laterally stable without any housing and completed with a minimum of 6.0 mm neoprene acoustical friction pads between the base plate and the support.

All mountings shall have levelling bolts that must be rigidly bolted to the equipment.

Spring diameters shall be no less than 80% of the compressed height of the spring at rated load with a horizontal spring stiffness 1.1 times the rated vertical spring stiffness.

Springs shall have a minimum additional travel to "solid" (fully compressed) equal to 50% of the rated deflection.

Springs shall be so designed that the ends of the springs remain parallel.

The springs selected for any given application shall be non-resonant with the equipment’s or support structure’s natural frequencies. This shall apply to all springs hereafter described.

C8.3.2 Type "B" - Restrained Spring Mounts

Equipment with operating weight different from the installed weight such as chillers, boilers, etc. and equipment exposed to the wind such as cooling towers and other roof mounted plants shall be mounted on spring mountings as Type 'A' but a housing shall be used that includes vertical limit stops to prevent spring extension when some of the weight is removed, i.e. when the system is drained or lifted by abnormal wind pressure.

C8.3.3 Type "C" - Double Deflection Neoprene Mounts

These mountings shall have a minimum static deflection of 8.5 mm. All metal surfaces shall be neoprene covered to avoid corrosion and shall have friction pads on both the top and the bottom so that they need not be bolted to the floor. Bolt holes shall be provided for applications where bolting down is required.

C8.3.4 Type "D" - Neoprene Pads

These mountings shall consist of "waffle" form neoprene pads of 8.0 mm thickness. Where required these shall be adhesive cemented to 3 mm steel plate of similar area so as to form a sandwich.

The area of pad to be used and the number of layers shall be determined for each application in accordance with the manufacturer's recommendations.

C8.3.5 Type "E" - Spring Hangers

These shall contain a steel spring located in a neoprene cup manufactured with a grommet to prevent short circuiting of the hanger rod.

The cup shall contain a steel washer designed to properly distribute the load on the neoprene and prevent its extrusion.

Spring diameters and hanger box lower hole sizes shall be large enough to permit the hanger rod to swing through a 30^{o} to 35^{o} arc before contacting the edge of the hole and short circuiting the spring.

Springs shall have a minimum additional travel to solid equal to 50% of the rated deflection.

C8.3.6 Type "F" - Spring and Double Deflection Neoprene Hangers

These shall be as Type "E" but incorporate an 8 mm deflection neoprene element at the top of the hanger box.

The neoprene element shall be moulded with a rod isolation bushing that passes through the upper part of the hanger box.

C8.3.7 Type "G" - Pre-Compressed Spring Hangers

These shall be as Type "F" but shall be pre-compressed to the rated deflection so as to keep the piping or equipment at a fixed elevation during installation.

The hangers shall be designed with a release mechanism to free the spring after the installation is completed and the hanger is subjected to its full load.

Deflection shall be clearly indicated by means of a scale.

C8.3.8 Type "H" - All Directional Anchor Units

These units shall consist of a telescopic arrangement of two sizes of steel tubing separated by a minimum 13 mm thickness of heavy duty neoprene isolation material for horizontal restraints.

Vertical restraints shall be provided by similar material arranged to prevent vertical travel in either direction.

C8.3.9 Type "I" - Pipe Anchors and Guides

Resilient pipe anchor shall be formed by welding a steel pipe clamp to the pipe and the clamp in turn supported at its two ends by a pair of Type "H" all directional anchor units. In this way, both the radial and axial motion of the pipe are controlled.

Resilient pipe guide shall be formed by welding localised longitudinal guide ribs around the pipe at location over which slides fit the oversized pipe clamp which is in turn supported at its two ends by a pair of Type 'H' all directional anchor units. In this way, radial motion of pipe is controlled while axial motion of pipe is guided.

C8.3.10 Type "J" - Split Wall/Floor Seals

These shall consist of two bolted pipe halves with 19 mm or thicker neoprene sponge bonded to the inner faces.

Seals shall project a minimum of 25 mm past either face of the walls.

Where temperatures exceed 115ºC, fibreglass shall be used in lieu of the sponge.

C8.3.11 Type "K" - Horizontal Thrust Restrains

Air handling equipment shall be protected where necessary against excessive displacement, which might result from high air thrusts in relation to the equipment weight.

The horizontal thrust restraint shall consist of a spring element located in a neoprene cup manufactured with a grommet to prevent short circuiting of the threaded rod. The thrust assembly shall be so designed that the spring element can be pre-set for thrust at the factory and adjusted at the site to allow for a maximum of 6 mm movement at start and stop.

The assembly shall be furnished with one threaded rod and two angle brackets for attachment to both the equipment and ductwork or the equipment and the structure. Horizontal restraints shall be attached at the centre line of thrust and symmetrically on either side of the unit.

C8.3.12 Type "L" - Built in Inertia Block Plant Support

Where specified in the contract document, the Building Contractor shall provide plant foundations and housekeeping pads in the form of large concrete blocks recessed into the main floor slab.

Unless otherwise indicated, the sides and bottom of the embedded portion of the concrete block shall be lined with a minimum of 50 mm thick "load bearing" cork pad to the following specification.

Table C8.3.12 Density of Vibration Isolators

Density Designation	Density (kg/m^3)	Loading (kg/m^2)
Light	3.0 – 4.5	250 - 2500
Medium	5.5 – 6.0	2500 - 20000
Heavy	7.0 – 7.5	15000 - 30000

C8.4 PLANT/EQUIPMENT VIBRATION ISOLATION

C8.4.1 General

All vibration isolators shall have their known undeflected heights or calibration markings so that, after adjustment when carrying their loads, the deflection under load can be verified, thus determining that the load is within the proper range of the device and that correct degree of vibration isolation is being achieved according to the design.

The static deflection of the isolator at each support point shall not differ from the design objective for the equipment as a whole by more than ±10%.

The ratio of lateral to vertical stiffness for spring shall be not less than 0.9 nor greater than 1.5.

All neoprene mountings shall have hardness of 40 to 65 durometers, after minimum aging of 20 days or corresponding over-aging.

In order to resist corrosion, all vibration isolation mountings and hangers shall be treated as follows: -

(a) Springs to be neoprene coated or hot dip galvanised;

(b) Wearing hardware to be cadmium plated steel or stainless steel of an appropriate grade; and

(c) All other metal parts to be hot dip galvanised.

For any Contract, all vibration isolators and associated equipment bases shall whenever possible be of the product of a single manufacturer. Acceptable manufacturer's systems shall strictly comply with the design intent of this and/or the Particular Specification.

C8.4.2 Selection Guide for Equipment Base and Vibration Isolator

Unless otherwise specified, the selection of the type of equipment base and vibration isolator (mounting/hanger) for different plant/equipment and on different floor spans and levels shall follow the requirements as indicated in the Selection Guide for Vibration Isolation (Table 47 in the Chapter 48 for "Sound and Vibration Control" of the ASHRAE Applications Handbook) and the static deflection of the vibration isolator selected shall either provide a minimum isolation efficiency of 90% in ground floor areas and 95% in upper level areas or be not less than the corresponding values shown in Table 47. However, the A/C Contractor shall be responsible to ensure that the selected vibration isolation system is suitable for the specific plant/equipment and the specific building structure on which the plant/equipment is mounted.

The A/C Contractor shall provide more efficient isolation than those suggested in Table 47 in case if the adjacent occupied space is a noise critical area such as board room and executive office. Advice from vibration isolator manufacturer shall be sought if necessary.

C8.5 PIPEWORK VIBRATION ISOLATION

C8.5.1 Flexible Connectors

Flexible connector shall consist of a single or twin-sphere body manufactured with reinforced rubber, the ends of which are raised and wire reinforced to form the cuffs for sealing purposes. The cuffs shall be backed by floating steel flanges.

The rubber body shall be reinforced by multi-layered nylon tire cord fabric.

Flexible connectors shall have a life in excess of 10 years under the design working conditions.

The rubber membranes shall have an indelible identification system to clearly identify the model and hence suitability for the application and working conditions and have the date of manufacture moulded into the cover to ensure that no units that have exceeded the recommended shelf life are used.

Straight connectors shall be of the twin-sphere construction whilst elbow connectors shall be of the single-sphere construction.

Straight connectors connected to resiliently supported equipment shall be equipped with acoustical control cables to prevent excessive elongation of the connectors if the system operating pressure is in excess of the value recommended by the manufacturer for use without control cables.

Acoustical control cable assembly shall consist of four large triangle anchor plates, two control cables with large swedged-on end fittings and 13 mm thick acoustical washer bushings of sufficiently large load bearing area to isolate the end fittings, axially and laterally.

C8.5.2 Flexible Metallic Hose

Allowable stress levels should be within PD 5500:2018+A1:2018.

The corrugated seamless hose body shall be of the annular and close pitched type.

For all ferrous applications, the hose body and the braid shall be manufactured from stainless steel material to BS EN 10095:1999 Type X8CrNi25-21. End terminations shall be carbon steel threaded male nipples to ISO 7-1:1994/Cor1:2007 for 65 mm size and below and flanges to BS EN 1092-1:2018 Standard for 75 mm and above.

For copper or non-ferrous pipework systems, the hose body and the braid shall be manufactured in bronze throughout. End terminations shall be copper female ferules suitable for soldering.

The lengths of the flexible metallic hoses shall be in accordance with the manufacturer's recommendation.

C8.6 DUCTWORK VIBRATION ISOLATION

They shall be made of approved materials such as lead vinyl or similar of minimum surface density of 5 kg/m^2 and installed such that airflow is not obstructed. The material used shall be approved or accepted by the FSD.

C8.7 DUCTWORK ACOUSTIC INSULATION

Unless otherwise specified, the acoustic ductwork liner shall conform to the requirements of ASTM C1071-16. It shall be composed of glass fibres type firmly bonded together with a thermosetting resin into a rigid board of 50 mm thickness and 48 kg/m^3 density. The air stream surface shall be overlaid with a fire-resistant black acrylic coating which adds strength to the product during fabrication, installation and system operation. The manufacturer's product identification shall appear on the air stream surface.

All components of the acoustic insulation including coverings and adhesive shall have a fire hazard classification with a flame spread rating of not over 25, and a smoke developed rating of not over 50. Ratings shall be as established by the tests conducted in accordance with UL 723:2018, ASTM E84-18b or NFPA 255:2006 or BS 476-4:1970. The A/C Contractor shall certify in writing, before any insulation is installed, that the products to be used meet with the above criteria.

The acoustic linings shall have the following minimum sound absorption coefficients when tested in accordance with ASTM C423-17.

Table C8.7 Minimum Sound Absorption Coefficient

Octave Band Centre Freq. (Hz)	125	250	500	1k	2k	4k
Sound Absorption Coefficient	0.12	0.67	0.99	0.97	0.91	0.87

C8.8 ACOUSTIC DUCTLAG

Unless otherwise specified, the acoustic duct lag shall consist of 50 mm thick glass fibre/lead sheet or barium loaded vinyl sheet/glass fibre with a factory applied aluminium vapour-barrier jacket which shall also be used for thermal insulation of ductwork.

The fibre glass shall have a density of 24 kg/m^3 and thermal conductivity of 0.032 W/m^{o}C or lower. The lead sheet shall have a surface weight of 5 kg/m^2.

Duct lag shall have the following minimum sound transmission loss when tested in accordance with ASTM E90-09.

Table C8.8 Minimum Sound Transmission Loss

Octave Band Centre Freq. (Hz)	125	250	500	1k	2k	4k
Sound Transmission Loss (dB)	15	17	19	24	30	33

C8.9 DUCTWORK SILENCERS

Outer casing of rectangular ductwork silencers shall be fabricated from galvanised steel not thinner than 0.8 mm in accordance with the recommended practices that specified in Clause C2.3. Seams shall be "lock-formed" and mastic filled. Each silencer shall be provided with flanged inlet and outlet. The internal baffles or splitters shall be of galvanised perforated steel not thinner than 0.5 mm and having a nominal open area of 30%.

All internal components shall be spot welded in place with welds on centres not exceeding 100 mm. All spot welds shall be treated after with anti-corrosive epoxy resin or other approved coating.

Mani folded silencers shall be provided with continuous metallic nosing crimped in place. Nosing pieces and tails shall be as per the manufacturer’s design. The filler material shall be of inorganic mineral or glass fibre of a density sufficient to obtain the specified acoustic performance and be packed under not less than 5%

compression to eliminate voids due to vibration and settling. Material shall be inert, vermin and moisture proof.

Combustion rating for the silencer acoustic in-fill shall not exceed the following when tested in accordance with ASTM E84-18b, NFPA Standard 255:2006 or UL 723:2018 or BS 476-4:1970.

- Flame Spread 25
- Smoke Developed 15
- Fuel Contributed 20

The silencer shall be leak-proof at a differential air pressure of 2 kPa.

Unless otherwise specified, ductwork silencers shall have the following minimum Dynamic Insertion Loss under forward and reverse flow conditions of 10 m/s: -

Table C8.9 - (1)Insertion Loss (dB) - for Lowest Pressure Drop Silencer

Silencer Length (mm)	Octave Band Centre Freq. (Hz)					
	125	250	500	1k	2k	4k
900	5	9	14	23	24	14
1500	7	13	21	29	39	20
2100	13	18	28	40	47	26

Table C8.9 - (2)Insertion Loss (dB) - for Low Pressure Drop Silencer

Silencer Length (mm)	Octave Band Centre Freq. (Hz)					
	125	250	500	1k	2k	4k
900	5	10	17	17	13	10
1500	8	15	28	30	21	14
2100	12	20	36	38	28	18

Table C8.9 - (3)Insertion Loss (dB) - for Medium Pressure Drop Silencer

Silencer Length (mm)	Octave Band Centre Freq. (Hz)					
	125	250	500	1k	2k	4k
900	7	12	19	23	23	18
1500	10	18	30	42	34	23
2100	14	24	36	48	44	31

Table C8.9 - (4)Insertion Loss (dB) - for Standard Pressure Drop Silencer

Silencer Length (mm)	Octave Band Centre Freq. (Hz)					
	125	250	500	1k	2k	4k
900	10	15	25	34	35	28
1500	16	22	38	45	46	41
2100	17	34	44	49	49	45

Unless otherwise specified, ductwork silencers shall have the following maximum self-generated sound power level (dB re 10^{-12} Watt) under the flow conditions of 10 m/s: -

Table C8.9 - (5) Maximum Self-Generated Sound Power Level

Silencer Length (mm)	Octave Band Centre Freq. (Hz)				
	125	250	500	1k	2k
Lowest	51	51	49	47	50
Low	52	46	43	42	45
Medium	54	52	50	47	48
Standard	69	63	64	61	63

Before ordering ductwork silencers, the A/C Contractor shall submit for the Supervising Officer's approval the proposed manufacturer's certified test data (from laboratories by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved) for pressure drop and insertion loss ratings.

C8.10 ACOUSTIC DOORS

Door leaf shall be at least 65 mm thick, fabricated from 1.5 mm steel and filled with sound-absorbing and damping materials. Door frame shall be fabricated from 1.5 mm steel and furnished in two inside and outside mitred and welded pieces.

Doors shall be fully gasket, hinged and secured by approved latch mechanism.

Door hinges shall be of cam-lift type which shall raise or lower as the door is opened or closed respectively.

Side and head of door and frame shall receive two sets of self-aligning compression seals. Acoustic labyrinth shall be created when the door is in the closed position. Bottom of door leaf shall contain continuous compression seal and the gravity action of the cam hinges shall cause the door to compress the bottom seal tightly against the floor every time the door is closed.

Unless otherwise specified, the door shall be 1-hour fire rated and the compression seals shall be fire-resistant to BS 476-20:1987 to BS 476-22:1987.

The acoustic door shall have the following minimum sound transmission loss when tested in accordance with ASTM E90-09.

Table C8.10 Minimum Sound Transmission Loss (Door)

Octave Band Centre Freq. (Hz)	125	250	500	1k	2k	4k
Sound Transmission Loss (dB)	26	42	43	47	52	56

C8.11 ACOUSTIC LOUVRES

Unless otherwise specified in the Particular Specifications, the acoustic louvres to be installed to the external walls of plant rooms when specified shall be not less than 300 mm thick.

Outer casings shall be made of 1.6 mm thick galvanised sheet steel. The noise absorbing surfaces of the louvre blades shall be made of 0.8 mm thick perforated galvanised sheet steel and all other surfaces of the louvre blades shall be made of 0.8 mm thick galvanised sheet steel.

Louvre blades shall be filled with glass fibre of density 48 kg/m^3.

The acoustic louvres shall have the following minimum Transmission Loss (TL).

Table C8.11 Minimum Transmission Loss (Louvre)

Octave Band Centre Freq. (Hz)	125	250	500	1k	2k	4k	8k
Insertion Loss (dB)	7	11	12	13	14	12	9

Static pressure drop of louvres shall not exceed 50 Pa at a face velocity of 2.2 m/s.

C8.12 ACOUSTIC ENCLOSURES

C8.12.1 General

Where required for in the Contract, double-wall, insulated, and air-pressure-tight acoustic enclosures for housing noisy plant or machinery shall be constructed as specified below and supplied by a specialist manufacturer of insulated housings and casings, with published standards of construction and performance.

C8.12.2 Panel Construction

The outer surface of the panel shall be made of 1.2 mm thick galvanised solid sheet steel and the inside surface shall be made of 0.8 mm thick perforated galvanised sheet steel. Interior panel perforation shall be of 2.4 mm round holes on 4.8 mm staggered centres.

Panels shall be 100 mm thick or as otherwise indicated and be filled with glass fibre insulation, 40 kg/m^3 minimum density, with following UL Composite Fire Resistance Ratings or to BS 476-20:1987 to BS 476-22:1987.

- Flame Spread 15
- Smoke Developed 0
- Fuel Contributed 0

Mineral wool to a comparable specification would also be accepted.

The insulation material shall be non-hygroscopic, inert and vermin-proof. It shall not settle, shed or dust.

Panel joints shall be of the joiner and connector type construction such that the adjacent panels are held rigidly in position, effective both on the inside and outside.

Mechanical joints shall be made leak-proof with ductwork sealer, which shall be retained between adjoining flat metal surfaces. Panel construction shall hold the assembly motionless to avoid sealer displacement. Sufficient sealer shall be used to allow extrusion of surplus sealer to give visible evidence of sealer. Assembled structure shall have deflection under load limited to 1/240 of span at 3.0 kPa pressure.

For spans greater than 3000 mm, additional and approved structural reinforcement shall be installed to provide for structural rigidity.

Connection of roof to wall panels shall be by suitably sized angles held by approved screws, and using an approved sealer to provide an airtight seal.

C8.12.3 Access Doors and Louvres

Where required under the Contract, access doors and louvres forming part of the complete acoustic enclosures shall be of the acoustic type design.

Access door shall be 600 mm wide x 1500 mm high or 900 mm wide x 1800 mm high as specified in the Drawings or otherwise indicated. Each door shall be factory/workshop installed in its panel opening which shall be reinforced with 3.4 mm thick galvanised sheet steel channel of suitable width to suit the wall thickness of the panel. The

doors shall be constructed of 1.2 mm thick galvanised solid sheet steel and they shall be 100 mm thick and of the overlapping seal type. Each door shall be equipped with single continuous air/acoustic seals around the sill, jambs and head and shall have 2 hinges and 2 latches with an inside release handle.

C8.12.4 Openings and Sealing

All openings with dimensions greater than 150 mm shall be factory/workshop cut and framed.

The clearance space between the acoustic enclosure and any ductwork, pipes, or conduits passing through the enclosure shall be tightly packed with glass fibre or rock wool. Both ends of the opening shall then be covered up by 1.2 mm thick sheet steel and sealed airtight by high pressure ductwork sealer.

C8.12.5 Acoustic Test Data for Panels

The minimum allowable Transmission Loss (TL) of the panel, including all components, when tested in accordance with ASTM E90-09, shall be as stated below: -

Table C8.12.5 - (1) Minimum Transmission Loss (Panel)

Octave Band Centre Freq. (Hz)	125	250	500	1k	2k	4k	8k
Sound Transmission Loss (dB)	23	30	42	51	59	58	58

The composite panel assembly when tested in accordance with ASTM C423-09a, shall have minimum sound absorption coefficients as follows: -

Table C8.12.5 - (2) Minimum Sound Absorption Coefficients

Octave Band Centre Freq. (Hz)	125	250	500	1k	2k	4k	8k
Sound Absorption Coefficient	0.89	1.20	1.16	1.09	1.01	1.03	0.93

C8.13 PLANT ROOM ACOUSTIC LININGS

Where required under the Contract, the acoustic linings to walls and/or ceilings of the plant rooms are used to reduce the reverberant noise levels of the plant rooms. The material and the sound absorption coefficients of the acoustic wall lining shall comply with Clause C8.7.

SECTION C9

PIPE MATERIAL, VALVES, COCKS AND STRAINERS

C9.1 AUTOMATIC AIR VENTS

Automatic air vents shall be used where indicated. They shall have gunmetal or brass bodies, non-ferrous or stainless steel floats and guides, corrosion resistance valves and seats. Each automatic air vent shall be controlled by a lock-shield valve. Air release pipes shall be run to discharge at the nearest suitable and visible point and agreed by the Supervising Officer.

C9.2 BALL FLOAT VALVES

Ball float valves shall be of the sizes indicated and shall suit the fill and expansion cisterns or tanks specified. Ball float valves for use with feed and expansion cisterns shall be of the long arm type arranged to shut off when the cistern contains 150 mm depth of water. Floats shall be of the vacated plastic or solid polystyrene construction and provided with a non-ferrous threaded in built connector.

C9.3 BUTTERFLY VALVES

C9.3.1 Butterfly valves shall be installed where indicated. These shall have resilient seats which are (in-the-field) replaceable with moulded-in 0-rings to serve as a flange gasket. For sizes of 50 mm dia. to 150 mm dia. inclusive, a notched plate handle shall be provided for the control of the valve and indication of disk position. For sizes of 200 mm dia. and above, gear actuator shall be used. All butterfly valves shall be capable of bubble tight shut off. Butterfly valves shall comply with the recognised international standards (e.g. ISO or BS EN).

C9.3.2 Butterfly valves in connection with wafer, full-lug, flange or grooved ends may also be accepted. The valves shall be in accordance with the following: -

(a) Grooved ends butterfly valves shall be bubble tight complying to ISO 5208:2015 or BS EN 593:2009 +A1:2011 standard, enabling quick assembly with mechanical grooved coupling on ISO standard pipes;

(b) The manufacturer shall provide tests for pressure rating by laboratories by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved. All testing records and data shall be submitted to the Supervising Officer for approval;

(c) Bodies shall be made of ductile iron grade 400-18 or ASTM A536 grade 65-45-12, completely coated with polyamide or products having equivalent functions or performance against corrosion, suitable for the temperature range of 0ºC to 50ºC. The valve shall provide dead end service at maximum rating;

(d) The discs shall be made of ductile iron, stainless steel, aluminium bronze or brass ASTM B124, with protective coating for fresh water application;

(e) The shafts stems shall be made of Type 420 stainless steel;

(f) The control handles and the gear operators shall be suitable for locking in any position. The micro switches shall be built in the actuators and factory adjusted at full open and full closure. Manufacturer shall provide certificate of factory adjustment;

(g) Valve electric operators shall be mounted on valves and tested at factory; and

(h) The valves shall have marking tag in accordance with ISO 5209:1977 standard.

C9.4 CHECK VALVES

The body of the check valves shall be made of cast iron to BS EN 1561:2011or ISO 185:2005 or ductile iron to ASTM A536 while the flaps/discs shall be made of bronze to ISO 197-4:1983 or ductile cast iron. The discs of swing check valves shall be of light construction and pivot on a spindle secured by two phosphor-bronzed hangers. Each valve shall be fitted with a stop to prevent undue movement of the flap and shall be as silent as possible in operation.

The discs of lift check valves shall be provided with means of guiding the discs and preventing components from becoming detached in service.

Recoil check valves with size 100 mm and above should have removable cover on top of the outlet body casing to facilitate inspection of bearings and movement door.

C9.5 PIPEWORK APPLICATIONS

Except as may otherwise be specified in Particular Specification, the application of pipework types to the various systems shall be as stated in Table C9.5. All pipes and fittings shall comply with the relevant Standard and shall have suitable markings to indicate the Standard.

Table C9.5 - (1) Chilled Water and Low Pressure Hot Water Circulation (Closed System)

Size	Type	Treatment
(i) Up to 150 mm	Steel to ISO 65:1981 (BS EN 10255: 2004) of medium grade	Black mild steel (painted external before insulation)
(ii) Over 150 mm up to and including 300 mm	Steel to ISO 9330-1 to ISO 9330-3 (BS EN 10217-1 to 10217-7) with wall thickness not less than 6 mm	Black mild steel (painted external before insulation)

Note: For pipe sizes of over 300 mm, the requirements, including the pipe wall thickness, will be fully detailed in the Particular Specification.

Table C9.5 - (2) Chilled Water Drain, Vent and Overflow

Size	Type	Treatment
(i) Up to 150 mm	Steel to ISO 65:1981 (BS EN 10255: 2004) of medium grade	Galvanised

Table C9.5 - (3) Chilled Water Condensate Drains

Size	Type	Treatment
(i) Up to 150 mm	Steel to ISO 65:1981 (BS EN 10255: 2004) of medium grade	Galvanised
(ii) Over 150 mm up to and including 300 mm	UPVC to BS EN ISO 1452-1 to 1452-5 or BS 3505:1986	Self-finish

Note: For pipe sizes of over 300 mm, the requirements, including the pipe wall thickness, will be fully detailed in the Particular Specification.

Table C9.5 - (4) Condenser Circulation Pipework, Fresh Water Closed System with Air/Water Heat Exchanger

Size		Type	Treatment
(i)	Up to 150 mm	Steel to ISO 65:1981 (BS EN 10255: 2004) of medium grade	Black mild steel (painted external before insulation)
(ii)	Over 150 mm up to and including 300 mm	Steel to ISO 9330-1 to 9330-3 (BS EN 10217-1 to 10217-7) with wall thickness not less than 6 mm	Black mild steel (painted external before insulation)

Note: For pipe sizes of over 300 mm, the requirements, including the pipe wall thickness, will be fully detailed in the Particular Specification.

Table C9.5 - (5) Condenser Circulation Pipework, Fresh Water passing through Cooling Tower

Size		Type	Treatment
(i)	Up to 150 mm	Steel to ISO 65:1981 (BS EN 10255: 2004) of medium grade	Galvanised
(ii)	Over 150 mm up to and including 300 mm	UPVC to BS EN ISO 1452-1 to 1452-5 or BS 3505:1986	Self-finish
(iii)	Over 150 mm up to and including 300 mm	Ductile iron to BS EN 545:2010 of appropriate grade For screw-on flanges connection, thickness grade of Class K12	External Coating: Metallic zinc covered by a finishing layer of bitumen paint Internal Lining: Cement Mortar as in Note 4 below

Note: For pipe sizes of over 300 mm, the requirements, including the pipe wall thickness, will be fully detailed in the Particular Specification.

Table C9.5 - (6) Condenser Circulation Pipework for Sea Water Treated Effluent Water and Brackish Well Water (Cooling tower or once through systems)

Size	Type	Treatment
(i) Up to 150 mm	UPVC to BS EN ISO 1452-1 to 1452-5 or BS 3505:1986	Self-finish
(ii) Over 150 mm up to and including 300 mm	Ductile iron or UPVC as for fresh water at Table C9.5 - (5)(iii)	As ductile iron treatment as in Table C9.5- (5) (iii)

Note: For pipe sizes of over 300 mm, the requirements, including the pipe wall thickness, will be fully detailed in the Particular Specification.

Table C9.5 - (7) Cold Water Make-up Supply to Air-conditioning Plant Cold Feed

Size	Type	Treatment
(i) Up to 150 mm	UPVC to BS 3505: 1986 or BS EN ISO 1452-1 to 1452-5 of appropriate grade	Self-finish

Where copper pipe work is indicated, the tubes shall be of the following types: -

(a) Light gauge copper to BS EN 1057:2006+A1:2010. Refrigeration copper tubes to BS EN 12735-1 (tubes for piping system) or 12735-2 (tubes for equipment) for refrigerant distribution purpose;

(b) Where buried underground tubes shall be to BS EN 1057:2006; and

(c) Tubes shall be suitably joined by capillary or compression fittings to ISO 2016:1981 or to BS EN ISO 6708:1996 and ISO 7268: 1983/Amd 1:1984 (BS EN 1254-1 to 1254-4). For jointing screwed copper tubes, cast copper alloy fittings to ISO 7-1:1994/Cor1:2007 (BS EN 1254-1 to 1254-4) shall be used.

Note 1: Expansion and contraction due to condenser water temperature changes must be adequately accommodated particularly for UPVC pipework.

Note 2: UPVC pipe has several pressure ratings, i.e. appropriate grade for BS EN ISO 1452-1 to 1452-5 or BS 3505:1986. If pressure ratings are not indicated in the Drawing or Particular Specification, A/C Contractor shall provide pipes with pressure ratings equal to twice the actual working pressure to which the pipes are being subjected.

Note 3: Where UPVC pipe is likely to be exposed to sunlight, it shall be protected against the effects of ultra violet light by a suitable paint work coating material or other form of protection to be agreed with the Supervising Officer.

Note 4: All pipes and fittings shall be cement mortar lined in accordance with BS EN 545:2010, BS EN 598:2007+A1:2009, BS EN 969:2009, Type A - Portland pulverised fuel ash cement (PFAC) in accordance with BS EN 197-1:2011 with a minimum pulverised fuel ash content of 25%; or Type B - sulphate resisting cement (SRC).

Note 5: UPVC pipework to BS 3505:1986 or BS EN ISO 1452 shall be in accordance with BS EN ISO 1452-1:2009, BS EN ISO 1452-2:2009, BS EN ISO 1452-3:2010, BS EN ISO1452-4:2009 and BS EN ISO 1452-5:2009.

C9.6 PLUG COCKS

Plugs for gland cocks shall be ground in. A loose key of mild steel forged to shape shall be provided for each gland cock.

Air cocks shall be nickel or chrome plated, of the spoutless pattern and with screwed taper thread. Two loose keys shall be provided for each installation having up to ten air cocks and one loose key shall be provided for every additional ten air cocks.

Three-way cocks shall be of the 'T' ported type, the position of the ports being clearly grooved on the square end of the plug. A loose key shall be provided for each three-way cock.

C9.7 PRESSURE REDUCING VALVES

Where indicated pressure reducing valves shall be installed. Unless otherwise specified they shall be as follows: - Valves of up to 50 mm size shall have bronze or malleable iron bodies and may have taper screwed ends. Valves of 65 mm size and over shall have cast iron bodies with ends flanged. Flanges for bronze and iron valves shall be to ISO 7005-2:1988 & ISO 7005-3:1988, each according to the maximum working pressure. Valves shall be of the following types, as indicated: -

(a) Valves for reducing pressure to apparatus not designed to withstand the maximum pressure of a high-pressure line shall be of an approved spring-loaded relay operated type. The valve seats and discs shall be of nickel-alloy or stainless steel and shall be renewable. Each valve shall be capable of maintaining a reduced outlet gauge pressure within 3.5 kPa of the set pressure and shall be installed with an excess pressure isolating protection valve on the low pressure side; and

(b) Where the apparatus on the low-pressure side is capable of withstanding the maximum pressure of the high-pressure line, valves shall be of the single-seated spring-loaded diaphragm type. They shall be adjustable within the specified low-pressure range and shall be installed with a safety or relief valve on the low pressure side.

Each reducing valve shall be installed with an isolating valve and strainer on the high-pressure side, excess pressure isolating valve or relief valve on the low pressure side, pressure gauge with mild steel siphon and bronze cock followed by down-stream side isolating valve.

Unions shall be provided on the pressure reducing valve side of both isolation valves in order to facilitate removal of the pressure reducing valve set for servicing or replacement. Where indicated, a bypass valve shall also be installed.

C9.8 STRAINERS

Strainers shall be of the single or the double type as indicated with connections screwed thread for bores of up to and including 50 mm and flanged for bores of 65 mm and over.

Strainers of up to 50 mm shall be of gunmetal or bronze. The bodies of single strainers of 65 mm bore and above and all double strainers shall be of cast iron or ductile iron.

Straining cages and their supporting structure shall be of non-ferrous metal or stainless steel with 1.5 mm diameter perforations or finer if indicated. Cage shall be at least five times the cross-sectional area of the pipe or Y-type strainer of appropriate size as approved by the Supervising Officer.

Double strainers shall incorporate a changeover device to enable either strainer to be selected and to isolate the idle strainer from the fluid flow.

C9.9 SPECIALISED CONTROL VALVES

Motorised control valves, and solenoid valves used for automatic control purposes shall be as specified in Clause C5.50 or as indicated in the Particular Specification. Mixing valves shall comply with BS EN 1287:2017.

C9.10 VALVE APPLICATIONS

C9.10.1 For fresh and chilled water; gate valves shall be used except where regulation is required in which case globe valve shall be installed but they must be positioned so as not to prevent drainage of the piping.

C9.10.2 For fresh water service valve both the gate and globe type shall be constructed of cast iron body with bolted cast iron bonnet, malleable iron hand wheel, bronze wedge and seat, forged manganese bronze or

high tensile bronze spindle, with graphited packing and compressed fibre.

C9.10.3 Sea water services valves installed in the sea water pump house and/or inside the air conditioning plant room shall be constructed of cast iron body with zinc free bronze trim, bolted cast iron bonnet, malleable iron hand wheel, zinc free bronze stuffing box, gland, thrust, plate, yoke, wedge, seat and yoke sleeve with nickel alloy faces, stainless steel spindle with outside screw of rising stem or inside screw of non-rising stem (whichever is specified), gunmetal nuts, and graphited packing compressed fibre packing.

C9.11 VALVES AND COCKS

C9.11.1 Valves, cocks, taps and other accessories shall be of the type and working pressure suitable for the applied system and shall be supported by valid documents with approval from the appropriate authority. They shall also bear the appropriate ISO Standard with marks. See also Clauses B9.5 and B9.10.

C9.11.2 Bodies of valves and cocks of up to and including 50 mm size shall be of cast gunmetal or bronze; approved valves having hot-pressed bodies may be offered as an alternative.

C9.11.3 Unless otherwise specified, bodies of valves of 65 mm size and larger shall be of cast iron or ductile iron. Castings and pressings shall be of good quality, clean and smooth and free from scale or flaws.

C9.11.4 All working parts shall be of gunmetal or chrome nickel alloy. Holes in covers or in gates for screwed portions of spindles shall have full threads of a length not less than the diameter of the spindle over the threads. Glands shall be machined to provide a naming fit between the spindle and the stuffing box. Stuffing boxes shall be properly packed, or fitted with 'O' rings which shall be located in plastic bushes.

C9.11.5 Gate valves shall have split or solid wedge gates. Disc valves shall have renewable discs free to rotate on the spindle.

C9.11.6 Valves and cocks on mild steel pipework of up to and including 50 mm size shall have taper screwed ends, and of 65 mm size and above shall have flanged ends.

Valves and cocks on copper pipework shall have connecting generally as for fittings.

C9.11.7 Wheel valves where exposed to view on appliances such as fan coil units and induction units shall have union ends and either: -

(a) Composition hand-wheels shaped to enclose the stem and gland; or

(b) Easy clean polished lock shields and composition hand-wheels.

Valves not normally exposed to view shall be fitted with cast metal hand wheel or lock shields.

C9.11.8 Straight pattern valves shall be of the full-way gate type. Angle valves shall have domed discs designed to offer minimum resistance to flow.

C9.11.9 Regulating valves on circuits shall have characterised plugs and a lockable spindle with an indicator to show the proportional opening.

C9.11.10 Lock-shield valves shall have easy-clean shields or enclosures to match with the inlet valves; a minimum of 2 loose keys shall be provided for each size of valve spindle used on the Contract. Where indicated, the lock-shield valves shall have characterised plugs as for the regulating valves.

C9.11.11 Isolating valves, lockable where indicated, shall be of the following types: -

(a) Full way gate type except for valves with side pressure tapping of up to 50 mm size which shall be of the oblique type; and

(b) Parallel or taper plug type.

C9.11.12 Full way gate valves shall have metal wheel handles. Wedge gates and all seating, including the top of the wedge and the associated back seat of the bonnet facing, shall be accurately machined, or alternatively designed to provide a back seating. Plug valves shall be arranged for 90^{o} operation with stops on the valve body to limit movement. Lubricated plug valves shall incorporate a check device in the plug for the retention of lubricant applied under pressure. A spare charge of lubricant shall be provided for each valve.

SECTION C10

SYSTEM MONITORING INSTRUMENT

C10.1 GENERAL

The content related to electrical control shall be read in conjunction with Sections C4, C5 and C7.

The system monitoring instrument in this Section shall also meet with the requirements as stipulated in the Guidance Notes for Management of IAQ in Offices & Public Places and the Guide for Participation in the IAQ Certification Scheme published by the HKSAR Government.

Scale ranges shall be appropriate for indicating the extreme values, on and off state, of the plant. The design maximum operating condition shall be indicated at not less than 75% of the total scale length.

Where required in the Particular Specification, all signals generated from the instruments and devices shall be suitable to work in conjunction with a Central Control and Monitoring System (CCMS).

C10.2 SYSTEM STATIC PRESSURE GAUGES FOR AIR DISTRIBUTION SYSTEMS

System static pressure gauges shall be of the single limb inclined manometer type with an accuracy of ±3%.

C10.3 THERMOMETERS - AIR IMMERSION

Thermometers shall be of the mercury-in-glass type of at least 150 mm long with accuracy of ±0.5ºC.

C10.4 THERMOMETERS - LIQUID IMMERSION

Thermometers shall be of the mercury or alcohol-in-glass type of at least 150 mm long with accuracy of ±0.5ºC.

Unless otherwise specified, material of thermometer pocket shall be of stainless steel AISI 316.

C10.5 PRESSURE GAUGES FOR WATER SYSTEMS

Pressure gauges shall comply with BS EN 837-1:1998 calibrated in kPa from zero to not less than 1.3 times and not more than twice the operating pressure of the respective equipment/system and shall be accurate to 1.5% of full scale reading, unless otherwise specified.

The dials of gauges shall not be less than 100 mm diameter and the cases shall be of polished brass or chromium-plated or anti-corrosive painted mild steel with optical sight glass.

Pressure gauges used solely to indicate the head and pressure of water shall be provided with an adjustable red pointer set to indicate the normal working pressure or head of the system.

C10.6 PITOT STATIC TUBE

The flow sensing device shall be of the annubar type in compliance with BS ISO 3966:2008 and BS ISO 7194:2008, inserted through the wall of the pipe via suitable bush supplied by the sensing device's manufacturer.

The equipment shall be manufactured by a reputable and proven manufacturer and shall receive the Supervising Officer's approval before installation.

Each pitot static sensor shall be permanently marked externally with the direction of flow.

C10.7 ORIFICE PLATE METERING

Where these are to be installed the orifice plates shall be of stainless steel and of the well-established manufacturer's make with proven performance characteristics in compliance with ISO 5167-1:2003 or BS 7350:1990. The resistance across the plant orifice shall not exceed 5 kPa (0.05 bar).

The plate shall have two-valves tappings for connection to manometer or responder meter, etc., similar to that described in Clause C10.6 above.

C10.8 ELECTROMAGNETIC AND ULTRASONIC FLOWMETERS

The flowmeter shall be of the direct reading type, i.e. in l/s, and shall be suitable for the chemical and physical properties of the fluids to be measured and suitable for both horizontal and vertical installations.

Each flowmeter shall consist of the flow sensor, an integral signal converter/ transmitter and a digital display unit. The flow sensor shall be installed in the water pipework without obstructing the flow. The protection class of the sensor and converter/transmitter housing shall be at least to IP 67 and IP 65 respectively. The flowmeter shall have a constant accuracy to a maximum error of ±0.5% of the actual flow for flow velocity of greater than or equal to 0.5 m/s. The installation of the flowmeter shall be as per the manufacturer's recommendation with sufficient length of straight pipe run both at the upstream and downstream piping.

The flowmeter shall conform to BS EN 61000-6-1:2007, BS EN 61000-6-2:2005, BS EN 61000-6-3:2007+A1:2011 and BS EN 61000-6-4:2007+A1:2011 or

similar international standards on Electro-magnetic Compatibility (EMC) compliance for industrial and commercial applications.

C10.9 ENERGY METERS

The calculator unit of an energy meter shall calculate and display digitally the water enthalpy consumption in kWh with an accuracy to a maximum error of ±1.5% throughout the range of measurement. The number of digits of accumulated enthalpy consumption display shall not be less than six. The housing protection for the microprocessor and calculator unit shall not be less than IP 54. The requirement for the temperature sensors and the flowmeter shall be as specified elsewhere in this General Specification.

Signal connection facilities to the CCMS shall be provided for displaying the energy consumption computed and the flow rate and temperature readings.

The requirements of energy metering shall comply with the Code of Practice for Energy Efficiency of Building Services Installation (2018 Edition), but not limited to the following:

A chiller, heat pump or unitary air-conditioner, of 350 kW or above cooling/heating capacity, should be equipped with continuous monitoring facilities to measure its power (kW) & energy (kWh) input, cooling/heating power (kW) & energy (kWh) output and coefficient of performance.

A chilled/heated water plant, of 350kW or above cooling/heating capacity, should be equipped with continuous monitoring facilities to measure its power (kW) & energy (kWh) input, and cooling/heating power (kW) & energy (kWh) output, such that the plant's coefficient of performance can be determined.

It is acceptable to make use of the manufacturer's curve or data indicating the chiller's flow rate and pressure drop relationship to obtain the chilled water flow rate based on its pressure drop through the evaporator, and likewise to obtain the heated water flow rate based on the flow's pressure drop through the heat pump's condenser.

In determining a chilled water plant's power & energy input, the inputs to all equipment for producing the cooling output, such as chiller compressors, circulation pumps of condensers or cooling towers, condenser fans, cooling tower fans, radiator fans etc. should be included, whereas the inputs to chilled water pumps should be excluded. Likewise for a heated water plant, the inputs to all equipment for producing the heating output, such as heat pump compressors, circulation pumps on heat input side of water source heat pumps, fans of air source heat pumps, boilers or hot water heaters etc. should be included, whereas the inputs to heated water pumps should be excluded.

The measurement parameters as stated in clauses 6.13.1 and 6.13.2 of the Code of Practice for Energy Efficiency of Building Services Installation (2018 Edition) should be trended every 15 minutes and include hourly, daily, monthly, and annual data. The monitoring facilities should be capable of maintaining all data collected for a minimum of 36 months.

For each of an air handling unit, with motor rated at 5 kW or above, being accommodated in plant room, metering devices or the provision of measurement should be provided for measurement of power (kW) consumption of the air handling unit.

SECTION C11

THERMAL INSULATION

C11.1 GENERAL

C11.1.1 Thermal insulation shall comply with the requirements of BS 5422:2009 and BS 5970:2012 or other statutory standards such as IEC, ISO and etc. or equivalent.

C11.1.2 Unless otherwise indicated, all thermal insulating materials used within any building shall, with fire performance of Class "O" as stipulated in BS 5422: 2009. The definition of Class "O" (national class) shall be referred to Annex E of BS 5422:2009. A class "O" (national class) material is one which: -

(a) has a Class 1 surface spread of flame rating in accordance with BS 476-7:1997 and has a fire propagation index of (I) of not more than 12.0 and a sub-index (i_1) of not more than 6.0 in accordance with BS 476-6:1989+A1:2009; or

(b) is of limited combustibility in accordance with "Materials of limited combustibility" (E.2 of Annex E, BS 5422:2009); or

(c) is non-combustible in accordance with Non-combustible materials (E.1 of Annex E, BS 5422:2009).

Test reports to substantiate the fire properties of the insulation material shall be issued by laboratories by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved.

C11.1.3 The insulation used for the air conditioning installation is "air" insulation which shall satisfy the following: -

(a) Adequate strength and rigidity to maintain the thickness of air;

(b) Creating adequate number of closed air cells within the material to minimise heat loss due to convection and conduction; and

(c) Covered on exposed surface with good quality foil to stop heat loss from radiation.

C11.1.4 Insulation materials and their finishes shall be free from asbestos. Where any work is carried out on existing insulation material or finish which contains asbestos in any form the A/C Contractor's attention is drawn to the responsibilities under the provisions of the Asbestos Regulations current in the Hong Kong SAR at the time of the works. The A/C Contractor shall also notify the Supervising Officer should the presence of asbestos be suspected.

C11.1.5 Insulation materials and finishes shall be inherently proof against rotting, mould and fungal growth and attack by vermin, be non-hygroscopic and in all respects not inducing or leading to corrosion to pipe work and ductwork and be suitable for continuous use throughout the range of operating temperatures and for the environment indicated.

C11.1.6 The A/C Contractor shall bear the cost and provide relevant certificates from laboratories by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved in order to prove the physical properties of the insulation to be used in the projects are conforming to the specification.

C11.1.7 The A/C Contractor shall prove with supporting documents or relevant test certificates from a reputable and proven manufacturer that the insulation materials are compatible with metallic elements, e.g. steel pipes and G.I sheets, and can remain constant or are stable enough throughtout the working life. The Supervising Officer's approval shall be obtained before installation.

C11.1.8 The installation procedures and details of the insulation materials shall be as per the manufacturer's recommendation.

C11.2 TYPES OF THERMAL INSULATION MATERIALS

The type of insulation required for a particular installation will generally be indicated in the Particular Specification. Where this is not so the A/C Contractor shall include for the types described herein: -

C11.2.1 Type "A" - CFC & HCFC Free Phenolic Foam Insulation

(a) Factory made phenolic foam products specification: BS EN 14314:2015;

(b) Temperature range: sub-zero to 120°C;

(c) Density: 40 kg/m3 ±10%;

Except at pipe, ductwork and other support points where a higher density load bearing quality insulation shall be used in accordance with the manufacturers' recommendations. In general, phenolic foam sections with 80 kg/m^3 for pipe sizes of up to 125 mm and 120 kg/m^3 for pipe sizes of 150 mm or above and made to the same thickness as the adjacent pipe insulation;

(d) Compressive Strength: 140 kN/m2(BS EN ISO 844:2014);

(e) Thermal Conductivity: 0.022 W/m°C at 20°C mean temperature (BS EN ISO 4590:2016 and BS ISO 1922:2018 or ISO 8302:1991);

(f) Closed Cell Content: 90% minimum (BS EN ISO 4590:2016 and BS ISO 1922:2012 or BS EN ISO 4590:2016);

(g) Vapour Transmission: 10 micron gram meter/Nh at 38°C 88% RH (BS EN ISO 4590:2016 and BS ISO 1922:2012 or ISO 1663:2007); and

(h) Fire Rating: shall have class "O" fire rating and test certificate from laboratories by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved.

The above properties shall be tested independent of facings which shall be factory applied Class "O" double sided reinforced foil vapour barrier for both condensation control and mechanical protection. The external side shall be of white antiglare coating and the internal side shall be of aluminium foil fully adhered to the phenolic foam. Facing with all service jackets on the outside is also acceptable. The surface emittance of the all service jackets shall be 0.7 or greater when tested with ASTM C1371-15 with reference to ASTM E408-13. In addition, the performance of both vapour barriers and all service jacket shall comply with the requirement stipulated at Clause C11.4.2.

C11.2.2 Type "B" - Preformed Rigid Fibreglass Insulation

Where specified the A/C Contractor shall supply and install preformed fibreglass sections of the appropriate size to fit hot water pipework only and capable of accommodating the temperature range for the system without structural failure of the fibres or the bonding agency.

Preformed fibre glass sections shall have a density of not less than 64 kg/m^3 and a minimum length of 0.9 m. Butt joint tape not less than 75 mm shall be used to ensure perfect sealing of the joints between sections.

The thermal conductivity (k value) of the fibreglass shall not be more than 0.033 W/m°C at a mean temperature of 20°C. The fibre diameter of the fibreglass shall be of 4 to 10 micron and fibre length 3 to 6 cm.

All fibreglass insulation shall be completely sealed at all joints. All holes, tears, punctures, etc. made in the vapour barrier shall be completely sealed with the same specified foil tape.

C11.2.3 Type "C" - Flexible (Semi Rigid) Glass Fibre Blanket Type Insulation

This form of insulation shall not be used on pipework.

Insulation used for ductwork shall be semi rigid having a density of not less than 32 kg/m^3 and thickness not less than 38 mm. The fibre

diameter of the fibreglass shall be of 4 to 10 micron and fibre length shall be of 3 to 6 cm.

The thermal conductivity (k value) of the fibreglass shall not be more than 0.036 W/m°C at a mean temperature of 20°C. The thermal resistance (R value) shall be more than 1.08 m^2°C/W.

C11.2.4 Type "D" - Flexible Closed Cell Elastomeric Insulation

Flexible closed Cell Elastomeric Insulation shall be CFC free, in continuous lengths, with factory applied talc coating or on-site applied talc coating on inner surface. Flexible Closed Cell Elastomeric Insulation shall comply with the following requirements:

(a) Factory made flexible elastomeric foam products specification: BS EN14304:2015;

(b) Thermal Conductivity (at 20 ^{o}C mean temperature): <0.04 W/m ^{o}C;

(c) Density:50 to 65 kg/m3;

(d) Water Vapour Permeability (without additional vapour barrier foil): 0.28 micron gram meter/Nh;

(e) Maximum Operating Temperature: > 80 ^{o}C;

(f) No putrefaction and mildew shall form on the insulation material. The water absorption properties of the insulation shall be of not more than 1.5% after 28 days;

(g) The material, including adhesives and all accessories shall have fire properties to Class 'O' as stipulated in BS 5422: 2009. The insulation material shall be a "built-in" vapour barrier and achieve condensation control without any additional vapour barrier foil;

(h) Smoke Visibility (ISO 5659-2:2017); and
The mean specific optical density, Dm shall be less than 500 under all test conditions. The thickness of the test specimen shall be 25 mm and the Dm shall be the maximum value of the specific optical density (Ds_{10}) of the three tests computed at 10 minutes time interval.

(i) Smoke Toxicity:
The results shall comply and in accordance with either of the following standards or equivalent: -

- International Maritime Organisation (IMO) – International Code for Application of Fire Test Procedure: Annex 1 Part 2 – Smoke and Toxicity Test, IMO MSC 307(88); or

- Naval Engineering Specification (NES) 713 (Issue 3) – Determination of the Toxicity Index of the Products of Combustion from Small Specimens of Material.

C11.2.5 Type 'E' - Polystyrene Insulation

Only where specified or approved preformed or slab polystyrene may be used.

Under all circumstances, the material shall be of the type which is defined as "non-self combustible" in order to meet with the requirements of Clause C11.3.

C11.2.6 Type "F" - Hydrous Calcium Silicate (HCS) and Rock Wool Pipe Insulation.

This material is more appropriate to the insulation of hot pipework and other hot metallic surfaces.

Where specified or approved, this material shall be provided in the preformed sections having a top density of 200 kg/m^3 of chemically-reacted calcium silicate combined with mineral fibre, with factory applied jacket.

C11.2.7 Type "G" - Magnesia Insulation

Where specified or approved, this material is appropriate to the insulation of hot pipework and other hot surfaces. It shall consist of 85% magnesia with 15% cement bonding agent applied wet to the hot surfaces allowed to dry out and when the appropriate thickness has been achieved smoothed off, covered with 25 mm spaced wire mesh of 1 mm diameter galvanised steel wire netting reinforcement, covered further with smoothly trowelled cement plaster of 15 mm thickness and painted to an approved colour when dry as described in Clause B11.8.

C11.2.8 Type "H" – Pre-insulated Panel of Foam Insulation with No Ozone Depleting Substances for Construction of Air Ducts

(a)	Temperature range	:	Sub-zero to 80 ^oC;
(b)	Density	:	48 kg/m^3 minimum;
(c)	Compressive strength	:	245kN/m^2 (BS EN ISO 844:2014);
(d)	Thermal Conductivity	:	0.024W/m ^oC at 20 ^oC mean Temperature; and
(e)	Close cell content	:	90% minimum (BS EN ISO 4590:2003 and BS ISO 1922:2012 or BS EN ISO 4590:2003).
(f)	Flexural Rigidity	:	Class R3 (BS EN 13430)

The insulation panel shall be laminated at factory with a minimum of 60-micron thick aluminium foils on both sides. The aluminium foil shall be embossed and coupled with a $2g/m^2$ layer of polyester paint.

The aluminium foil shall comply with the following requirement: -

(a) Aluminium with pureness : 98.8% (Aluminium Alloy ISO 8079:1984);

(b) Thickness :60µm;

(c) Tensile strength (DIN 50154:1980) : > $60N/m^2$; and

(d) Elongation (DIN 50154:1980) : > 8%.

The insulation panel together with the above-specified aluminium foils shall achieve condensation control without any additional vapour barrier foil as stated in Clause C11.4.

C11.2.9 Type "I" – Foaming for Pre-insulated Pipes

Foam insulation used shall be CFC, HCFC and HFC free.

Pre-insulated pipes should be produced in off-site factory using foaming machine by foam injection method between the service pipe and cladding/ outer jacket to ensure the foam insulation forms a strong adhesive bond to the pipe's surface resulting in a firm and seamless insulation enveloping the service pipe.

The foam insulation for pre-insulated pipe shall comply with all of the following requirements:

(a) Temperature range : Sub zero to 80^oC

(b) Density : 48 kg/m^3 minimum;

(c) Compressive strength : $245N/m^2$(BS EN ISO 844: 2014); and

(d) Thermal conductivity : $0.024W/m^oC$ at 20^oC mean temperature; and

(e) Close cell content : 95% minimum (BS EN ISO 4590:2003 and BS ISO 1922:2012 or BS EN ISO 4590:2003)

Galvanized steel or other materials such as aluminium, stainless steel, etc. approved by the Supervising Officer shall be applied as outer jacket/ cladding of the pre-insulated pipe and acts as vapour barrier.

Approved pipe sleeves and pipe collars, and approved fire rated pipe sleeves, collars or barriers shall be provided where necessary and applicable, or the pre-insulated pipes itself having a fire penetration time not less than the structure through which it passes when tested in accordance with BS 476 – 20:1987 for all pre-insulated pipes passing through compartments, walls, floors and any structural openings in compliance with relevant regulations and code of practices. The fire

barriers shall have the same fire resisting rating as the structure through which the pre-insulated pipe passes.

Pre-insulated pipes shall only be supported on the outside of the cladding/ outer jacket and high density load bearing or hard wood block is not required between the service pipe and cladding/ outer jacket. For pre-insulated pipes, cladding/ outer jacket act as a vapour barrier.

The foam insulation of pre-insulated pipe system should be seamless throughout the system and bond tightly with the service pipe and cladding/ outer jacket to minimize condensation.

C11.3 MEASURES TO PREVENT SMOKE, NOXIOUS & TOXIC FUMES PROPAGATION IN EVENT OF FIRE

When requested by the Supervising Officer, proof of fire classification, obtained from laboratories by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved, shall be provided by the A/C Contractor in order to certify that materials in compliance with Clause C11.1.

Under circumstances, where insulation materials have been permitted which do not strictly meet with the fire properties stated in Clause C11.1, the materials shall not be construed as acceptance unless for the following exceptional conditions: -

(a) The sections are secured to the pipework or ductwork with non-flammable or toxic smoke producing adhesives; or

(b) They are wrapped over by 25 mm spaced wire mesh, of 1 mm diameter galvanised steel netting reinforcement, covered further with smoothly trowelled self-netting cement plaster of 15 mm thickness and if required (because they are exposed) painted in accordance with Part G.

Such insulation shall similarly be sealed above the ductwork that is fitted tight and adjacent to the ceilings and beams or at the points near other obstructions.

Where total sealing by 1 mm diameter galvanised steel wire netting reinforcement and cement plaster of 15 mm thickness cannot be achieved, then any form of permission expressed shall not be construed as if such forms of insulation have been permitted.

Permission to use insulation materials that must be sealed with cement plaster in order to avoid generation of toxic fumes and smoke in the event of a fire will only be given under such circumstance that their applications are considered safe by the Supervising Officer.

C11.4 VAPOUR BARRIERS

C11.4.1 Where thermal insulation is applied to the outside of pipework and ductwork, equipment and plant used to convey, store or generate fluids

or gases at temperatures lower than the design ambient dew point temperature indicated, a water vapour barrier shall be provided unless the Particular Specification states otherwise. The vapour barrier where deployed shall be applied such that it is continuous and gives protection to the whole surface of the insulation which it protects.

It shall not be pierced or otherwise damaged by supports or by the application of external cladding.

The insulation on continuous pipework and ductwork shall be sectionalised by vapour barriers to be applied at a maximum of 5 m intervals to isolate condensation problems caused by perforation of external barrier to the affected section.

C11.4.2 Aluminium foil vapour barriers used for insulation of all pipework and ductwork shall conform to the following requirements: -

(a) Machine Direction Tensile Strength (BS EN ISO 1942-2:2008) ≥12 kN/m;

(b) Cross Direction Tensile Strength (BS EN ISO 1942-2:2008) ≥ 9 kN/m;

(c) Bursting Force (AS2001.2.19:1988) ≥ 120N or Bursting Strength ≥ 6 kg/cm^2(BS EN ISO 2758:2014);

(d) Water Vapour Permeance (ASTM E96/E96M-16) ≤ 1.0ηg/Ns; and

(e) Surface emittance of external surface (ASTM E408-13) ≥ 0.7.

C11.4.3 All joints shall be either factory or on job site fabricated. All joints shall allow for 50 mm overlap of vapour barrier and the joints shall be completely sealed using foil tape with a minimum width of 75 mm conforming to the following specifications: -

(a) Tape thickness minimum 38 microns without release paper;

(b) Machine and Cross Direction Tensile Strength (ASTM D882-18) ≥2.0 kN/m;

(c) Peel Adhesion to steel (ASTM D3330/D3330M-04:2010) ≥ 10N/25 mm;

(d) Shear adhesion (BS7116:1990): 31; and

(e) Surface Emittance (ASTM E408-13) ≥ 0.7 or Surface Emissivity (BS 5422) ≥ 0.85 (Paint, white).

Any and all punctures, holes, tears, etc. that can be seen or occur on the job site shall be completely sealed with the same tape as specified above.

C11.4.4 The material chosen for the vapour barrier and its method of application shall be compatible with the thermal insulation on which it is to protect. The following shall be used: -

(a) Wet-applied vapour barriers of the cut-back bitumen type, bitumen emulsions with or without elastomer latex, vinyl emulsions and solvent based polymers;

(b) Elastomer sheets with all joints adequately overlapped and continuously sealed;

(c) Polyvinyl chlorides, polyethylene, polyisobutylene or other plastics tapes or sheets;

(d) Epoxide and polyester resins;

(e) Sheet metal with all joints adequately overlapped and continuously sealed to a vapour-tight condition; or

(f) Metal foil used alone or laminated to building paper, building sheet or plastics film with all joints adequately lapped and continuously vapour sealed.

Facing materials used on insulation materials to provide vapour barrier shall not be more than 0.8 mm thick. All metal foil vapour barrier and foil tape used shall be of Class 'O' as stipulated in BS 5422: 2009.

C11.5 INSULATION THICKNESSES

C11.5.1 Chilled Water Pipe

All chilled water pipes should be insulated with minimum insulation thickness in accordance with Code of Practice for Energy Efficiency of Building Services Installation.

C11.5.2 Refrigerant Pipe

All refrigerant pipes on suction side of refrigeration cycle should be insulated with minimum insulation thickness in accordance with Code of Practice for Energy Efficiency of Building Services Installation.

C11.5.3 Ductwork and/or Plant Equipment Carrying Warmed or Chilled Air

All Ductwork and/or Plant Equipment Carrying Warmed or Chilled Air should be insulated with minimum insulation thickness in accordance with Code of Practice for Energy Efficiency of Building Services Installation.

SECTION C12

UNITARY AIR-CONDITIONER

C12.1 GENERAL

Unitary air-conditioners shall include: -

(a) Single package unit;
(b) Packaged unit and remote condenser;
(c) Condensing unit and blower coils;
(d) Condensing unit with variable refrigerant volume flow and indoor fan coil units;
(e) Multi-split system; and
(f) Water-cooled package and water pump package.

Unitary air-conditioners shall be factory fabricated and assembled. The equipment shall be rated and tested to meet the requirements of internationally recognised quality assurance standards approved by the Supervising Officer.

The most energy efficient model in the series shall be selected for submission and shall be referred to Clause C12.19 of this General Specification.

Refrigerants adoption for refrigeration and air-conditioning system in government building projects shall comply with flammability safety classification in accordance with Clause B6.1 of this General Specification.

C12.2 EQUIPMENT SUITABLE FOR LOCAL ELECTRICITY SUPPLY

Unless otherwise specified, electrical equipment of the unitary air-conditioners shall be suitable for use with 3-phase and neutral, 4-wire, 380/220 V, 50 Hz source neutral earthed system with provision of bonding.

Transformer may be used for equipment designed for operation on voltages other those specified above. Whenever possible, these shall be installed within the unit.

C12.3 SELECTION OF AIR-COOLED CONDENSERS AND CONDENSING UNITS

Air-cooled condensers and condensing units of unitary air-conditioners shall be selected to give rated capacity with condensing temperature not exceeding 50°C for the ambient condition as specified under Clause A3.11 of this General Specification.

C12.4 CASING OF CONDENSING UNIT

Casings of condensing unit of unitary air-conditioners shall be constructed of rigid galvanised sheet steel and painted in accordance with Part G, suitably reinforced with channels and sections to form a robust cabinet. Casing for outdoor installation shall be of weatherproof finish, preferably galvanised, painted or anodised aluminium.

C12.5 COMPRESSOR

Compressors shall be rotary, scroll or reciprocating of either the hermetically sealed type or the semi hermetically sealed type. Compressor shall be complete with internal motor protection, lubrication, crankcase heater, and internal and external vibration isolation.

C12.6 SUPPLY AIR FAN AND MOTOR

Supply air fans shall be centrifugal type of ample sized for operation against the specified static pressure. Fan motors shall be permanently lubricated and have adequate power so as to be non-overloading throughout the range of the fan characteristic. The motor shall be high efficiency motor.

C12.7 COOLING AND HEATING COILS

Cooling coils shall be of the direct expansion type and constructed with copper tubes and aluminium fins to give high heat transfer performance. The coils shall have sufficient number of rows of tubes to provide efficient dehumidification of the air in addition to its cooling.

Heating coil shall be constructed with copper tubes and aluminium fins to give high heat transfer performance.

C12.8 AIR FILTER

Air filters shall unless otherwise specified be of the washable panel type. The filter performance of air duct connection unit shall be referred to Clause C1. Higher filter efficiency shall be adopted to meet with the IAQ objective designed.

C12.9 AIR-COOLED CONDENSERS

Air-cooled condensers shall unless otherwise specified be suitable for outdoor installation with ample capacity to dissipate heat from the air conditioning system. Condenser coils shall be constructed with copper tube and aluminium fins. Special corrosion resistant treatment for the condenser coils and fins shall be considered for the equipment to be located on corrosive environment.

C12.10 ELECTRIC DUCTWORK HEATER

Electric ductwork heaters shall be provided for winter heating or re-heating and designed in accordance with Clause C3.2.14.

C12.11 REFRIGERANT PIPING

External refrigerant piping when required shall include all necessary valves, fitting and insulation. All insulation shall be properly protected with mechanical means such as metallic cladding or cement plastering and painting. Size of the refrigerant pipe and fittings shall be in accordance with the recommended standards as stated in Sections B6 and C6.

C12.12 CONDENSATE DRAIN PIPE

Condensate drain pipe shall be adequate insulated and mechanical protected in accordance with Sections B11 and C11 of this General Specification.

C12.13 SAFETY CONTROL

Controls shall be factory wired. Field wiring in conduit or trunking shall be limited to interconnections between separate pieces of equipment and power wiring. Each unit shall be protected and controlled by a factory built control panel incorporating all necessary devices, switches, indicator, etc. Functions required shall include those such as isolating switches and emergency stop facilities.

Safety protections shall include low pressure cut out, high pressure cut out, low refrigerant temperature cut out, high compressor discharge temperature cut out, and other protections necessary for the proper and safe operation of the unit. Overload protections shall be provided as well.

C12.14 OPERATIONAL CONTROL

For a conventional split type A/C unit, a wired or wireless remote controller shall be provided for the selection of room temperature setting, fan speed and timer setting. For an advance multi-zone modular split type, the remote controller shall be of the liquid crystal display (LCD) type with an on-off switch for operational features such as speed selection, timer setting, temperature setting, self-diagnosis function and auto restart function.

C12.15 SINGLE PACKAGED AIR-CONDITIONER

Single package unit shall be of the completely self-contained type with factory wired controls and factory assembled components and piping. The unit shall include one/two rotary, scroll or reciprocating compressors of either the hermetically sealed or semi-hermetically sealed type, condenser coil, condenser fan and motor, direct expansion cooling coil, blower, air filters, drier of the

renewable cartridge type completed with isolating valve, expansion valve, controls and safety devices all housed in a weather-proof and metal casing of robust construction yet attractive appearance.

C12.16 PACKAGED AIR-CONDITIONER WITH REMOTE CONDENSER

The unit shall contain all components factory assembled, (as the single packaged unit with the exception of the condenser), in a sturdy painted G.I. metal casing arranged for vertical or horizontal mounting inside the building.

C12.17 SPLIT CONDENSING UNIT AND AHU

The condensing unit shall include rotary, scroll or reciprocating compressors, air-cooled condensing coils, fans and motors control and safety devices, piping and all necessary accessories factory assembled in a weatherproof painted G.I. casing. The refrigerant circuit shall be field connected to the matched AHU or fan coil units each completed with direct expansion cooling coil, expansion valve, blower with motor and the necessary number of air filters in a well-insulated, sturdy G.I. metal casing with paint to an attractive appearance.

C12.18 VARIABLE REFRIGERANT FLOW SYSTEM

The air conditioning system shall be of the multi-zone modular split type. Each zone shall consist of one air-cooled outdoor condensing unit connected to a group of indoor fan coil units in one single refrigerant circuit. For multi compressors outdoor unit, one shall be inverter control compressor. The inverter compressor shall be incorporated with a frequency inverter control to achieve the optimum flow of refrigerant in response to the actual load.

C12.19 ENERGY EFFICIENCY PERFORMANCE

All unitary air conditioners shall be selected aiming for the highest operation efficiency. The minimum Coefficient of Performance (COP) for Air-Cooled Unitary Air Conditioner and Water-Cooled Unitary Air Conditioner shall comply with the requirement as specified in Code of Practice for Energy Efficiency of Building Services Installation (2018 Edition).

SECTION C13

WATER HANDLING EQUIPMENT

C13.1 FRESH WATER PUMPS

C13.1.1 Type

(a) Pumps for chilled water circulation or other fresh water pumping duties unless otherwise specified, shall be of one of the following types: -

(i) Centrifugal type with volute casing split on the centreline of the shaft with suction and delivery connections flanged and fitted to the non-removable half of the casing;

(ii) End suction type, the pump set shall be installed with spacer type coupling so that the pump impeller can be dismantled from the motor side for servicing without disruption of the pipe-work nor dismounting the motor; or

(iii) Vertical spindle type centrifugal pump installed on pump plinth or supported by pipework.

(b) Where large static heads have to be pumped against, type (a)(ii) or (a)(iii) shall be used in multi-stage configurations. Generally, the type of pump required will be specified in the Particular Specifications and/or in the Tender Drawings. However, if this is not so, the type as detailed in (a)(ii) above shall be installed if suitable.

(c) Motor efficiency for the pumps shall be of minimum IE4 under International Efficiency (IE) classes according to IEC 60034-30-1.

C13.1.2 Materials of Construction

Unless otherwise specified, the materials of construction of the pumps shall be as follows: -

(a)	Casing	:	Cast iron
(b)	Impeller	:	Stainless steel / Zinc free bronze (*cast iron or stainless steel)
(c)	Shaft	:	Carbon steel (*stainless steel)
(d)	Sleeves	:	Bronze (*stainless steel)
(e)	Casing rings	:	Bronze (*stainless or cast iron)
(f)	Shaft nuts	:	Bronze
(g)	Stuffing box housing	:	Cast iron

*Alternative materials subject to the approval of the Supervising Officer

Note 1: Stainless steel shall be used for water with temperature >28^{o}C.

C13.1.3 Standards

(a) Casing Material

Unless otherwise specified for the above types of pumps, cast iron shall comply with BS EN 1561:2011 or ISO 185:2005.

(b) Impellers & Guide Rings

The impeller shall be of the enclosed type and be of stainless steel, Leaded Gunmetal to BS EN 1982:2017 or ISO 197-4:1983, keyed to the shaft. Renewable guide rings shall be bronze and shall be provided in the casing, keyed to prevent rotation.

(c) Shaft, Sleeves and Glands

Stainless steel shall be to BS EN 10095:1999, BS EN ISO 683-3:2018 and BS EN ISO 683-4:2018, ground and polished.

Bronze sleeves shall comply with BS EN 1982:2017 or ISO 197-4:1983 and shall be provided through the sealing glands to protect the shaft from wear. The sleeves shall be keyed to prevent rotation and secured against axial movement.

(d) Stuffing Boxes and Drain Piping

Cast iron stuffing boxes housing shall comply with BS EN 1561:2011 or ISO 185:2005 and shall be of ample length with bronze lined gland and neck bush, fitted with approved packing and lantern ring water seal. Drain piping to the nearest builder's drain to remove gland leakage shall be provided. Alternatively, a mechanical seal may be offered. Mechanical seals shall be of leak free operation. The mechanical seal shall be the product of specialist proprietor and the materials used shall be suitable for the pumped liquid.

C13.2 SALINE WATER PUMPS

C13.2.1 Type

(a) These pumps shall be utilised for pumping seawater, brackish well water, or treated effluent water wherever these applications apply.

(b) Unless otherwise specified, the configuration of saline water pumps inside a building plant rooms shall be of the split casing type as specified in Clause C13.1.1 (a)(i) while for installation in the primary harbour side sea water pump chamber, pumps shall generally be of the vertical spindle type as specified in Clause C13.1.1 (a)(iii).

C13.2.2 Materials of Construction

Unless otherwise specified, the materials of construction for saline water pump shall be as follows: -

(a) Casing:Stainless Steel

(b) Impeller:Stainless Steel

(c) Shaft:Stainless steel

(d) Sleeves:Stainless steel

(e) Casing rings:Stainless steel

(f) Shaft nuts:Stainless Steel

(g) Stuffing box housing:Stainless Steel

(h) Glands:Carbon steel

(i) Lantern rings:Bronze

Note 1:Stainless steel shall be used for water with temperature >28^{o}C.

C13.2.3 Standards

(a) Casing

Unless otherwise indicated, the casing shall be of cast iron to BS EN 1561:2011 or ISO 185:2005 or better and approved.

(b) Impeller and Shaft Sleeve

Impeller and shaft sleeve of saline water pumps shall be of one of the materials as below:-

(i) Zinc-free bronze to BS EN 1982:2017 Grade PB1; or Grade CT1; or ISO 197-4:1983;

(ii) Austenitic cast iron to BS EN 13835:2012 Grade F1; or ISO 2892: 2007/Cor 1:2009; or

(iii) Stainless steel to BS EN 10095:1999, AISI 316.

(c) For pumping seawater in harbour area, items (b) (i) & (ii) above shall not be used.

(d) The shaft shall be of stainless steel to BS EN 10095:1999, BS EN ISO 683-3:2018 and BS EN ISO 683-4:2018, AISI 316, ground and polished.

(e) Stuffing Boxes and Drain Piping

Stuffing boxes shall be of cast iron housing and ample length completed with bronze lined gland and necks bushes, fitted with approved packing and bronze lantern ring water seal. Drain piping to the nearest builder's drain for gland leakage shall be provided. Alternatively, a mechanical seal may be offered. Mechanical seals shall be of leak free operation. The mechanical seal shall be the product of specialist proprietor and the materials used shall be suitable for the pumped liquid.

C13.3 BOILER FEED PUMP

Unless otherwise specified, all feed pumps for boilers handling hot water at 175°C and above shall have the major parts, i.e. casing, impeller, shaft and wearing rings made of stainless steel to AISI 316.

C13.4 SUMP PUMP

C13.4.1 Materials of Construction of Dry Pit Pumps

Unless otherwise specified, the materials for dry pit non-clog pumps areas shall be as follows: -

(a) Pump casing:Cast iron

(b) Impeller:Cast iron (*stainless steel)

(c) Shaft:Stainless steel

(d) Shaft sleeve:Stainless steel (*bronze)

(e) Packing gland:Ductile iron (*bronze)

(f) Casing bolts:Steel

(g) Cap screw and :Stainless Steel washer, impeller

(h) Key, impeller:Steel

*Alternative materials subject to the approval of the Supervising Officer

C13.4.2 Materials of Construction of Submersible Pumps

Unless otherwise specified, the materials for submersible non-clog pumps shall be as follows: -

(a) Pump casing:Cast iron

(b) Impeller:Cast iron (*stainless steel)

(c) Motor casing:Cast iron

(d) Shaft:Stainless steel

(e) Impeller screw:Stainless steel

(f) Mechanical seals:Carbon (*ceramic faces)

(g) Base plate:Steel

(h) Discharge elbow:Cast iron

(i) O-ring seal:Neoprene

*Alternative materials subject to the approval of the Supervising Officer

C13.4.3 General Requirements

All bolts nuts and fasteners shall be of stainless steel and electric cable entry shall be of watertight construction.

Sump pumps for rainwater application shall generally be of materials complying with Standards as specified in Clause C13.1.3. Sump pumps for pumping other fluids shall be of materials compatible with the fluid that are being handled. If sea water is pumped, the pump materials shall comply with Standards as specified in Clause C13.3.3. The sump pumps shall operate automatically by float level control.

The guide bars and brackets for wet sump installation shall be of stainless steel to AISI 316.

Cable supports shall be of stainless steel. A safety provision shall be incorporated for automatic electrical disconnection of the supply in case of cable entry seal failure.

Pumps for flammable zones shall be equipped with flameproof submersible motor in compliance with BS EN IEC 60079-0:2018 and BS EN 60079-1:2014.

C13.5 BORE WELL PUMPS

All bolts, nuts and fasteners shall be of stainless steel and electric cable entry shall be of watertight construction.

Bore well pumps unless otherwise specified shall be of all stainless steel construction. The stainless steel shall be of Grade 304 for fresh water application while AISI 316 stainless steel shall be used for other water applications.
The level switch shall be of the maintenance free mercury type or electrode type.

C13.6 PUMP BASE PLATE

The based plate shall be made of cast iron or fabricated mild steel. Couplings shall be flexible of the steel pin and synthetic rubber bushing type, and fitted with steel guards.

C13.7 VALVES

Automatic air valves, butterfly valves, check (non-return) valves and float ball valves, etc., shall be as specified in Section C9.

C13.8 VIBRATION ISOLATORS

The bases shall be mounted on the raised housekeeping plinth using appropriate anti-vibration spring mountings that shall be individually selected according to load distribution and shall have an additional free travel equal to one half of the rated deflection as specified in Clause C8.3.

C13.9 GAUGES

Gauges shall be in accordance with Clause C10.5.

C13.10 DRAIN AND VENT

The drain vent shall be built-in completed with a drain plug except where the pump is inherently self-venting, the drain and drip connection valves and air cock shall comply with Section C9.

C13.11 FLANGED CONNECTIONS

Pumps shall have flanged connections conforming to the Table of BS EN 1515-1:2000, BS EN 1092-1:2018, BS EN 1092-2:1997, ISO 7005-1:2011 or ISO 7005-2:1988 as appropriate to the maximum working pressure. Taper pieces shall be provided where necessary for connection to pipe-work.

C13.12 WATER FILTERS

The materials used in water filters shall not corrode or cause corrosion in the water and shall generally be as specified for water-cooled condensers and water chillers.

C13.13 AUTO STRAINERS

The strainer shall be completed with a motor-controlled continuously rotating inner drum or stationary drum and equipped with an automatic backwash arrangement.

The unit body shall be provided with an inspection opening for visual checking. In addition, a drain opening with drain valve shall be provided at the lower part and connected to the nearest floor drain.

The straining element /screening drum shall be of stainless steel AISI 316 and shall be of the type and size suitable for removal of captured materials as specified in the Drawing/Particular Specification. A drip proof squirrel cage motor shall drive the inner drum, if the strainer is a rotating drum design, or to drive the rotating backwash arm if the strainer is a stationary drum design, with suitable geared facilities that shall be mounted on the top of the strainer body.

The body of the auto-strainer shall be of stainless steel AISI 316 cast iron to BS EN 1561:2011, ISO 185:2005, ASTM A278 Class 40 or carbon steel to BS EN 10095:1999, BS EN ISO 683-3:2018 or BS EN ISO 683-4:2018. Body of carbon steel shall be provided with internal coating or lining recommended by the strainer manufacturer and with zinc sacrificial anodes. It houses a rotating tapered drum attached to stainless steel shaft of AISI 316 or a stationary drum with rotating arm driven by stainless steel shaft of AISI 316 and backwash mechanism. The unit shall be suitable in operation under a pressure of 1034 kPa. Auto-strainer for handling sea water shall have its body of duplex stainless steel to ASTM A240 or EN 1.4410 or austenitic grey cast iron to ASTM A436 Grade 1B, or otherwise the materials of construction as specified in the Particular Specification of the Contract.

The automatic control of backwash arrangement shall comprise a motor-controlled valve on the outlet and an adjustable timer and differential pressure switch set to a maximum pressure drop allowed to regulate the frequency of backwash. Such control shall interface with the Central Control and Monitoring System (CCMS) if available.

C13.14 FEED AND EXPANSION FACILITY

C13.14.1 General

For the purpose of this General Specification, the following definitions shall apply: -

(a) Cistern - An open top vessel; and

(b) Water Tank - A closed vessel.

C13.14.2 Types of Cistern and Tank

(a) Cisterns and tanks shall be of one of the following types as below: -

(i) Welded or riveted mild steel, to BS 417-2:1987 Grade A, hot-dip galvanised after manufacture;

(ii) Pressed steel sectional to BS 1564:1975, heavily galvanised after manufacture; or

(iii) Fibre-glass or plastics, for cisterns not exceeding 500 litre capacity to BS 4213:2004.

(b) Pressed steel tanks shall be of the externally flanged type and completed with all necessary tie rods. Galvanised mild steel cisterns and pressed steel tanks shall be cleaned and painted internally with two coats of an approved bituminous or epoxy solution or shall receive other such internal treatment as indicated in the contract Drawings or Particular Specification.

(c) Covers to Cisterns

Each cistern shall be provided with a loose cover formed in sections not exceeding 2 m long and 1 m wide. Covers for plastic or fibre-glass cisterns shall be of the same material as the cistern body.

(d) Connections

Connections to mild steel cisterns and tanks shall be made by means of bossed, screwed flanges or pads and studs. Connections on mild steel cisterns shall be welded before galvanising. Flanges shall comply with BS EN 1092-1:2018 or ISO 7005-1:2011, ISO 7005-2:1988 and ISO 7005-3:1988.

C13.15 PLATE TYPE HEAT EXCHANGERS

The specification of plate type heat exchangers shall be in accordance with Clause C6.16 of this General Specification.

PART D - INDOOR AIR QUALITY (IAQ)

D1 GENERAL

The specifications stated in this section shall be the cleanliness standard of outdoor air to be introduced into the building, the requirements on the indoor air quality objectives suitable for different types and uses of buildings and for different levels of comfort and health for the occupants, the treatment and conditioning processes of air, the equipment/materials for treatment and conditioning, the testing and commissioning of the system, the methodologies of assessing indoor air quality, the licensing/registration requirement, the training requirements of qualified IAQ workers, the operation and maintenance relating IAQ issues, and the housekeeping and energy efficiency relating to IAQ issues.

This General Specification shall apply to all buildings or totally enclosed areas provided with air-conditioning and mechanical ventilation installations (ACMV) for human comfort.

The requirements of the specification shall in any case fulfil the requirements as published by the Environmental Protection Department.

The specifications shall not in any way provide exemption from existing legal obligations relating to indoor air quality. Legal provisions on ventilation and certain other factors affecting indoor air quality in buildings are contained in the following Regulations: -

- Building (Planning) Regulations, under the Buildings Ordinance (Cap. 123);
- Ventilation of Scheduled Premises Regulation, under the Public health and Municipal Services Ordinance (Cap. 132);
- Places of Public Entertainment Regulations (Cap. 172);
- Air Pollution Control Ordinance (Cap. 311);
- Smoking (Public Health) (Amendment) Ordinance (Cap. 371);
- Consumer Goods Safety Ordinance (Cap. 456);
- Ozone Layer Protection Ordinance (Cap. 403);
- Pesticides Ordinance (Cap. 133); and
- Occupational Safety & Health Ordinance (Cap. 509).

The overall quality of indoor air is influenced by thermal acceptability and air contaminants. The thermal acceptability includes temperature, humidity and air movement. The air contaminants include airborne particles (Respirable Suspended Particulates), volatile organic compounds (VOC), tobacco smoke, asbestos, formaldehyde, radon, combustion gases, ozone, respiratory products and body odours, and micro-organisms.

A building fitted with air-conditioning and mechanical ventilation (ACMV) system shall be provided with a natural or mechanical ventilation system to introduce and distribute outdoor air with acceptable quality. For these buildings,

the factors which determine the adequacy and quality of the air supplied by the ACMV system are: -

- The quality of outdoor air;
- The outdoor air intake rate;
- The performance of air filters and cleaners;
- Siting of ventilation equipment;
- The recirculation rate;
- Thickness and thermal value of insulation;
- Effectiveness of air distribution systems;
- Variable air volume system controls on minimum fresh air intake rate;
- Ventilation controls;
- Humid climatic conditions;
- The ventilation rate of pollution-emitting activities; and
- Ventilation rates.

The list shown above is not exhaustive and the A/C Contractor shall assess the site condition and compile a check list for ventilation for submission to the Supervising Officer for endorsement.

The level of emission and design parameters of indoor air quality shall meet the requirements as generally described in Clauses D3 and D4. The paints and painting works for air-duct and finishes shall comply with IAQ relevant requirements and standards.

IAQ control and sensor requirements shall be as detailed under Part E: Energy Efficiency and Energy Conservation; Section B4: Installation Methodology of Automatic Control and Section C4: Material and Equipment specification of Automatic Control.

To prevent the ingress of containment from outside, a net positive pressure should be maintained inside the building. The exact requirement of pressurisation shall be in according to the specific requirements as stipulate in the Particular Specification. Unless otherwise specified in the Particular Specification, pressure sensors shall be installed on each floor of the building to monitor and control the fan output so as to maintain the specified positive pressure. Such requirements are exempted for those buildings where negative inside pressure is required and specified in the Particular Specification.

Unless otherwise stated in the Particular Specification and/or Drawings, for single chiller system, at least one condensing circuit shall incorporate heat reclaim function. For multi-chillers, at least one chiller shall perform as heat pump. For only heat pumps arrangement, the heat pumps shall have both heating and chilling functions. For VRV units alone, the VRV units shall cover both heating and chilling functions.

All internal surfaces including walls, floors, ceiling and equipment plinth of AHU and fan rooms shall be treated with epoxy paint. All sealing with

fibreglass/rock wool for vibration isolation sealing across structural wall/floor/ceiling shall be caulked airtight and properly sealed with approved means.

D2 OUTDOOR AIR QUALITY

The A/C Contractor shall select air cleaning and air treatment equipment for the control of IAQ based on the measured outdoor air quality as stated in the Particular Specification, or as indicated in Table D2, whichever is worse. Prior to selection of equipment for the Installations as specified in the Particular Specification, the outdoor air quality shall be verified again an independent party appointed by the A/C Contractor. In case of discrepancy, the A/C Contractor shall submit proposal for approval to rectify the outdoor air conditions in meeting the minimum standard as shown in Table D2.

Table D2 Outdoor Air Quality Objectives
(Maximum Acceptable Concentration Level)

Pollutant	Concentration in micron gram/m^3(i) (vii) Averaging Time			
	1 hr (ii)	8 hrs (iii)	24 hrs (iii)	1 yr (iv)
Respirable Suspended Particulate (PM_{10})(v)			180	55
Nitrogen Dioxide	300		150	80
Carbon Monoxide	30,000	10,000		
Photochemical Oxidants (as ozone) (vi)	240			

(i) Measured at 298K (25ºC) and 101.325 kPa (one atmosphere)

(ii) Not to be exceeded more than three times a year

(iii) Not to be exceeded more than once per year

(iv) Arithmetic means

(v) Respirable suspended particulates mean particles suspended in air with a nominal aerodynamic diameter of 10 micron meter or less

(vi) Photochemical oxidants are determined by measurement of ozone only

(vii) Formula for conversion from micron gram/m^3 to ppm for gases is as follows: -

$$\text{ppm} = \frac{(\mu g)/\text{m}^3 \text{ x } 24.45}{1000 \text{ x MW}}$$

where MW = molecular weight of gas

The outdoor air intakes shall be located where the air induced shall be the cleanest taking into account any sources of contaminants which are close to or at upwind

of the intake. No rectification work is required if outdoor air data measured is below concentration level shown in Table D2.

D3 DESIGN PARAMETERS OF INDOOR AIR QUALITY

The indoor air quality objectives and levels of achievement shall be in following the Guidance Notes as published by the Environmental Protection Department or other recognised Authority as specified in the particular specification.

The indoor air quality objectives will not be applicable to any part of the building such as plant rooms and switch rooms or places where only mechanical ventilation is specified.

D4 INSTALLATION – PART B: TREATMENT AND CONDITIONING PROCESS

Air cleaning is usually most effective when used in conjunction with either source control or ventilation. Most air cleaning in large buildings is aimed primarily at preventing contaminant buildup in ACMV equipment and enhancing equipment efficiency. Air cleaning equipment intended to provide better indoor air quality for occupants must be properly selected and designed for the particular pollutants being treated.

Table D4 Treatment and Conditioning Processes for achieving different IAQ Parameters

IAQ Parameters	Treatment and Conditioning Processes
Carbon Dioxide	Dilution by Outdoor Air
Carbon Monoxide	Dilution by Outdoor Air
Respirable Suspended Particulate	Particulate Filtration Electrostatic Precipitation High Efficiency Filtering
Nitrogen Dioxide	Electronic Air Cleaner
Ozone	Dilution/Purging by Outdoor Air Activate Carbon Filter
Formaldehyde	Electronic Air Cleaner
Total Volatile Organic Compound	Electronic Air Cleaner
Radon	Purging by Outdoor Air Activate Carbon Filter
Airborne Bacteria	Germicidal Ultraviolet Air Steriliser
Room Temperature	Heating /Cooling
Relative Humidity	Dehumidifier / Humidifier

D4.1 Particulate Filtration

Particulate filtration removes the air-borne respirable suspended particulates. In order to achieve the required level of filtration, it is necessary to combine filters in different stages to achieve multi-stage filtration. There are usually three stages: - the first stage or primary, the secondary, and the final stage in which high efficiency particulate arrestance (HEPA) filters are used to capture fine particles smaller than 1.0 micron meter.
The primary filter is normally exposed to the full velocity of the air stream and is normally dry panel or a panel consisting of washable filter elements. The secondary stage which normally comprises roll or bag filters covers an extended surface area to reduce air velocity through the media to about 0.12 m/s. The final stage comprises HEPA filters which are normally pleated to increase surface area so as to reduce the air velocities through the media to about 0.03 m/s.

This multi-stage filtration is used not only because of the cleanliness of air required but it also prolongs the life of the filter unit of each stage hence reduces the maintenance cost of the filtration system.

D4.2 Electrostatic Precipitation

Electrostatic precipitation uses the attraction of charged particles to oppositely charged surfaces to collect airborne particulates. In this process, the particles are charged by ionising the air with an electric field. The charged particles are then collected by a strong electric field generated between oppositely charged electrodes. Electrostatic precipitation provides relatively high efficiency filtration of small respirable particulates at low air pressure losses. Electrostatic precipitators may be installed in air distribution equipment or in specific usage areas.

D4.3 Germicidal Ultraviolet Air Steriliser

Germicidal, or short-wave ultraviolet has wavelength band between 200 nm and 300 nm. Germicidal ultraviolet is primarily intended for the destruction of bacteria and other micro-organisms, like mould and spores in the air or on exposed surfaces. The exposure of germicidal ultraviolet necessary to kill bacteria is proportional to exposure time and the intensity of ultraviolet. The inverse square law applies to the germicidal ultraviolet, that is, the killing power decreases as the distance from the lamps increases.

D4.4 Electronic Air Cleaners

Electronic air cleaners work on the principle of ionisation created by an electromagnetic field known as corona discharge. In the ionisation process, neutral oxygen atoms or molecules are electrically charged and converted to negative and positive ions. The negative ions help to reduce or eliminate airborne micro-organisms, organic smells and,

volatile organic components. Electronic air cleaners should maintain purification efficiency of not less than 85% total bacteria count.

D4.5 Physical Adsorbers on Ozone and Radon

Adsorption is a surface phenomenon, similar in many ways to condensation. Pollutant gas molecules that strike a surface and remain bound to it for an appreciable time. The adsorbers are in granular of fibrous form to increase the gross surface exposed to an airstream. The surface of the adsorber is treated to develop pores of microscopic dimensions, which greatly increase the area available for molecular contacts. Typical adsorber media are treated activated alumina and carbon.

Activated carbon adsorbs ozone readily, both reacting with it and catalysing its conversion to oxygen.

Radon is a radioactive gas that decays by alpha-particle emission, eventually yielding individual atoms of polonium, bismuth, and lead. These atoms form extremely fine aerosol particles called radon daughters or radon progeny, which are also radioactive; they are especially toxic in that they lodge deep in the human lung where they emit cancer-producing alpha particles. Radon progeny, both attached to larger aerosol particles and unattached, can be captured by particulate air filters. Radon gas itself may be removed with activated carbon but in ACMV systems, this method costs too much for the benefit derived. Control of radon emission at the source and ventilation is the preferred method of radon control.

D5 EQUIPMENT/MATERIALS – PART C: TREATMENT AND CONDITIONING MEDIA

D5.1 Outdoor Air Pre-conditioner

All dehumidifiers specified in the Particular Specification shall comply with the minimum energy efficiency as specified in this General Specification unless otherwise specified in the Particular Specification. The outdoor air pre-conditioner system employing wasted energy recovery equipment shall conform to the followings: -

D5.1.1 Specification of Desiccant Type Outdoor Air Pre-conditioner

(a) General

The pre-conditioner shall comprise a 3Å molecular sieve Potassium Aluminosilicate coated total energy wheel, an exhaust fan, an outdoor air fan and air filters in both fresh and exhaust streams (upstream of the fan). These components shall be housed in a common insulated casing and shall be suitable for mounting in any orientation.

(b) Casing

(i) The casing shall be constructed from 1 mm (Gauge 20) galvanised steel sheet with epoxy powder coating. The interior shall be insulated with at least 12 mm thick insulation material in order to prevent condensation on the interior and exterior of the casing.

(ii) Removable access panel of suitable size shall be provided for replacement of filters and inspection of fans and wheel. The access panels shall be perfectly sealed and hinged to the casing.

(iii) Four sets of 230 mm diameter flanged collars shall be provided for the connection of fresh air, supply air, return air and exhaust ductworks.

(iv) A control panel shall be provided in the casing, together with termination blocks, for the connection of electricity supply.

(c) Fan and Motor

(i) The outdoor air and exhaust air fans shall be single inlet, single width, forward curve centrifugal fans. The blades shall be designed for maximum efficiency and quiet operation. Impellers shall be statically and dynamically balanced. The exhaust air fan and the fresh air fan shall be driven by the same motor on a common shaft.

(ii) The motor shall be standard NEMA frame with open drip-proof enclosure and shall be suitable for 220V, single phase, 50 Hz electricity supply.

(iii) The motor shall have the minimum efficiency complying to Section C7 of this General Specification.

(d) Total Heat Recovery Wheel

(i) The total heat recovery wheel shall be in the form of a disc and of rotating type. The wheel is the media for sensible and latent heat transfer between fresh air and exhaust air. The wheel shall be driven by a motor

and rotate across the intake and exhaust air streams.

(ii) The wheel shall be made from aluminium and coated with a layer of ceramic material to resist corrosion; and a layer of desiccant type non-migrating permanently bonded inorganic solid adsorbent.

(iii) The desiccant coating shall be sprayed on or dip-coated and shall not be required to re-apply onto the surface over the life of the wheel. The coating shall not support the growth of bacteria.

(iv) The desiccant shall be able to adsorb water vapour. The internal pore diameter distribution inherent in the desiccant being provided shall limit adsorption to materials not larger than the diameter of a water molecule (2.8 Angstroms). The desiccant shall be potassium aluminosilicate and have a 3Å molecular sieve. Other materials will not be accepted.

(v) The transfer media coated shall have equal sensible and latent effectiveness and the recovery efficiency shall be clearly documented through an independent test certification programme conducted in accordance with ANSI/ASHRAE Standard 84-2013 and AHRI-1060(I-P/2018) standards. The molecular sieve shall have high water pick up rate at both high and low relative humidity so as to give a constant effectiveness over the entire relative humidity range and to allow the wheel to be effective at high face velocities up to 5.5 m/s.

(vi) The media shall be able to be cleaned with low pressure steam or hot water without degrading or damaging the latent heat recovery and shall maintain a non-deliquescent state at all times. The pores of the desiccant shall be small enough to prevent from cross contamination.

(vii) The media shall be designed to induce laminar flow under all conditions inside the flutes and to enable the flutes to be self-cleaning (e.g. purging).

(viii) The wheel shall be independently tested; shall conform with the requirements of NFPA-90A:2018 and shall have a flame spread less than 25 and a smoke developed less than 50 when both rated in accordance with ASTM E84-18b.

(ix) The cross leakage of wheel shall not be greater than 5% of total air flow.

(e) Filter

(i) The filter shall be of washable type and about 25 mm in thickness.

(ii) The filter shall be listed by Underwriters laboratories as Class 2 and the filter efficiency shall be 30% to ANSI/ASHRAE Standard 52.2-2017.

(f) Purge Sector

(i) A purge sector shall be provided in the wheel so that the exhaust air shall not be carried over to the supply air.

D5.1.2 Specification of Paper Plate Type Outdoor Air Pre-conditioner

(a) The paper plate type outdoor air pre-conditioner shall be the product from a manufacturer holding the quality assurance standards of ISO 9001:2015 or products having equivalent functions or performance.

(b) The pre-conditioner shall comprise supply air fan, exhaust air fan and resin net (washable) filter. Each pre-conditioner shall comprise a non flammable heat exchange element as the media for the enthalpy exchange between outdoor air intake and exhaust air. The pre-conditioner shall be designed for cross flow type with a high durability and reliability, a high performance and low pressure loss type.

(c) The pre-conditioner shall transfer both sensible and latent heat with same effectiveness and shall not support bacteria growth.

(d) The pre-conditioner shall comprise indoor and outdoor temperature sensors to detect indoor and outdoor air temperature in order to determine bypass or enthalpy exchange mode.

(e) The pre-conditioner shall have 3-steps air flow rate changeover.

(f) The ON/OFF operation shall be controlled from the double poles switch installed at the entrance of the room under the electrical work of the Contract. However, the remote controller supplied with the fresh air pre-treated unit shall be installed adjacent to the unit for maintenance use. The unit shall have automatic ventilation mode changeover controlled by the air temperature sensor.

(g) The casing shall be made of galvanised steel plate. The pre-conditioner shall be insulated with fire retardant, closed cell, flexible elastomeric thermal insulation in continuous length, factory applied on the inner surface. The insulation shall comply with the requirements as stipulated in Sections B11 and C11 of this General Specification.

(h) The energy efficiency of the motor of the pre-conditioner shall comply to the requirements as specified in Section C7 of this General Specification.

D5.1.3 Specification for Polyester (P.E.) Fibre Type Fresh Air Pre-conditioner

(a) The Polyester fibre type fresh air pre-conditioner shall comprise a rotary wheel as the media for sensible and latent heat transfer between the outdoor air and the exhaust air.

(b) The wheel shall be fabricated from corrosion resistant material and supported by bearings, which can be maintained or replaced without the removal of the rotor from its casing. It shall be driven by an electric motor with or without a gearbox and shall rotate across the two air streams to achieve the heat transfer. The energy efficiency of the motor of the pre-conditioner shall comply to the requirements as specified in Section C7 of this General Specification.

(c) The casing shall be fabricated from galvanised steel or equivalent material. Two aluminium filters shall be fitted on the air inlets of the casing.

(d) The heat transfer media in the rotary wheel shall be P.E. fibre of 25 to 150 μm in diameter with a surface density of 3.6 kg/m2. The media shall not support the growth of bacteria. The efficiencies of sensible

and latent heat recovery shall not be less than 80% and 50% respectively, based on ANSI/AHRI 1060:2005.

(e) The media shall be securely held by a structural spoke system and shall be removable and washable. It can be cleaned with low pressure steam, water or light detergent without degrading the heat recovery effectiveness.

(f) The unit shall have been tested to BS 476 Part 6 or equivalent and satisfied all stipulated requirements.

(g) The unit shall have a sound pressure level less than 40 dBA at high flow measured at 1.5 m from the supply air discharge.

D5.2 Rotary Solid Desiccant Dehumidifiers

All technical requirements shall comply with the requirements stipulated in Clause D5.1 of this General Specification. The type of reactivation power shall be as specified in the Particular Specification. Liquid desiccant type dehumidifier shall be submitted for Supervising Officer's approval.

D5.3 Desiccant Type Dehumidifier Air Handling Unit

(a) General

The dehumidifier AHU shall be a combination of desiccant heat recovery rotor and refrigeration dehumidification system. Humid inlet process air shall firstly be cooled and dried by the evaporator and further dried by the desiccant rotor, or alternative arrangement to be specified in the Particular Specification. The rotor shall be regenerated by hot air after the condenser in the heat pump refrigeration circuit, or by room air as to meet the system design as specified. The desiccant dehumidifier shall maintain the specified room relative humidity and temperature when cooling system is turned off at night time.

Each dehumidifier AHU shall be a complete unit comprising cabinet, desiccant rotor, heat pump, process air fan, reactivation air fan, air filters, control panel, access panels, etc. with a standard and specification same as the air handling unit. The casing shall be of insulated double skin construction same as the air handling unit.

(b) Rotor

Rotor shall be high efficiency silica gel or lithium chloride. The rotor matrix is manufactured from alternative layers of flat and corrugated sheets of silica gel or lithium chloride, chemically

bonded into a tissue of inorganic fibres. Rotor material shall be robust construction, incombustible, non-toxic and washable. Rotor shall be suitable for non-stop operation and the service life is minimum 10 years. The rotor shall be controlled by a variable speed motor in order to maintain the specified room condition. Rotor shall not have any loose powder in its structure.

(c) Heat Pump System

Heat pump refrigeration system where specified shall be integrated into the dehumidifier AHU to pre-cool the process air and regenerate the rotor. The heat pump system shall include at least evaporator, condenser, compressor and throttling device. Refrigerant shall be R-407C, R134a or other non-CFC refrigerant. The compressor shall be screw or rotary type with an electric motor. To avoid short cycling, the compressor shall be protected by a time delay during start up. Both the condenser and the evaporator coil shall be manufactured from copper tube with aluminium fins.

(d) Fan

The fan shall be centrifugal type. Fan motor shall be mounted within the dehumidifier's cabinet. The process air fan and the reactivation air fan shall provide sufficient static pressure for the application.

(e) Control

The compressor, process air fan and reactivation fan shall be cycled on when the outside relative humidity or temperature or the enthalpy is higher than the pre-set values. The speed of rotary desiccant wheel shall be varied to control the room temperature and humidity. Carbon dioxide sensors shall be installed at the return air stream of AHU to determine the state of occupancy. When humidification is specified in the Particular Specification, the humidification process shall be operated by means of steam humidifier.

D5.4 Electrostatic Precipitators

Electrostatic precipitators shall comply with the FSD's requirements and shall be of the type under the FSD's approved material list. Average efficiency of the auto clean electrostatic filter shall not be less than 90% rated at ANSI/ASHRAE 52.2-2017 "Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size". Auto clean electrostatic filter shall consist of a washer/adhesive applicator section and an ioniser-collector section, with overspray filters, all factory assembled into a sectioned housing of overall depth not greater than 1 m in direction of airflow. Each section of the galvanised steel housing assembly shall incorporate a pair of hinged, quick opening access doors permitting access for

servicing of all internal components; and a watertight, all welded, galvanised steel, drain pan and drain connections. Access doors shall be sealed against air leakage by continuous perimeter gaskets of closed cell neoprene.

Each ioniser-collector section shall be finished with the required number of one-piece or multi-piece cells of aluminium construction. Each cell shall be fitted with stainless steel slides for mounting on the tracks which form an integral component of the side access housing and to facilitate removal of cells for servicing. Cell support framework shall be completely open beneath the ioniser-collector section to ensure complete drainage of wash water and excess adhesive, minimising the possibility of short circuits when high voltage power is restored following completion of the wash cycle. Cells shall be designed so that high voltage input terminals and the high volt rated glass or ceramic fill polyseal insulators are located completely out of contact with the moving air-stream to avoid buildup of dirt which could permit dissipation of high voltage charge and reduce air cleaning efficiency. The high voltage bus-bars and terminals (contactors) shall be inherent to the design of each cell and shall permit cell removal without disconnecting any high voltage wiring. Insulators shall be fully exposed, for ease of cleaning, when cells are removed for service. Cells shall be designed for full face ionisation and have completely flat collector plates to prevent buildup of residual, inaccessible dirt accumulations.

Each washer/adhesive applicator section shall incorporate slide-in type, perforated, galvanised steel air distribution baffles and a header assembly which connected to the inlet water solenoid valve and to the adhesive pump by means of copper piping and/or non-snag, expanded PVC hose with a braided polyester exterior protective cover. Washer rams, each equipped with multi-directional, 360^{o} washer spray nozzles, shall be driven by reactive force from inlet water pressure. The removable brass adhesive nozzles shall be mounted on a separate, fixed, vertical header forming an integral component of the assembly. The filter adhesive shall be cold water soluble and non-flammable. The A/C Contractor shall supply a rotary gear adhesive pump with bronze impeller and sufficient adhesive for reconditioning cycle.

The washer supply water solenoid valve, the manifold drive motor, and the manifold limit switch shall be pre-wired to an accessible, internally mounted. Program timer control, with field adjustable timer and a timer bypass switch shall be provided to control the washing cycles. The washer control enclosure access door shall incorporate a status light to indicate when the reconditioning cycles is energised. An internal panel is to be equipped with a combination of LED status lights and display unit to indicate which part of the reconditioning cycle is in operation. The display unit is to be visible through a window in the control cover.

The power shall be of solid state design, having single or multi steps, relays for remote indication of status of the power and solid state

voltage supply, and "fail-safe" low voltage relays to interrupt power to the ioniser circuit in the event of a malfunction in the plate circuit. Power pack covers shall each include neon glow lamps to indicate status of the power and solid state voltage supply. The power pack shall also include safety provisions of a circuit breaker, a reset button, safety type door interlock switches.

D5.5 Electronic Air Cleaners

The electronic air cleaner shall be capable of removing odours of bacteria, organic and chemical origin and shall also be capable of reducing airborne bacteria and particulate in the treated area as specified.

The electronic air cleaner shall be tested by laboratories by independent regulatory/ testing bodies, independent accredited laboratories or elsewhere as approved to show the removal efficiency to be not less than 95% of airborne bacteria (total count), 95% of airborne particulate of 0.5 micron to 5.0 micron, 95% of cigarette smoke particles, 80% of odours and 95% of hydrogen sulphide.

The maximum output voltage of the electronic air cleaner shall be less than 3,000 volts.

The electronic air cleaner shall not generate ozone in excess of 0.05 part per million by volume(ppmv) of air circulating through the air cleaner according to the standards specified by the Food & Drug Authority (FDA) of USA.

A stainless steel mounting flange shall be provided for mounting the electronic air cleaner to the air plenum of the air handling equipment. The electronic air cleaner shall be interlocked with the respective blower electrically and mechanically so that it can be safely switched off when the fan of the blower stops. The electronic air cleaner shall be wired so that the units may be unplugged and removed for regular servicing. The electrical wiring shall conform to the relevant safety standards.

The electronic air cleaner shall consist of a power generator and screw-in electrode tubes. The length of each electrode shall not be less than 400 mm. The number of electrodes required shall be able to handle maximum return air of system application design.

The power generator of the electronic air cleaner shall be able to operate on the single phase mains power supply. The power generator shall be equipped with built-in regulator for output adjustment. The power generator shall also be fitted with on/off switch, on/off indicator lamps, output regulating rotary switch, overload circuit breaker and electrode tube sockets.

The electrode tubes shall consist of screw-in base and a glass tube. The electrode tube shall be protected with a stainless steel mesh and shall

be earthen by means of a firmly fixed grounding wire to the power generator.

The air purifier shall be controlled in auto or manual mode. In auto mode, the electronic air cleaner shall be switched on/off at a pre-determined time period.

The electronic air cleaner shall not generate ozone in excess of 0.05 part per million by volume(ppmv) of air circulating through the air cleaner.
All materials used in the air supply stream shall not emit any harmful if case of fire and shall be tested to surface flammability test UL 94-5VA and BS 476 Part 6.

D5.6 Germicidal Ultraviolet Air Steriliser

Air steriliser shall be of ductwork mount type. Each steriliser shall consist of ultraviolet lamps, transformer with enclosure, lamp supporting rods and inspection glass window. Air steriliser shall be operated on 220V/1ph/50Hz.

Air steriliser shall have one-pass bacteria removal efficiency at least 90%. The selection of UV air steriliser shall be based on face air velocity, temperature and ductwork size. Detail selection methods shall be submitted to the Supervising Officer for approval.

The UV lamps shall be manufactured of special short-wave transmitting glass or quartz. The UV lamps shall emit UV at the 200 nm to 300 nm mercury spectral line, known as germicidal, or shortwave ultraviolet. Each lamp shall not consume power more than 40W but emit pure UVC irradiation not less than 120 micron meter/cm^2 measured at 1 metre from source after 100 hours burning at 25 ^oC. The total UV light intensity shall be not less than 360 micron W/cm^2 per 1.0 m^3/s airflow measured at 1.0 m from source.

To prevent eye and skin injuries, sources of UV light must be conspicuously labelled with a warning attached to the housing of the source. The warning sign should state: -

WARNING

DO NOT EXPOSE EYES AND SKIN TO ULTRA-VIOLET LIGHT
RAYS ARE HARMFUL TO UNPROTECTED EYES AND SKIN

警告

切勿讓眼睛及皮膚暴露於紫外光之下, 可引致損害

The UV steriliser lamps shall be positioned perpendicular to the air flow at velocity less than 5.0 m/s to allow maximum exposure. Access door with safety current-cut switch shall be provided to access the UV lamps. Suitable inspection window shall be provided on the equipment. Baffle type filters on the ductwork openings shall be provided in case that direct UV light may be emitted out of the ductwork openings. Safety labels shall be provided on the ductwork access panel. Additional water-tight metal enclosure shall be provided to house the transformer enclosure if there is a chance of water spraying into the equipment.
The operating life of the UV lamps shall be at least 10,000 hours. The operation of the UV air steriliser shall be interlocked with the blower/air handling unit such that the UV air steriliser is operated when the blower/air handling unit is operated. The steriliser shall be switched off with an indicator light on when the maintenance access is opened.

The generated ozone from the air steriliser shall be at a level less than 0.05 ppmv of air circulating through the air steriliser according to the standards specified by the Food & Drug Authority (FDA).

Safety precautions shall be taken in the installation and maintenance of the air steriliser to prevent the leakage of UV light. When the UV exposure level exceeds 0.2 micron W/cm^2 over 8 hours, baffle filters shall be installed for those air discharge louvres to reduce UV light intensity level.

Remote control panel shall consist of circuit breaker, auto-off-manual switch, hour run meter, ampere meter, pilot lamp and fine-wire fuse.

On-site performance test shall be conducted to verify: -

- The total bacteria count (TBC) removal efficiency;
- Background UV intensity; and
- Ozone level.

Pressure sensors shall be located at both upstream and downstream across filter section for PAU/AHU. When comparing the pressure differential of the upstream and downstream with reference to a reference value, the controller shall send either one of the following signals to the control panel: -

- Filter normal;
- Filter leakage and alarm signal; or
- Filter clog and alarm signal.

D5.7 Water Scrubbers

(a) General

(i) Horizontal cross flow fibreglass reinforced polyester (FRP) foul air water scrubber system shall be supplied and installed for central air treatment of odour, gas, liquid and solid contaminants prior to discharge to outside of the building.

(ii) The water scrubber systems shall be outdoor type tailor-made and designed by a single recognised scrubber specialist as a complete package to suit the available space and in accordance with the specified performance and requirements in the Particular Specification. Every major components such as the fan, recycle pumps, scrubber section completed with packing, mist eliminator and nozzle shall be compatible in all aspect and wholly imported, factory built and assembled as complete units before shipping. The only field connections required on Site shall comprise only external control circuitry, pipeworks, fan and ductwork connections.

(iii) Scrubber section shall be of horizontal draw-through cross-flow packed tower bed type with mist eliminator at the last section of the scrubber. Each complete scrubbing system shall comprise a scrubber section with recycle pumps, chemical feed pumps, fan, chemical tanks, silencers, instrumentation, acoustic enclosure and all necessary controls as well as any other accessories required to build up a functional plant to the satisfaction of the Supervising Officer.

(iv) All material and components adopted in the scrubbing system shall be suitable for operation with selected chemicals including sodium hypochlorite, sodium hydroxide and the resulting by-products of scrubbing.

(v) Those items specified to be constructed of fibreglass reinforced polyester (FRP) resin shall conform to relevant BS or ASTM standards and shall be stabilised against ultraviolet degradation. This shall apply to the scrubbers and fan. The resin shall be Duracor 6000-6 series or products having equivalent functions or performance and approved.

(vi) All internal wetted bolts and fasteners, and all external bolts and fasteners including anchor bolts and flange bolts shall be high grade AISI 316 stainless steel or products having equivalent functions or performance.

(vii) Scrubber section shall be finished with three nos. of recycle pumps, one of which as standby. Manual selection switch shall be provided to enable selection of either one of them as standby pump. The pumps shall be

direct coupled to TEFC motor, self-priming, horizontal end suction, corrosion resistant and centrifugal type. Accessories such as pressure gauges, stop and vent cocks shall be provided for each pump. The flow rate shall be determined by the A/C Contractor to suit the performance specification with adequate flow rate and pump heads to cater for the piping and scrubber paint friction losses.
The pump casing, impeller shall be of rigid PVC and the impeller shaft shall be of stainless steel to be approved by the Supervising Officer.

(viii) A detail design report on the offered water scrubber system shall be submitted for agreement with Supervising Officer. Full technical details shall be provided including at least the followings:-

I) Certificates and documentary evidence of excellent chemical resistance of all material, component and equipments adopted for the operation with the selected chemicals and specified application; and

II) Detail information and calculations on:-

- Chemical reaction formulation and design criteria;

- Selection of the type and depth of packing, mist eliminators, nozzles, etc. with manufacture's test data or recognised standards; and

- Scrubber overall height and dimension, packing depth, mist eliminators depth, etc.

(b) Construction

(i) The mist eliminator section shall be replaceable, corrosion resistant packing, mesh type or other approved type fabricated of fibreglass reinforced polyester or products having equivalent functions or performance and approved. The eliminator section shall be in modular form of adequate surface area and strength to withstand the handling air flow area and pressure.

(ii) The scrubbing liquid distribution system shall be the spray type or other approved type, sized for the flow rate to suit the design of the scrubber system to meet specified performance. Material of construction shall be fibreglass reinforced polyester.

(c) Control

(i) The water scrubber system shall be capable of both automatic and manual operation. In "auto" mode, the central exhaust fan shall be started or stopped automatically. The scrubber exhaust fan shall be inter-locked with the recycle pumps' operation such that it will not be operative unless the pumps are operating. The 2-way motorised valve and flow regulating valve at water feed-in pipe shall be provided and interlocked with the fan.

(ii) Chemical feed pumps shall dose proportionately to maintain the desired concentration of the scrubbing liquid. NaOH shall be controlled with pH analyser to maintain a pH value of 8 to 9 while NaOC1 shall be controlled with oxidation-reduction-potential (ORP) analyser to maintain an ORP value of 300 to 400 mV or to values recommended by the manufacturer in order to comply the performance specification.

(iii) Low level sensors in the water scrubber chamber shall be provided and installed to give audio and visual warning signals at the local & remote control panels and to stop the circulating pumps during low water level condition.

(iv) Corrosion resistance low level sensors shall be provided and installed for each of the chemical tanks to give audio and visual warning signals at the local & remote control panels during low chemical level condition.

(v) Flow switch shall be provided and installed at the feed-in water pipe to give audio and visual warning signals at the local & remote panels during "no flow" condition.

(vi) In "manual" mode, the fan and pumps shall be operated by means of start/stop buttons at the water scrubber control panel.

(vii) Local and remote control panels shall be provided for the water scrubber systems as specified in the Particular Specification. Local/remote selector switch shall be provided at the local panels for choice of control mode. In "remote" mode, the water scrubber system shall be started or stopped via manual push buttons at the remote control panel. The scrubber exhaust fan shall be interlocked with the recycle pumps' operation such that it will not be operative unless the recycle pumps are operating.

(viii) In "Local" mode, the fan and pumps shall be operated by means of start/stop buttons at the local control panel.

(ix) Provision shall be provided for roller shutter for refuse collection point, poultry scalding room and other areas as specified in Particular Specification to interlock the operation of the roller shutter with the scrubber operation.

(x) The remote panel for the water scrubber system shall be of constructions as specified in the Particular Specification or products having equivalent functions or performance as approved and weather-proof suitable for outdoor installation.

(d) Fan

(i) Motor driven fans shall be provided for each scrubber unit and shall be of sufficient capacity and horsepower, as indicated in the Particular Specification to deliver the required volume of air against the total pressure losses in the air intake, duct pickup systems, packed bed, mist eliminator, silencers and ducting.

Fans shall be of high efficiency and low speed backward curved types with lowest noise level suitable for outdoor application. Sound power level spectrum shall be submitted for approval and the data shall be verified on Site as specified.

(ii) Fan housings, flanges and impellers shall be constructed of a fibreglass reinforced polyester (FRP) laminate using Duracor 6000-6 series or products having equivalent functions or performance as approved.

(iii) Inlet connections shall be Neoprene slip type flex connector with stainless steel draw-bands. Outlet connection shall be a rectangular undrilled flange.

(iv) Each of the blowers shall have V-belt drive with a minimum service factor of 1.5 times the rated brake horsepower of the fan motor and shall be equipped with heavy-duty, self aligning sealed ball bearings.

(v) Fan shafts shall be carbon steel and oversized to run above critical speed. A steel hub encapsulated with FRP shall be provided to a point flush with the housing. Wheel and shaft assemblies shall be statically and dynamically balanced in two directions according with recognised international standards.

(vi) The fan base shall be made of corrosion material of sufficient strength or carbon steel treated with anti-

corrosion coatings approved by the Supervising Officer. No metal parts including bearing supports shall be exposed to the corrosive air stream.

(vii) Fans shall come completed with motors, drives, belts, FRP motor and drive canopy, housing drains, access doors and flexible connectors for inlet and outlet.

(viii) Each fan shall be provided with a horizontal squirrel cage induction type motor of sufficient power such that no point on the fan curve requires more than the nameplate horsepower of the motor furnished.

(ix) Each electric motor shall be suitable for 380 V, 3-phase, 50 Hz continuous 24 hour's operation.

(x) The motor enclosure shall be totally enclosed, fan cooled and suitable for outdoor application.

(xi) The motors shall be designed, constructed and tested in accordance with all the requirements of the applicable standards of the IEEE, NEMA and ANSI.

(xii) The fan static pressure to suit the ducting configuration and proposed equipment with calculations shall be submitted for Supervising Officer's approval.

(xiii) Acoustic treatment, such as silencers and acoustic enclosure, shall be provided to ensure the noise break out to adjacent areas is at an acceptable level complied with the requirement of the Environmental Protection Department.

(xiv) Silencers shall be of packless type or to be completed with adequate coating and shall be suitable for the chemical corrosive environment. The exhaust fan and driving motor shall be housed in an acoustic G.I. sheet enclosure as specified in the Particular Specification.

(e) Chemical Feed System

(i) Each scrubber system shall be provided with a complete chemical feed system for storing and feeding the chemicals required. All adequate provisions shall be provided for the storage, installation and operation of the chemical solutions in compliance with the Fire Services Regulations as the scrubbing chemical solutions used are in the list of Dangerous Goods Category. The Chemical feed system shall comprise chemical storage tank and feed pump for each scrubbing chemical solution, piping and valves, and all necessary controls.

(ii) Chemical storage tanks shall be vertical flat bottom type made of FRP with scale and lockable screw lid and shall be suitable for storing the scrubbing chemical solution. Each tank shall have a minimum effective capacity of holding the exempted quantity at specified concentration allowable by the FSD, typically of 250 litres.

(iii) Chemical metering pumps shall be solenoid - operated diaphragm pump for the type of weatherproof protection. The pumps shall be operated on 220 V/single phase/50 cycles. Housing and liquid end shall be corrosion proof as well as dust and waterproof to protection Class IP65. Housing shall be light-metal alloy die. Solenoid shall be proof against over-load and excessive counter pressure such that it will not result in failure. Pumping capacity shall be adjusted in ratio of 1:10 through stroke length and 1:25 through stroke frequency, accessories shall include PVC dosing valve and foot valve.

(iv) pH and ORP Control

Each scrubber shall be provided with pH and ORP probes suitably located for analysing the contents in the scrubber sump. Probes shall meet the following table:-

Table D5.7 Technical Requirement of Measuring Probes

	pH Probe	ORP Probe
Range	0 to 14pH	0 to 990 mV
Stability	0.03pH units per day, non-cumulative	0.5 mV per 24 hours, non-cumulative
Temperature	0 to 60 °C	0 to 60 °C
Pressure Rating	4.8 kPa	4.8 kPa
Wetted Materials	Glass	Glass
Accuracy Sensitivity	0.1 pH unit	5 mV

Each probe shall be supplied with analyser and level alarm at the local and remote control panels and they shall be actuated when the chemical levels at chemical tanks are lower than the present values.

D6 CONFORMITIES OF IAQ DESIGN OBJECTIVE AND COMPLIANCE

One or more software tools for predicting the performance of the IAQ equipment and system shall be proposed by the A/C Contractor and submitted to the

Supervising Officer for approval. The proposed tool shall demonstrate the conformities of IAQ objectives performed by the IAQ equipment and system.

Testing and commissioning of IAQ equipment and system shall be carried out for the conformities of IAQ design objective and to the satisfaction of the Supervising Officer or to meet the requirements as stated in the Particular Specification.

The details of T&C work are detailed in T&C Procedure No.1 clause 4.2.5 – IAQ Equipment and System Test under Part H: Inspection, Commissioning and Testing. Upon satisfactory completion of all the tests, a certificate of IAQ compliance level of building according to the format and detailed requirements as specified in the Particular Specification shall be submitted to the Supervising Officer for approval.

D7 IAQ ASSESSMENT AND METHODOLOGIES

IAQ assessment shall be performed as the last part of the testing and commissioning process upon completion of the ACMV installation. Further assessments shall be done six months after the building has been occupied and at two months before the expiry of the Maintenance Period, i.e.

(a)	First Assessment	-	After testing & commissioning
(b)	Second Assessment	-	Six months after the date of occupation of the building or substantial completion
(c)	Third Assessment	-	Two months before the expiry of the Maintenance Period

IAQ compliance shall be proved by results of measurements. In addition, an end user satisfaction survey shall be conducted before expiry of the Maintenance Period.

The A/C Contractor shall provide recommendation to improve the indoor air quality condition for the approval of the Supervising Officer should any one of the three assessments fail to meet the requirement.

The details of measurements, assessment and methodologies are described in T&C Procedure No.1 clause 4.2.5 – IAQ Equipment and System Test under Part H: Inspection, Commissioning and Testing.

D8 OPERATION AND MAINTENANCE

D8.1 O & M Matters

In addition to the contractual requirements of training, operation and maintenance as described in Part I: Operation and Maintenance Requirements for the ACMV installation, similar requirements for Indoor Air Quality installation as mentioned below shall be met.

D8.2 Training Requirements

Facilities familiarisation and training programme shall be provided to ensure that the owner's operation and maintenance staff acquire full knowledge and appreciation of all aspects of the design, operation, breakdown attendance, routine maintenance and diagnosis of installation, which have effects on the indoor air quality.

A training proposal shall be submitted to the Supervising Officer for approval at least three months prior to completion of the ACMV installation. Training shall include both aspects of operation and maintenance as well as trouble shooting procedures and the use of special tools.

D8.3 Operation and Maintenance Requirements

Full responsibility shall be held for the following, in addition to those required for O&M of ACMV installation mentioned elsewhere in the specification, within the Maintenance Period: -

(a) Instruction to Employer's O&M Staff

Training shall be provided to Employer's staff involved in operation and maintenance to understand the design intent, to operate and to maintain the IAQ system correctly, to achieve and maintain the designed IAQ parameters. An O&M manual shall be prepared by qualified personnel.

(b) Attendance to Faults and Complaints

IAQ faults and complaints shall be attended and rectified for arising from defective work and materials. Report shall be submitted to the Supervising Officer for these incidents.

(c) Periodical IAQ Audit with Logs and Records

Periodical IAQ audit shall be carried out as specified to ascertain the status of the IAQ parameters and submit records/logs with details such as date, results of audit, measurements and name of person conducting the audit to the Supervising Officer.

(d) IAQ Assessment as Specified with Logs and Records

In addition to the IAQ assessment during testing and commissioning, IAQ assessment shall be carried out six months after building occupation and at the expiry of the Maintenance Period. IAQ compliance shall be proved by results of measurements. In addition, a satisfaction end user survey report shall be submitted to the Supervising Officer for endorsement. According to the agreed end user report, an end user satisfaction

survey shall be conducted before the expiry of the Maintenance Period.

D8.4 Maintenance Concept

IAQ maintenance should be an on-going exercise consisting of periodic IAQ assessment, identification of IAQ problems and deficiencies as well as follow-up IAQ improvement scheme to bring the IAQ to the designed and acceptable standard. The following are general maintenance items that need to be carried out regularly during the Maintenance Period: -

Service requirements shall include functional inspection, cleaning, adjustment, sample test and rectification. The detailed arrangement shall be: -

(a) Monthly Services: -

(i) Outdoor air intake equipment including screens and louvres;

(ii) Air pre-filters;

(iii) Cooling coils and heating coils;

(iv) All trays and sumps;

(v) Condensate drains and water traps;

(vi) Water cooling towers;

(vii) Water treatment system; and

(viii) Boiler and Humidifier.

(b) Quarterly Services: -

(i) Air dampers;

(ii) All types of filters including HEPA filters, electrostatic filters, chemical filters, carbon filters;

(iii) Air Cleaners;

(iv) UV light chambers; and

(v) Check system performance.

(c) Half-yearly Services: -

(i) IAQ sensors such as thermostat, humidistat, pressurestat, CO2 sensors, air movement sensors;

(ii) Humidifiers, dehumidifiers;

(iii) Inspect all components of the ventilation system for cleanliness and microbial growth, and clean them as necessary; and

(iv) Volume control dampers.

(d) Annual Services (before the expiry of Maintenance Period): -

(i) Inspect and clean as necessary accessible parts of ductwork and air grilles;

(ii) Fans, fan wheels, fan blades, belt drives;

(iii) AHUs, fan coil units, VAV boxes and terminal units;

(iv) Supply and return air plenums;

(v) Variable speed drive control for fans; and

(vi) Inspect aluminium foil, paints or other concrete sealing layers and wall surface which are meant to stop radon gas emission and touch up if applicable.

D9 HOUSEKEEPING AND ENERGY EFFICIENCY RELATING TO IAQ ISSUE

Indoor air quality is affected by the quality of maintenance and the materials used and procedures in operating and maintaining the building components including the ACMV system. Contractors are required to familiarise with building systems in general and with the features of the building in particular which are important resources in preventing and resolving indoor air quality problems in the Maintenance Period.

To best respond to indoor air quality concerns, the A/C Contractor shall have good understanding on how the building activities affect indoor air quality. The housekeeping procedures in relation to the following items shall be carried out: -

D9.1 Equipment Operating Schedules

(a) Confirm that the timing of occupied and unoccupied cycles is compatible with actual occupied periods, and that the building is flushed by the ACMV system before occupants arrive;

(b) Maintain essential ventilation or suitable air treatment in areas with long unoccupied periods to prevent mould growth in hot humid climates; and

(c) Check control and use free air cooling mode at mild season.

D9.2 Control of Odours and Contaminants

(a) Maintain appropriate pressure relationships between building usage areas;

(b) Avoid recirculating air from areas that are strong sources of contaminants (e.g. smoking lounges, chemical storage and printing areas);

(c) Ensure adequate local exhaust depending on different Sites and as specified in the Particular Specification for activities that

produce odours, dust, or contaminants, or confine those activities to locations that are maintained under negative pressure (relative to adjacent areas);

(d) Make sure paints, solvents and other chemicals not being stored in the ACMV plant rooms;

(e) Maintain regular maintenance depending on different Sites and as specified in the Particular Specification on local filter traps and adsorbents; and

(f) Carry out routine cleansing with dry steam only.

D9.3 Ventilation Quantities

Compare outdoor air quantities to the building design goal and the IAQ targets, and make adjustments as necessary and the adjustments should be carried out without compromising the IAQ objectives.

D9.4 ACMV Equipment Maintenance Schedules

(a) Inspect all equipment regularly as per manufacturers recommended maintenance schedule to ensure that they are in good condition and are operating as designed (i.e. as close to the design set points for controls as possible); and

(b) Provide scrupulous maintenance on components that are exposed to water, e.g. drainage pans, coils, cooling towers, humidifiers, etc. to prevent microbiological growth and the entry of undesired microbiological organisms or chemicals into the indoor airstream.

D9.5 ACMV Inspection

(a) Prepare checklists for thorough inspection of the ACMV equipment in the building to avoid missing items such as small exhaust fans which may operate independently from the rest of the ACMV system and are often ignored during inspections;

(b) Maintain proper records on alteration/addition/removal of the ACMV installation for reference on IAQ impact due to changes in function, capacity, or operating schedule;

(c) Maintain proper records on occupant complaints on ACMV services for easy comparison if IAQ problems arise; and

(d) Change in occupancy/space function.

D9.6 Building Maintenance Schedule

(a) Schedule maintenance activities that interfere with ACMV operation or produce odours and emissions (e.g. painting, false

ceiling or roofing operations) so that they are executed when the building is unoccupied; and

(b) Inform occupants when such activities are scheduled and, if possible, use ventilation to ensure that ductwork and odours are confined to the work area.

D9.7 Preventive Maintenance

Provide adequate preventive maintenance and prompt attention to repairs of the ACMV equipment in order to maintain the ACMV systems in suitable control conditions so as to deliver good indoor air quality.

(a) General elements of preventive maintenance plan shall include: -

(i) Periodic inspections, cleaning, and service as warranted;

(ii) Adjustment and calibration of control system components; and

(iii) Maintenance equipment and replacement parts that are of good quality and properly selected for intended function.

(b) Critical ACMV system components that require preventive maintenance in order to maintain comfort and deliver adequate ventilation air shall include: -

- Outdoor air intake opening;
- Damper control;
- Air filters;
- Drip pans;
- Cooling and heating coils;
- Fan belts;
- Humidification and dehumidification equipment and controls;
- Distribution system; and
- Exhausts, exhaust fans and pressure relief fans.

Provide adequate training to the maintenance staff to ensure that they have adequate understanding of the overall system design, its intended function, and its limitations.

D10 TRAINING AND LICENSING REQUIREMENTS

Training and licensing are required for IAQ workers carrying out IAQ installation, testing and commissioning, assessment and measurement, operation and maintenance or personnel supervising these works.

Recognised training includes training and certificates from the following: -

- Relevant professional or academic institutions;
- Vocational Training Council;
- Equipment supplier; and
- Other training organisations recognised and accepted by the Supervising Officer.

Installation, testing, commissioning, assessment, measurement, operation and maintenance shall be carried out by IAQ licensed personnel who must have recognised training or adequate experience accepted by the Supervising Officer.

D11 CERTIFICATION AND REGISTRATION

IAQ assessment shall be carried out upon completion of ACMV installation, six months after date of occupation of the building or substantial completion of the Works stated in the certificate of completion issued in accordance with the Contract and at the expiry of the Maintenance Period. After each assessment, a report will be issued by the A/C Contractor recording the measurement made and the readings taken from the IAQ parameters as specified in the Particular Specification. Before expiry of Maintenance Period, in addition, the A/C Contractor shall also carry out an IAQ satisfaction survey to ascertain the situation of the IAQ in the building and the feedback of the occupants. Quantity of survey and report on satisfaction survey shall be submitted to the Supervising Officer for approval.

For each of the three assessments, the methods of measurement, the models and serial numbers of the instruments with date of calibration used in the measurement and assessment, the locations of assessment and sampling as well as the results of the assessment (IAQ compliance or not) and the readings obtained shall be reported. The report forms shall be submitted and approved by the Supervising Officer one month before the measurement and assessment proceed. These Forms shall be endorsed by the responsible personnel of the A/C Contractor, who must be qualified personnel under any one of the following categories. Endorsed Forms (verifying IAQ compliance) shall be submitted to the Supervising Officer who will then verify that the Installations comply with the relevant IAQ requirements.

Recognised qualified personnel for assessing and verifying IAQ compliance shall be: -

D11.1 Registered Professional Engineer in building services or mechanical discipline under the Engineers Registration Ordinance (Cap. 409) or

D11.2 Person with other approved and recognised qualification and/or experience as accepted by the Supervising Officer.

After verification of IAQ compliance, A/C Contractor shall submit a certificate signed by recognised qualified personnel and guidelines for maintaining IAQ level to the Employer.

PART E - ENERGY EFFICIENCY AND ENERGY CONSERVATION

E1 GENERAL

All equipment provided by the A/C Contractor for the Installations shall conform to the highest efficient rating of energy efficiency and energy conservation requirement as stipulated in this General Specification, and/or the Building Energy Code.

In case of any non-compliance, the A/C Contractor shall submit full justification with technical data supporting the deviation from the requirements as specified in this General Specification and the Building Energy Code.

The A/C Contractor shall also refer to other Sections of this General Specification for the energy saving provisions.

E2 MINIMUM COEFFICIENT OF PERFORMANCE (COP) OF MAJOR AIR CONDITIONING AND VENTILATION EQUIPMENT

All major air conditioning and ventilation equipment shall have the minimum COP for both cooling and heating meeting the requirement as stipulated in this General Specification and the Building Energy Code.

The A/C Contractor shall submit documents and calculation showing the minimum COP for both cooling and heating of the following major air conditioning and ventilation equipment: -

- Air-cooled unitary air conditioner;
- Water-cooled unitary air conditioner;
- Air-cooled water chiller or heat pump with reciprocating compressor;
- Air-cooled water chiller or heat pump with centrifugal compressor;
- Air-cooled water chiller or heat pump with screw or scroll compressor;
- Water-cooled water chiller or heat pump with reciprocating compressor;
- Water-cooled water chiller or heat pump with centrifugal compressor;
- Water-cooled water chiller or heat pump with screw or scroll compressor;
- Total energy heat pumps utilising both cooling and heating output; and
- A/C Equipment with simultaneous cooling and heating.

The A/C Contractor shall note that the system energy shall be the main sources of energy in achieving the HKSAR's IAQ Objectives as specified under Part D of this General Specification. Energy discharged to the environment shall be kept to minimum. Energy reclaim from the heat dissipating condenser and from the air conditioning exhaust shall be incorporated wherever practical. Electric reheat or re-heating using only hot water boilers without recapturing the wasted energy shall not be accepted. The A/C Contractor shall refer to the Contract Drawings and Particular Specification for exact requirements and details. The A/C

Contractor shall also check with the major equipment manufacturers and submit proposal in relating to the wasted energy reclaim as specified in the Contract Drawings and Particular Specification to the Supervising Officer for consideration.

E3 MINIMUM EFFICIENCY OF FANS, PUMPS AND MOTORS

The minimum energy efficiency of all electrical driven motors shall comply with the requirements as specified in Sections C5 and C13 of the Electrical General Specification and the Building Energy Code.

The minimum efficiency of pumps and fans shall comply with the requirement as specified in Sections C3 and C13 of this General Specification.

The A/C Contractor in selecting fans for the air-conditioning and ventilation system(s) shall comply with the total fan motor power requirements as stipulated in the Building Energy Code.

The A/C Contractor shall note that the minimum efficiency specified in this General Specification shall be the absolute minimum requirement. All enhanced or higher quality of products shall be offered if available.

E4 THERMAL INSULATION

The A/C Contractor in selecting the thermal insulation for chilled water pipes, refrigerant pipes, air ductworks and air handling units shall comply with the minimum thickness requirements as specified in Clause C11.5.

E5 SENSING DEVICE

All sensing device for monitoring the air quality shall comply with Clause C4.4.6 of this General Specification.

E6 MOTION DETECTING SENSING DEVICE

In case of motion detecting system controlling the air conditioning supply to the conditioned space is specified, the motion detection sensor shall meet the following requirements: -

E6.1 Movement detectors shall be of passive infrared microwave verified type which shall detect movement by passive infrared technology and also by microwave technology. Reaction of A/C control system shall only be activated if both the passive infrared and microwave components of the sensor have been activated within a specified time.

E6.2 For the passive infrared component, the detectors shall keep constant monitoring of the "thermal pattern" of the controlled area. Any change of the infrared energy within the controlled area shall trigger the control

of the passive infrared component. The infrared beam shall not penetrate glass, thin wall or plastics.

E6.3 The microwave component shall keep constant monitoring of the controlled area by detecting the Doppler shift of microwave emitted from the detector. The detector shall generate "K" band microwave frequency of around 24 GHz and emit it as unmodulated electromagnetic field to the controlled area or space.

E6.4 The range of detection shall be adjustable from 6 m to 20 m, the pattern of detection shall be 90^{o} adjustable $\pm 45^{o}$ horizontally and -7^{o} vertically. The velocity of the target to be detected shall be 0.15 – 3m per second.

E6.5 The sensitivity of the passive infrared component shall be 2 ^{o}C at a target velocity of 0.6 m per second.

E6.6 The electronic circuit of the detectors shall have immunity to radio frequency interference and electromagnetic interference, and shall be insensitive to thermal and optical source of interference.

E6.7 LED signals indicating trouble shall be lit upon

(a) Excessive temperature;

(b) Fall in input voltage below the correct performance of the detector is assured; and

(c) Interruption of microwave operation, e.g. due to masking or failure of the microwave component.

E6.8 A LED shall be provided to indicate on/off status of the walk test mode.

E6.9 The detector shall be one piece and shall be housed in a tamper-proof housing with tampering switches. Alarm signal shall be sent to Intelligent Local Controller when the housing is tampered.

E7 DEVICES FOR ENTHALPY CONTROL OF FREE AIR COOLING

In case of free air cooling and enthalpy control is specified, the system shall meet the following requirements: -

E7.1 The free air cooling control system shall be energised to monitor the system conditions when the supply air fan of air handling unit is turned on.

E7.2 The system shall have an exhaust air fan extracting return air under free air cooling operation.

E7.3 Motorised control exhaust air damper shall be installed at the exhaust air outlet and normally opened at pre-set position. This exhaust damper

shall be interlocked with the exhaust air fan and fully opened under the free air cooling operation.

E7.4 Motorised control damper shall be provided in the returned air path for isolating the return air side and supply air side under the free air cooling mode. This isolating damper shall be normally opened and fully closed under the free air cooling operation.

E7.5 Motorised outdoor air supply damper shall have minimum setting to provide the minimum outdoor air supply to the system and shall be fully opened under the free air cooling operation.

E7.6 Temperature and humidity sensing devices shall be provided in the outdoor air supply intake to monitor the outdoor air conditions. These sensing devices shall provide all necessary information to the system controller which shall determine and operate the free air mode when conditions meet with the specified criteria.

E7.7 Temperature and humidity sensing devices shall also be installed in the downstream of the supply air fan to monitor the supply air conditions. The control system shall allow the top priority to these sensing devices to override the signal of free air cooling when the conditions of the supply air fails to meet with the specified condition.

E7.8 All sensing devices shall comply with the requirement as stipulated under Clause C4.4.6 of this General Specification.

E7.9 The details and final configuration of free air cooling system shall comply with the criteria specified under the Particular Specification.

E8 AUTOMATIC CONDENSER TUBE CLEANING SYSTEM

For automatic condenser tube cleaning system, refer to Clause C6.27.

E9 HEAT PIPE INSTALLATION

For heat pipe installation, refer to Clause C3.18.

E10 SOLAR HEATING INSTALLATION

In case solar heating installation for providing low pressure hot water is specified, all materials and standard of performance shall comply with Clauses B6.15 and C6.28 of this General Specification.

E11 DEHUMIDIFIER

All dehumidifiers specified in the Particular Specification shall comply with the minimum energy efficiency as specified in this General Specification unless otherwise specified in the Particular Specification. Desiccant type and paper type outdoor air pre-conditioner systems employing wasted energy recovery for the latent heat transfer in the exhaust air and outdoor air in the air-conditioning system shall conform the specification in Clause D5.

The equipment with rated dehumidifying capacity not exceeding 35 litres per day shall have obtained a Grade 1 Energy Label under the Energy Efficiency Labelling scheme of the EMSD.

E12 OUTDOOR AIR PRE-CONDITIONER

For outdoor air pre-conditioner installation, refer to Clause D5.1.

PART F - ACMV SYSTEM WATER TREATMENT

F1 GENERAL

Water treatment for air conditioning water systems as follows shall be carried out to maintain water in proper "balance" condition (pH, hardness, total dissolved solids, total alkalinity, etc.) and to comply with the "COP" issued by the EMSD for requirement not indicated in the General Specification.: -

F1.1 Treatment of sea water for condenser cooling to kill or inhibit marine growth and to inhibit the formation of scale, slime and foam in the pumps, pipework and condensers;

F1.2 Treatment of water being circulated between condensers and cooling towers including the water in the tower;

(a) To inhibit corrosion, scaling, slime and foam formation; and

(b) To sterilise the water to prevent biofouling and the growth of pathological bacteria such as Legionella Pneumophila.

F1.3 Treatment of chilled water or low pressure hot water in circulation system to inhibit corrosion, formation of foam, scale and slime in the pipework and evaporator tubes.

The design, installation, commissioning, testing and operation of the water treatment system shall be carried out by a water treatment specialist who has at least five years local water treatment experience in compliance with the Particular Specification, this General Specification, the relevant parts of the Code of Practice for Fresh Water Cooling Towers issued by the EMSD, Code of Practice for Prevention of Legionnaires' Disease issued by Prevention of Legionnaires' Disease Committee, the Government of the HKSAR, other currently in force Legislation and Subsidiary Legislation in Hong Kong and subject to the approval of the Supervising Officer.

F2 FORM OF WATER TREATMENT

Where the types of treatment and plant are specified in the Particular Specification, the A/C Contractor shall install the plant and equipment as required.

Where no specific system or treatment is mentioned in the Particular Specification, the A/C Contractor shall provide a basic water treatment system in accordance with Clauses F1, F.4, F5 or F7 as appropriate.

The A/C Contractor shall submit drawings and technical information detailing the set-up of the proposed water treatment equipment, the type of chemicals used and the treatment proposal to the Supervising Officer for approval prior to ordering of the equipment.

The water treatment proposal shall include water specification, method of analysis and testing recommended by water treatment specialist together with the testing

report format. Bacteria count and identification of existence of pathological bacteria such as Legionella Pneumophila shall be included in the water analysis for cooling tower.

The A/C Contractor shall supply the necessary labour, testing equipment and chemicals for testing and commissioning, pre-cleaning and day-to-day water treatment of the systems within the Contract Period. In addition, the A/C Contractor shall also allow for continuing the treatment for the whole Maintenance Period (including costs for the sampling exercises and laboratory tests required) until the maintenance certificate is issued.

During the above-mentioned periods, the A/C Contractor shall employ the water treatment specialist to carry out on-site water treatment service and water analysis at least once a month to prove that the performance of the treatment system is satisfactory and conforming to the approved treatment proposal. Monthly report on the details of water treatment service and water analysis including tests, water treatments, consumption of chemicals, etc. shall be forwarded to the Supervising Officer each month.

F3 SEA WATER TREATMENT BY ELECTROCHLORINATOR

Systems designed for the injection of sodium hypochlorite solution produced on-site by an Electrochlorinator shall only be installed by the A/C Contractor where required and specified in the Particular Specification. Such system shall take water under pressure upstream of the main sea water pump (usually in pump chamber) and after passing through the Electrochlorinator, inject the solution back into the pump inlet side immediately after the first (primary) sea water inlet valve from the sea. The operation of the Electrochlorinator shall be interlocked to work or stop as the seawater pumps.

The resulting concentration of free chlorine residue at this point shall be between 1 ppm minimum and 6 ppm maximums. Facilities shall also be provided at the same point to input a supercharge of concentrated liquid sodium hypochlorite or other suitable chemical to achieve periodic "super-chlorination" of the system.

The water to the Electrochlorinator equipment must be passed through coarse and fine strainers installed in its supply pipework, to ensure minimum fouling up of the equipment cells. Duplicate Electrochlorinator plant shall be provided to ensure continued treatment when one unit is "off-line" for maintenance.

The electrodes shall be made of high corrosion resistant material, in particular, anodes shall be made of titanium substrate coated with protective oxide.

Integral safety facilities in the electrolytic cells such as water flow switch and cell voltage imbalance detector shall be provided to prevent build-up of hydrogen gas by-product. Vent and other necessary facilities shall be provided to dilute and disperse the hydrogen gas from the degas tank or degas cyclone to outdoor safely according to the requirements specified in the Particular Specification and the FSD’s statutory requirements.

Unless otherwise specified in the Particular Specification, an adequate electrical supply point will be made available to the equipment plant room by others. The electrical supply requirement and its connection to the Electrochlorinator shall be carried out by the A/C Contractor.

F4 SEA WATER TREATMENT BY BIOCIDES

Where no other system is specified and unless otherwise instructed by the Supervising Officer, this method shall be provided by the A/C Contractor as the basic form of treatment for condenser with sea water cooling applications.

F4.1 Basic Requirements

The biocides used shall inhibit the growth of marine organisms throughout the system. It shall also inhibit the formation of scale and slime by acting as an efficient dispersant. This shall be achieved by the appropriate biocide treatment being carried out at 2 to 3 day intervals such that on these occasions the whole system shall contain a 6-ppm concentration of biocide solution for approximate 1 hour, which is sufficient to kill all organisms. Continuous dosages shall not be applied at lower ppm levels lest they allow the organisms to build up immunity.

The biocidal and dispersing agents for sea water condenser cooling systems shall have the following properties: -

- Strong biocidal properties;
- Dispersing effect on deposits;
- Filming properties providing a protective film to internal of pipework;
- pH value of 6.8;
- Specific gravity of 0.98;
- Non-flammable;
- Easily dosed by chemical metering pump with or without dilution; and
- Being sufficiently bio-degradable such that they do not cause environmental difficulties for the marine life. In that respect, they must be of a type acceptable and approved by the HKSAR Environmental Protection Department or relevant Government Authorities.

F4.2 System Sizing and Design

Advice of the approved water treatment specialist shall be sought on the dosages required, together with calculation, for a specified system water volume.

In case the cooling system is running with fixed sea water flow rate, the metering pump(s)of the water treatment system can be set for a

particular input rate to achieve the appropriate dosage and duration which is usually possible to pump biocide direct from its supply container.

Where the cooling system is running with variable flow rate of sea water, the metering pump(s) concerned shall have the facility to automatically vary the amounts of chemicals dosing in proportion with the actual sea water flow. This can be achieved by metering pump(s) which can respond to the reading of a flow meter measuring the total sea water flow. Arrangement of variable chemical pumping rates shall be required where the sea water pump(s)is/are "stage" controlled or of "variable speed" control.

For “stage” controlled sea water pump(s), each sea water pump can be supplied with fixed biocide input from one metering pump. The inlet point shall be arranged before the pump and as near as possible to the primary inlet sea water gate valve. Such metering pump(s) would be controlled by the individual pump circuit such that they only operate when the respective pump is operated.

As an alternative, the sea water pump set(s) can also be supplied with a single source variable metering pump which is controlled by a flow measuring device placed after the outlet of main header. In such case, the chemical injection shall be distributed to all pump inlets via solenoid valves. Each solenoid valve shall be opened when the respective main sea water pump is switched on.

F4.3 Flow Measurement and Control

The flow measuring device shall be of a low flow interference inserted velocity / static differential headed type as described in more details in Section C10.

The unit shall be inserted through and across the centre of the pipe in which the fluid flow is to be measured. It shall be inserted with water tight glands at a position not less than a length of 12 pipe diameters downstream from any bend or any turbulence creating feature. The position chosen shall also be one that best assures an even velocity cross section flow of the fluid to be measured.

F4.4 Biocide Storage

Apart from the necessity to periodically replenish the biocide supply, the Installations shall be capable of catering for minimum 4 weeks unmanned automatic operation. Chemical tanks shall be provided to meet the requirement as specified in Clause F4.5.

F4.5 Chemical Tanks

The A/C Contractor shall supply and install two chemical mixing tanks which made of ultra violet resistant round moulded fibre glass or polyethylene. The capacity of each tank shall not be less than 180 litres.

The tanks shall be completed with cover of high rigidity fibre glass or polyethylene having suitable moulded recessed or other approved arrangements to support mountings of metering pump, agitator and liquid level controller switch.

The tanks shall be graduated in 10 litre steps and shall have the maximum storage capacity with its chemical name labelled on the tank body for easy identification.

The tanks shall be suitable for mixing the specified chemicals and be suitable for solutions at temperatures of up to 40 ^{o}C.

Each tank shall have a strong flat bottom providing adequate support when full such that the outer perimeter of the tank shall not be forced up by water pressure causing the bottom to bulge.

F4.6 Chemical Tube Connection to the Circulation System

Unless otherwise instructed by the Supervising Officer, the A/C Contractor shall allow for drilling and tapping into the delivery pipe at points near to the sea water intake and installing a suitable sized PVC valve completed with connectors for attachment of the chemical tubes from the metering pumps.

F4.7 Make Up Water Supply to Chemical Tanks

Unless otherwise specified, this shall take the form of an 18 mm bib tap situated over each chemical tank. The A/C Contractor shall provide a suitable supply to these bib taps with pipework securely fixed to the walls. A 25 mm mains valve supply will be provided by others within a 30 metres pipe run of the tanks. The A/C Contractor shall also supply sufficient lengths of chemical resistant flexible hose from bib taps to the tanks to facilitate the filling operation.

F4.8 Chemical Metering Pump

In conjunction with the chemical tanks, the A/C Contractor shall provide panel or tank-top mounted high efficiency metering pumps one per tank capable of pumping from 2 litres to 90 litres of solution each in 1 hour. Metering pumps exceeding 90 litres/hour will be considered subject to approval by the Supervising Officer. Chemical pump shall have ON/OFF switch and protection fuse.
The pumps shall be suitable for 100 : 1 output range facilitated by means of independently variable stroke length and stroke frequency.
Pump housing shall be of corrosion resistant glass fibre reinforced polypropylene and all electrical/electronic components shall be encapsulated. If necessary, anti-siphon/pressure release valve mechanisms shall be provided to ensure anti-siphon protection plus priming ease, even under pressure.

The pumps shall have an acrylic/polypropylene pump head, PVC/polypropylene fittings, ceramic valve balls, metal reinforced Teflon diaphragm, Teflon seal rings and liquiform face, anti-siphon mechanism. The discharge tubes shall be 10 mm internal diameter and of suitable PVC to transport the solutions involved.

The pump suctions shall be mounted into the tank using an UPVC suction tube assembly that will prevent the suction tube becoming wrapped around the agitator shaft. The end of the pump suction tube shall not extend beyond the bottom of the UPVC tube shield.

F4.9 Chemical Tank Agitator

The A/C Contractor shall supply and install into the provisions made on the chemical mixing tank cover one agitator assembly per mixing tank.

This shall consist of a fractional HP motor driving a stainless steel shaft and neoprene with bronze hub impeller. The shaft shall be of suitable length to suit the depth of the solution in the mixing tank.

The motor casing and screws shall be manufactured in nonferrous metal.

F4.10 Chemical Tank Liquid Level Switch

In order to prevent the metering pump and agitator from running if the chemical solution drops below a pre-set low level, the A/C Contractor shall supply and install into each tank cover a suitable liquid level switch and control system. A visual and audio alarm shall also be provided at the control/indication panel.

The level switch shall be contained in a corrosion resistant assembly of glass reinforced polypropylene. It shall have PVC float tube, foamed polypropylene float and encapsulated reed switch.

In each case, there shall be a float protector to prevent false actuation due to turbulence. An extra low voltage transformer shall be incorporated to provide the supply to the reed switch for safety.

The liquid level switch casing shall be manufactured from corrosion resistance material.

F4.11 Electricity Supply

Unless otherwise specified, the electricity supply for the metering pumps, agitators and level switch assemblies shall be operated with 220 V single phase 50 Hz supply and connected by the A/C Contractor from the supply point within the plant room to the water treatment equipment.

F5 COOLING TOWER/CONDENSER COOLING WATER TREATMENT BY CHEMICAL AGENTS

Where no other system is specified in the Particular Specification, this method shall be provided by the A/C Contractor as the basic form of treatment for water recirculation between cooling tower and condenser applications. The minimum provisions shall be follows: -

F5.1 Pre-cleaning and Flushing Out Operation

(a) The entire cooling tower/condenser cooling water system shall be flushed out using appropriate chemical dispersant, detergent and de-foamed of type and strength recommended by a reputable chemical water treatment manufacturer and guaranteed in writing by that company as suitable in every respect for the application in question.

(b) The chemicals shall remain in the system for 48-72 hours including a minimum of 24 hours with the pumped circulation in operation, unless otherwise recommended by the supplier with free technical support accepted by the Supervising Officer.

(c) The system shall then be completely drained and flushed until tests at all drain points show that traces of suspended matter have been substantially removed to the Supervising Officer's approval.

(d) The system water shall be completely drained as rapid as possible and the A/C Contractor shall provide temporary 50 mm valve drain outlets on all points where the main pipework is 50 mm or over.

(e) The A/C Contractor shall ascertain that there is adequate drainage nearby to discharge to by large hose in order to ensure flooding of low level areas will not occur. It is the responsibility of the A/C Contractor to ensure that the discharge to the building drainage system and public sewer are in full compliance with the requirements of the Drainage Services Department and the Environmental Protection Department. If pre-treatment is required, Clause F10 shall be referred.

(f) Subsequent to the flushing out operations, the large drain down points shall be reduced to 15 mm valves or cocks or the sizes as indicated on the Drawings. The system shall be refilled and flushed as necessary to achieve the required water quality level.

F5.2 Chemical Treatment to Prevent Corrosion, Sludge Formation and Microbiological Activity (Open System)

The chemical agent employed shall be a combination of chemicals which will provide corrosion protection, scaling and microbiological

inhibition to the metal pipe lines and the construction material within condensers and cooling towers.

The chemical agent shall be non-flammable liquid chemicals such as molybdate or phosphate based agent blended with anti-foulant and amine based biocide. The agent shall be guaranteed by the chemical manufacturer as suitable in every respect for the application.

F5.3 Chemical Dosage System

The chemical dosage system shall be a fully automatic system comprising the following minimum equipment: -

(a) Chemical metering pump as specified in Clause F4.8 and control panel constructed to IP 54 to BS EN 60529:1992+A2:2013 completed with system status indication, visual and audio alarm, timer, etc. as required to facilitate ease of operation and maintenance of the water treatment system;

(b) Chemical tanks as specified in Clause F4.5; and

(c) Chemical tank liquid level switch as specified in Clause F4.10.

F6 COOLING TOWER/CONDENSER COOLING WATER TREATMENT BY OZONE

This method of water treatment for fresh (including well water) or sea water circulating between cooling tower and condenser shall only be installed by the A/C Contractor where required and fully detailed in the Particular Specification. The minimum provisions shall be follows: -

F6.1 Pre-cleaning and Flushing Out Operation

As specified in Clause F5.1.

F6.2 Ozone Generation System for Cooling Water Treatment

The ozone generation system shall include all major ozone generating equipment, circulating pumps, interconnecting piping, pipe fittings, enclosure, wiring, accessories, controls and instrumentation to form a compatible and complete working system. Weather-proof enclosure with self-contained lighting and ventilation shall be provided for the system that is susceptible to weather or outdoor conditions.

A complete ozone piping system separated from the main cooling tower/condenser cooling water system shall be provided to take water from the recirculating pump discharge side of the cooling water circuit, through the in-line ozone injector /contactor for ozone dosing, a solid separator and then recirculated into the sump of the water cooling tower or tank. The system operation and ozone dosing shall be fully automatic with programmable direct digital real time control

incorporated. Multiple injection points shall be adopted for cooling systems with turnover rate not more than four times per hour.

Unless otherwise specified, the A/C Contractor shall be fully responsible for the design of the system, selection of equipment and ozone dosage rate for the particular fresh/sea water cooling water system with specific recirculation rate and system volume. The ozone dosage rate shall not be less than 0.1 mg/l in any case. The system shall be suitably oversized to satisfy the ozone demand at the initial stage for cleaning and descaling of the cooling water system for a period of not more than two weeks' period. Detailed system design and equipment selection proposal with all relevant design criteria, data, parameter, calculations and system schematic diagrams shall be submitted to the Supervising Officer for approval before placing order and actual commencement of installation works.

Each ozone generation system shall be constructed in modular form which shall comprise major equipment modules of pressure swing absorption type oxygen generator, high frequency ozone generator, ozone injector/contactor, solid particle separator, circulating pumps, piping, pipe fittings, all necessary accessories, wiring, controls and instrumentation. The modular enclosure shall be designed for ease of maintenance and safe operation with demountable panels, hinged doors, visual panels and adequate electrical segregation for the high voltage section.

The ozone generation system shall be easily connected to ozone-in-air monitor and other control instrument for automatic stopping and control of the entire system. Visual and audio alarm shall be incorporated as specified. Ozone-in-air monitors shall be fixed at locations as indicated in the Drawings if specified in the Particular Specification and properly connected to the ozone generation system.

All components in contact with ozone produced shall be made of ozone resistant material designed for continuous and prolonged usage without deterioration or damage. Unless otherwise specified in the Particular Specification, all system components in contact with ozonated water shall be made of stainless steel to AISI 316. In particular, Teflon tubing shall be used for connecting ozone generator and in-line injector, Polyflo tubing for oxygen conveying pipe, UPVC piping and fittings for other interconnecting pipework.

Major ozone generating equipment shall comprise, inter alia, the following component: -

(a) Pressure Swing Absorption Oxygen Generator

The oxygen generator comprises a built-in oil-free compressor for air compression, air dryer pre-chiller, an automatic high efficient desiccant air dryer with marcoporous drying agent, a nitrogen absorption tank to produce constant and stable supply of oxygen with purity 85% ±5%. Regeneration shall be

accomplished by heating the desiccant material and purging it with a small flow of dried air to expel moisture when they are saturated with moisture.

A dewpoint monitoring system shall be incorporated, which comprises a control unit and measuring probe situated within the pipework leading from the air dryer to the ozone generator. The monitoring system shall automatically stop the ozone production with an visual and audible alarm in case of an increase in dewpoint over a preset value in order to prevent failure or damage to the ozone generator.

Air dryer pre-chiller shall reduce the incoming air temperature to approximately 10°C or other optimum operating temperature recommended by the manufacturer to suit the type of desiccant used.

(b) Ozone Generator

The ozone generator unit shall comprise independent solid-state high frequency ozone generator modules, air-cooled plate type and constructed of either sandwich heat dissipating structure with ceramic coated steel plate discharge electrodes or cylindrical concentric ozone generating tube.

Each module shall be equipped with built-in safety circuit to give visual and audible alarm and to switch off the generator when abnormal operation of the generator occurs. Relevant type-test or factory test certificates of the generator's high voltage transformer section as listed below shall be submitted for verification of safe operation:-

(i) Voltage ratio and phase relationship test;

(ii) Induced over-voltage withstand test;

(iii) Insulation resistance test; and

(iv) High voltage withstand test.

Minimum safety controls shall be provided as follows:-

Door mechanically interlocked with the main isolating switch;

Over current cut-out;

High temperature cut-out;

Low air flow or low cooling water cut-out as appropriate;

High dew point cut-out;

High/low voltage cut-out;

External fault cut-out (if external devices connected); and

Isolation of power supply when panel doors or side panels are opened.

Unless otherwise specified, water-cooled type ozone generator shall be offered; air-cooled type modules shall only be offered for low capacity ozone generator unit as specified in the Particular Specification. The cooling water shall be taken from the chilled water system of the building as indicated in the Drawings or at nearest A/C plant room. Pressure reducing valve, regulating valve and connecting chilled water piping shall be provided to maintain the design constant operating conditions of the modules.

(c) In-line Injector/Contactor

The in-line injector shall be venturi type completed with double check valves fabricated of Kynar or products having equivalent functions or performance.

(d) Solid Particle Separator

The separator shall be fabricated of Noryl plastic or products having equivalent functions or performance selected to suit system flow rate and requirements.

(e) Circulating Pump

The circulating pump shall be compatible with the ozone system and supplied by the same ozone equipment supplier. The pump shall comply with relevant sections of this General Specification.

(f) Test Kit and Ozone Monitoring Equipment

Sampling points in the system together with a complete set of test kit for residual ozone testing shall be provided to facilitate daily inspection and assessment of ozone content.

A portable ozone-in-air monitor with range 0 - 9.5 ppm and 4-digit LCD shall also be provided.

The above test kit and monitor shall be handed over to the operating staff prior to the expiry of Maintenance Period.

(g) On Site Operational Training

Familiarisation of equipment and on-site training of the whole ozone water treatment system shall comply with the requirements in Clause F9. In addition, a competent specialist of the ozone system shall hold the on-site training of the water treatment system.

F7 CLOSE CIRCUIT CHILLED WATER OR LOW PRESSURE HOT WATER HEATING SYSTEMS TREATMENT BY CHEMICAL AGENTS

Where no other system is specified in the Particular Specification, this method shall be included for by the A/C Contractor as the basic form of water treatment for the close circuit chilled water or hot water heating system applications.

The minimum provisions shall be as follows: -

F7.1 Pre-cleaning and Flushing Out Operations

As specified in Clause F5.1.

F7.2 Chemical Treatment to Prevent Corrosion, Scaling and Sludge Formation

The chemical agent shall be a combination of chemicals guaranteed by the manufacturer as appropriate in every respect to prevent corrosion, scaling and sludge formation.

The agent should be liquid chemicals such as molybdate or nitrite based agent blended with corrosion inhibitor which can provide such protection to the metal of closed circuit pipe lines, system and equipment.

Chemicals used within chilled water or low pressure hot water (LPHW) heating system shall, unless otherwise recommended by the supplier with full technical support and accepted by the Supervising Officer, have the following characteristics: -

Suitable for the application, system operation conditions and fluid;

Non-flammable; and

Low toxicity.

F7.3 Chemical Dosage Equipment

As specified in Clause F5.3.

F8 WATER TESTING EQUIPMENT

Unless otherwise specified in the Particular Specification, water testing equipment corresponding to the type of water treatment system and chemical used shall be provided to monitor and verify the performance of the water treatment system offered and shall be handed over to the operation and maintenance staff prior to the expiry of Maintenance Period.

The equipment shall be of portable type suitable for field sampling and testing. For chlorine residual concentration testing, plain tablets and colour disc shall be provided. For pH value testing, pH meter or phenol red solution and colour disc shall be provided. Other relevant test kits shall include but not limited to total dissolved solid and corrosion inhibitor level tester.

F9 TRAINING, OPERATION AND MAINTENANCE FACILITIES

No matter which type of water treatment system is offered, adequate on-site operational training and demonstration of the water treatment system shall be provided to the operation and maintenance staff prior to handover of the system or after completion of the Installations. It shall include but not limit to the following: -

F9.1 Familiarisation of equipment and system including function of each dosing chemical.

F9.2 Water treatment equipment set-up/adjustment.

F9.3 On-site training of water sampling and testing, equipment and system operation and maintenance procedures.

F9.4 Precautions in handling the chemicals and the remedial actions following a spillage and accidental human contact.

Competent persons from the approved water treatment specialist and equipment suppliers shall conduct the on-site training with full day in-hand training. The exact training requirement shall be submitted by the A/C Contractor to the Supervising Officer for endorsement.

The A/C Contractor shall provide prominent warning notices, goggles, gloves and necessary accessories for handling the chemicals.

Sufficient number of sampling points in the pipework or equipment for water analysis, routine inspection and testing shall be provided.

F10 PRE-TREATMENT FOR DUMPING OF CHEMICAL WASTES

All chemical wastes generated by the A/C Contractor shall be handled, collected and disposed of in accordance with the Waste Disposal (Chemical Waste) (General) Regulation. The A/C Contractor shall register as a Chemical Waste Producer with the Environmental Protection Department and the wastes shall be collected by a licensed Chemical Waste Collector for disposal at an approved facility.

PART G - PAINTING, FINISHING AND PROTECTIVE TREATMENT

G1 GENERAL

All surfaces except otherwise specified in the particular specification, other than those indicated to be left self-finished such as stainless steel, anodized aluminium, shall be finished in first class paint work. All metallic surfaces shall be wire-brushed and cleaned to make it free from rust, scale, dirt and grease prior to painting. Primer shall be applied to metal surface on the same day as they have been clean. All work shall be carried out by qualified tradesmen/skilled workers.

All paints shall be submitted for the approval of the Supervising Officer. The volatile organic compound (VOC) content, in grams per litre, of all paint and primer shall not exceed the prescribed limit under the Air Pollution Control (Volatile Organic Compounds) Regulation or the limit set by EPD, whichever is more stringent.

VOC content of paint shall be determined by methods stipulated in Air Pollution Control (Volatile Organic Compounds) Regulation or other methods acceptable to EPD.

All painting works shall be completed and left in ventilated environment for at least one week, or the curing period recommended by the paint manufacturer whichever is longer, before occupation or handover of the renovated area to minimise VOC exposure.

All surfaces shall be painted and finished as specified in the Particular Specification to meet and match the aesthetic architectural design as required.

All internal surfaces including cladding walls, floors, ceiling and equipment plinth of AHU and fan rooms or plant rooms affecting IAQ shall be painted as specified in D.1 of this General Specification.

G2 NUMBER OF PAINT COATS REQUIRED

All painted surfaces are to receive at least one primer coat and two coats of the finishing colour. For external installation / equipment installation, polyurethane paint shall be used for finishing colour to provide better UV resistance unless otherwise specified. Ferrous surfaces shall receive one coat of rust inhibiting primer, one under-coat and two finishing coats.

Where painting is carried out in occupied areas with central air-conditioning or areas without good natural ventilation, pre-painting preparation and primer coat shall be carried out off-site and only the finishing coats shall be painted on-site.

G3 IDENTIFICATION OF PIPELINES

All pipework in the plant/machinery rooms shall be finished generally in accordance with ISO 3864-1:2011. All pipework, where exposed on surfaces outside the plant/machinery room, shall be painted either as in the plant/machinery room or to match the surrounding surface with distinguishing colour code bands plus flow arrows in the specified colour scheme as directed by the Supervising Officer.

Pipes and pipelines shall be painted in colours either in accordance with ISO 3864-1:2011 or as directed by the Supervising Officer completed with the identification colour code indicators. The basic identification colour or the decoration colour shall be applied over the whole length of the pipe with colour code indicators placed at all junctions, at both sides of valves, service appliances, bulkheads, wall penetrations and at any other places where identification is necessary as directed by the Supervising Officer.

Valves may be painted in the same colour as the associated pipework. However, if the pipeline is part of the fire services installation and has been coded only with the safety colour, the valves involved shall be fully painted "safety-red".

The direction of flow of fluid shall be indicated by an arrow over the basic identification colour and painted white or black in order to contrast clearly with the basic identification colour.

Colour code numbers are those of BS 4800:2011. The schedule of colour for ready mixed paints and BS colour reference shall be as Clause G4, in table G4-(1) and G4-(2).

G4 SCHEDULE OF COLOURS

Colour schedule as stated below are those of BS 4800:2011 for ready mixed paints.

Table G4 – (1) Schedule of Colours

Description of Services		Basic Colour	Colour Code Indication 100 mm approx.			Basic Colour
Pipework:						
Water	Drinking	Green	Blue			Green
	Cooling (Primary)	Green	White			Green
	Boiler Feed	Green	Crimson	White	Crimson	Green
	Condensate	Green	Crimson	Emerald Green	Crimson	Green
	Chilled	Green	White	Emerald Green	White	Green
	Mains supply, Cold	Green	White	Blue	White	Green
	Mains supply, Hot	Green	White	Crimson	White	Green
	Sea, river Untreated	Green				
	Fire Fighting	Green	Safety Red			Green
Gases	In either gaseous or liquefied condition (exception)	Yellow ochre				
Compressed Air		Light blue				
Steam		Silver grey				
Oil Lubricating		Brown	Emerald Green			Brown
Gas	Town	Yellow ochre	Emerald Green			Yellow ochre
	Natural	Yellow ochre	Yellow			Yellow ochre
Drainage		Black				
Acids &Alkaline		Violet	Black & Yellow Stripes			Violet
Equipment:						
Plant		Opaline Green				
Electrical Conduits & Ductwork		Orange				
Ductwork		White				

Table G4 – (2) BS Colour Reference

	BS 4800:2011
(1) Basic Identification Colours	
Green	12D45
Silver grey	10A03
Brown	06C39
Yellow ochre	08C35
Violet	22C37
Light blue	20E51
Black	00E53
Orange	06E51
(2) Safety Colour	
Red	04E53
Yellow	08E51
Auxiliary blue	18E53
(3) Code Indication Colour	
Crimson	04D45
Emerald green	14E53
Yellow	10E53

G5 MACHINERY AND PIPEWORK

All machinery, unless otherwise specified, shall be finished in a colour as instructed by the Supervising Officer at the time of installation. The A/C Contractor shall seek the Supervising Officer's instructions in good time to obtain the materials required. In the event that no instruction is given, the plant shall be painted in opaline green with black relief on flanges in accordance with BS EN 60073:2002.

G6 COPPER PIPE AND FITTING

Copper pipes and fittings for refrigerant, which are not insulated shall be polished bright by sanding, wiped with mineral spirits and coated with an approved heat resisting clear synthetic varnish.

G7 PIPES AND DUCTWORK

The final external treatment for insulated pipes and ductwork shall be as specified in Section C11 of this General Specification or as indicated in the Particular Specification or as directed on Site by the Supervising Officer.

Pipes and ductwork concealed in false ceiling or ductwork not normally accessible need not be painted, unless otherwise specified in the Particular Specification but appropriate colour code identifications shall be applied.

Insulated pipes and ductwork running in visual positions shall be plastered or otherwise finished as specified. They shall be painted in the appropriate identifying colour or as directed by the Supervising Officering another colour plus identifying colour code bands.

Uninsulated pipes and ductwork running in visual areas shall be painted in the appropriate colour throughout or painted in another colour as directed by the Supervising Officer but identified with appropriate colour code bands.

G8 PROTECTION OF PLANT, EQUIPMENT, PIPEWORK, ETC.

G8.1 Temporary Dehumidifiers and/or Air Conditioners

For temperature and/or humidity sensitive electrical or electronic control panels and equipment, the A/C Contractor shall where necessary protect them against high humidity and/or temperature by operating portable or temporary dehumidifiers and/or air conditioners in the enclosures containing this equipment.

In order to protect this equipment against dust infiltration, the A/C Contractor shall store them in a dust free room or enclose them in heavy duty PVC sheets or bags. Where necessary, filters shall be provided in the temporary air conditioning systems.

G8.2 Metal Surface

All stainless steel parts shall be covered with PVC wrapper of tape until handover. All ferrous parts shall be painted or greased (whichever is most suitable). All bright parts (chrome plates, polished stainless steel or aluminium, etc.) which are liable to deterioration shall be covered with tallow or a suitable protective coating during the progress of work. Upon completion of work, the protective coating shall be removed and the parts polished as appropriate.

Any damage to the primer or protective coatings shall be made good. When it is necessary to remove, or partly remove the protection for installation or making connections, the A/C Contractor shall ensure that the standard of protection provided originally is re-applied at the earliest possible time.

G8.3 Rust and Foreign Matter

All plants, pipes valves, and fittings shall be, as far as possible, thoroughly cleaned and cleared of rust and other foreign matters both before erection and before subjection to pressure tests.

G9 PROTECTIVE MEASURES AGAINST CORROSION

Where normal painting is not practicable, all possible measures to prevent corrosion to the plant shall be applied such as special protective coverings, special anti-corrosive paints, etc. as recommended by the supplier or specified in the Particular Specification.

For protection against system internal corrosion, chemical treatment of the internal water as described in Part F of this General Specification shall be applied. The provision of sacrificial anodes and bonding to eliminate electrolytic action shall also be applied wherever applicable.

PART H - INSPECTION, TESTING AND COMMISSIONING DURING CONSTRUCTION PERIOD

SECTION H1

GENERAL REQUIREMENTS

H1.1 GENERAL

The inspection, testing and commissioning shall be carried out in accordance with the requirements specified in this Part and Testing and Commissioning Procedure for A/C Installation in Government Buildings which shall be referred to and adopted where appropriate.

Throughout the execution of the Installations, the A/C Contractor shall be responsible for ensuring compliance with the statutory and related requirements included in Section A2, manufacturers' recommendations and specifications and shall notify the Supervising Officer of any infringement which directly or indirectly detracts from the safe and satisfactory operation of the Installations whether or not such infringement relates to the works covered in the Installations or to those associated with others. All sub-standard works or defects found during inspection, testing and commissioning shall be rectified or replaced to the satisfaction of the Supervising Officer.

H1.2 METHODS AND PROCEDURES

The A/C Contractor is required to submit detailed inspection, testing and commissioning methods and procedures together with report formats for reporting the inspection, testing and commissioning results for the Supervising Officer's approval at least four months before commencement of the testing and commissioning works, or four months after the acceptance of his Tender, whichever is earlier.

H1.3 NOTICES OF INSPECTION, TESTING AND COMMISSIONING WORKS

For items to be witnessed by the Supervising Officer or his Representative, the A/C Contractor is required to provide advanced notice for inspection, testing and commissioning works, together with details of date, time and list of items to be inspected or tested, unless otherwise specified in the Conditions: -

(a) Off-site Inspection and Test

An advanced notice of at least one week before commencement of the inspection or test shall be provided.

(b) On-site Inspection, Testing and Commissioning

An advanced notice of at least 3 days before commencement of inspection, testing or commissioning of any part or parts of the Installations shall be provided.

H1.4 LABOUR AND MATERIALS

The A/C Contractor is responsible for provision of all labour and both consumable and non-consumable materials for carrying out the inspection, testing and commissioning works at their expenses. Unless otherwise indicated in the Conditions, all electricity supply, water supply, chemicals, and other fuels, such as diesel, LP gas and town gas necessary for the operation of the plant during preliminary runs and for full adjustments and inspection and commissioning tests shall also be arranged and provided at no cost by the A/C Contractor unless otherwise specified in the Contract. The A/C Contractor shall also properly drain the water and exhaust the gas during and after the inspection, testing and commissioning works as required. The A/C Contractor shall provide and adopt measures to avoid damage to the building, Installations, decorations and fixtures during the inspection, testing and commissioning works for any of the Installations.

The A/C Contractor shall also provide all necessary equipment, apparatus and tools for carrying out the inspection, testing and commissioning works.

The A/C Contractor shall despatch competent and experienced commissioning personnel to carry out the inspection, testing and commissioning works.

H1.5 INSPECTION, MEASURING AND TESTING EQUIPMENT

The A/C Contractor is required to supply the calibrated equipment and instrument for the inspection, testing and commissioning works in accordance with the requirements as specified in the Particular Specification for supply of inspection, measuring and testing equipment. Certified true copy of calibration certificates shall be submitted. The period between calibration and testing shall not exceed the calibration period as recommended by the equipment/instrument manufacturer or 12 months whichever is shorter.

H1.6 READINESS FOR INSPECTION, TESTING AND COMMISSIONING

The A/C Contractor is required to check the completion of the works to be inspected, tested or commissioned, the associated builder’s works, the associated building services installations and all other prerequisites to ensure that inspection, testing and commissioning can be preceded in a safe and satisfactory manner without obstruction.

H1.7 "TYPE-TEST" CERTIFICATE

"Type-test" for materials and equipment, where specified, shall be carried out at the manufacturer’s works, recognised institutions or accredited laboratories, or elsewhere as approved in order to demonstrate their compliance with the specified requirements. "Type-test" certificates together with the corresponding drawings,

sketches, reports and any other necessary documents shall be submitted to the Supervising Officer for approval before delivery of the materials and equipment. Cases where appropriate, “type-test” certificates will be accepted are as follows:

(a) Fans: “type-test” certificates showing fan characteristic curves (ISO 5801:2017), "type-tests" Certificates for sound power levels (BS EN ISO 5136: 2009), fan dynamic balancing test Certificates completed with a method of statement from manufacturer on testing to Grade 2.5, 4 & 6.3 on appropriate fan types in accordance with ISO 21940-11:2016 and ISO 21940-14:2012.

(b) Pumps: "type-test" certificates for head, discharge, speed and power input (BS EN ISO 9906:2012 as appropriate).

(c) Electric motors: "type-test" certificates in accordance with BS EN 60034-1:2010 and/or IEC 60072-1:1991, IEC 60072-2:1990 & IEC 60072-3:1994.

(d) Low voltage starter switchgear and control gear assembly: "type-test" certificates for starter (e.g. auto-transformer) and control panels assembly as a whole in accordance with IEC 61439-1:2011.

(e) High voltage switchgear and motor control switchboard: "type-test" certificates for high voltage switchgear and switchboard in accordance with IEC 62271-100:2008+A1:2012+A2:2017.

(f) Other electrical equipment, such as air heaters (but excluding thermostatic control equipment): "type-test" certificates in accordance with BS EN 60335-1:2012+A13:2017, BS EN 60669-1:2018, BS 5733:2010+A1:2014 and BS EN 60670-22:2006.

(g) Refrigeration plant: "type-tests" Certificates for hydraulic and air pressure testing at works in accordance with BS EN 378-1:2016, BS EN 378-2:2016, BS EN 378-3:2016 and BS EN 378-4:2016

H1.8 OFF-SITE TESTS / FACTORY TESTS

Factory tests and off-site tests as required shall be carried out at the manufacturer’s works, laboratories by independent regulatory/testing bodies, independent accredited laboratories or elsewhere as approved. This shall include quality control tests and general inspection tests in factory recommended by the manufacturer or for compliance with relevant standards.

Where collection of test samples on the Site is required for the off-site tests, i.e. indoor air quality test and water quality test for fresh water cooling tower, the A/C Contractor shall submit the sampling and analysis methodology, including but not limited to the proposed independent accredited laboratory and the procedures for collection and analysis of test samples and submission of test results, for the Supervising Officer’s approval. The A/C Contractor shall notify in advance the date for collection of test samples to the Supervising Officer’s Representative, who shall supervise the sampling, transport and delivery of the test samples. Collection of test samples shall be conducted by the independent accredited laboratory unless otherwise agreed by the Supervising Officer. The collected test samples shall be kept in sealed and locked containers inaccessible to unauthorised

persons at all times. The test results in sealed envelope shall be submitted by the independent accredited laboratory to the Supervising Officer directly.

Where specified, performance tests shall be carried out in factory for each or some of the offered equipment before delivery. After the performance tests, factory test report/certificate certified by a qualified factory engineer shall be submitted in duplicate to the Supervising Officer for approval immediately after the tests and before the equipment is dispatched from the manufacturer's works.

Factory tests shall be witnessed by an independent approved agency where specified. The A/C Contractor shall note that the Supervising Officer may require witnessing the tests and inspection of locally and/or overseas manufactured equipment during construction at the manufacturer's works.

H1.9 SITE TESTS

The A/C Contractor shall carry out site tests for all static systems during construction period for individual components and/or part of the installed works to ensure safe and proper operation of the complete installation according to the specified requirements. Such tests shall include integrity test of welds and pressure test on the hydraulic systems where applicable. Any component or equipment set to operate at or below the test pressure shall be isolated or removed prior to applying the pressure test. Site tests for electrical works in the Installations shall comply with the COP for the Electricity (Wiring) Regulations unless otherwise specified. Registered or suitably qualified workers shall be deployed to conduct site tests, where applicable, for the Installations.

Works to be permanently covered up shall be subject to inspection and testing before covering up. If the Supervising Officer or his Representative discovers any work that has been covered up before inspection and testing, this work shall be uncovered for inspection and testing to the satisfaction of the Supervising Officer or his Representative. The cost involved in uncovering the work, inspecting, testing and re-concealing the work together with any consequential losses shall be paid by the A/C Contractor at no additional cost to the Employer.

In particular, the following arrangements shall also be included:

(a) The A/C Contractor shall carry out "on-site" tests in respect of all static systems to ensure safe and proper operation as conforming to the design intent. Such tests shall include test of welds and pressure tests on the hydraulic systems.

(b) On completion of cleaning operations described in Clauses 3.6.1 and 4.1.6.5 of the Testing and Commissioning Procedure for Air-conditioning, Refrigeration, Ventilation and Central Monitoring &Control Systems Installation, each water distribution system shall be re-charged with clean water and then subjected to a hydraulic test as required by Clause 4.1.6.6 of T&C Procedure for Air-conditioning, Refrigeration, Ventilation and Central Monitoring &Control Systems Installation.

Any items of equipment set to operate at or below the test pressure shall be isolated or removed prior to applying this test.

(c) All ductwork shall be tested for air leakage in accordance with Clause B2.10.

SECTION H2

INSPECTION

H2.1 INSPECTION OF MATERIALS AND EQUIPMENT DELIVERED TO SITE

The A/C Contractor shall provide details of materials and equipment delivered to the Site including, but not limited to, brand name, model number, country of origin (if specified), their tested standards and record of Supervising Officer's approval, purchase order, delivery order, record of delivery, payment vouchers, ex-factory certificate and shipping voucher, and all other relevant documents as applicable to the Supervising Officer for identification and verification of the materials and equipment delivered to the Site are in compliance with the approved submissions.

H2.2 VISUAL INSPECTION AND CHECKING

The A/C Contractor shall be responsible for arranging adequate provisions to facilitate visual inspections and checking of the work in progress to be carried out by the Supervising Officer or his Representative from time to time during the construction period. The A/C Contractor shall keep such inspection record for checking from time to time. Any defective works or sub-standard works found during visual inspection and checking shall be rectified or replaced before proceeding with further tests.

Visual inspection and checking shall include but not limited to the inspection and verification of the installed equipment being the approved brands and models and checking of any visible damages (such as scratches or dents, or painting problems) found on the equipment surface.

H2.3 HANDOVER INSPECTION

The A/C Contractor shall carry out detailed inspections for all components and equipment installed by him and make all necessary checking including operational settings for all equipment and systems in accordance with the instructions and recommendations from the manufacturer and to the satisfaction of the Supervising Officer before the handover of the Installations.

If it is considered difficult or impossible to gain access to a part or parts of the complete installation for dismantling or maintenance purposes, the A/C Contractor shall be required to carry out demonstrations on dismantling and assembling those parts/components of the installation to confirm the provisions are adequate. The A/C Contractor shall be responsible for carrying out all necessary modification work at no additional cost to the Employer to alleviate the difficulties associated with dismantling or maintenance access.

The A/C Contractor shall note that the Installations cannot be handed over until all the foregoing requirements where applicable have been carried out to the satisfaction of the Supervising Officer.

The A/C Contractor shall provide the following documents and data before the handover inspection: -

(i) Test Certificates

Test records/certificates where applicable shall be provided: -

(a) Copies of manufacturer's works test records/certificates on plant items comprising heat generating plant, heat exchangers, chillers units, packaged air-conditioning units, tanks, vessels, motors, fans, pumps, etc.;

(b) Copies of hydraulic and pressure test records/certificates for works carried out on site;

(c) Copies of boiler and/or refrigeration plant efficiency test/record certificate;

(d) Copies of Registered Surveyor's test/record certificates for pressure vessels (if any);

(e) Copies of performance test/record certificate including water balancing, air balancing, room conditions, etc. These certificates shall be accompanied with all appropriate charts and diagrams;

(f) Copies of all noise test/survey records on every noise emitting plant and machineries, individual room/space and a statement of compliance with the statutory requirements under the current Noise Control Ordinance (Cap. 400); and

(g) Copies of works completion certificates for electrical works;

(ii) "As-built" Drawings

"As-built" drawings as detailed in the contract documents shall be provided.

(iii) Operation and Maintenance Manuals and User Manual

O&M Manuals and User Manual as detailed in the contract documents shall be provided.

(iv) Manufacturer's Name Plate

Every item of plant/equipment/apparatus supplied by a manufacturer, if any, shall be fitted with a clearly engraved, stamped or cast manufacturer's name plate properly secured to the plant/equipment/apparatus and showing: -

- Manufacturer’s Name;
- Serial and/or Model No.;
- Date of Supply;
- Rating/Capacity; and
- Test and Working Pressure (where applicable).

(v) Labels and Related Instructions

Labels and the related instructions shall be provided according to relevant clause(s) of this General Specification.

SECTION H3

TESTING AND COMMISSIONING

H3.1 GENERAL

Where testing and commissioning works for the Installations are required to be witnessed by the Supervising Officer or his Representative, the A/C Contractor shall carry out the proper testing and commissioning works to his satisfaction before inviting them to witness the works. The A/C Contractor shall arrange to enable the Supervising Officer or his Representative to witness the complete testing and commissioning. Unless otherwise approved by the Supervising Officer, testing and commissioning works carried out by the A/C Contractor in the absence of the Supervising Officer or his Representative shall not be accepted as the approved test record.

Any defects of alignment, adjustment, workmanship, materials and performance or other irregularities which become apparent during commissioning or testing shall be rectified by the A/C Contractor and the relevant part of the commissioning or testing procedure shall be repeated at the A/C Contractor's own expense.

For the purpose of this General Specification the following definitions shall apply: -

(i) Commissioning: the advancement of an installation from the stage of static completion to full working conditions and to meet the specified requirements. This will include setting into operation and regulation of the Installations.

(ii) Setting to work: the process of setting a static system into motion.

(iii) Off-site Tests: tests carried out on items of equipment at manufacturer's works or elsewhere to ensure compliance with the requirements of Specifications and/or relevant Standards or Codes of Practice (or other standards specified).

(iv) Site Tests: tests on static plant and systems (e.g. inspection and testing of welds, hydraulic testing of pipe work, etc.) to ensure correct and safe installation and operation.

(v) Regulation: the process of adjusting the rates of fluid flow and heat transfer in a distribution system within specified tolerances as stated in the relevant CIBSE Commissioning Code.

(vi) Performance Testing: the measuring and recording of the performance of the commissioned installation.

H3.2 PROCEDURES, STANDARDS AND REQUIREMENTS

The A/C Contractor shall follow relevant approved standards, procedures, guidelines in the testing and commissioning works, which shall include but not limited to:-

(a) Statutory obligations and requirements, specifications and standards specified in Part A;

(b) Testing and Commissioning Procedure for Air-conditioning, Refrigeration, Ventilation and Central Monitoring & Control System Installation in Government Buildings of the Hong Kong Special Administrative Region issued by BSB, ArchSD;

(c) Detailed inspection, testing and commissioning methods and procedures approved by the Supervising Officer; and

(d) Equipment manufacturers' recommendations and specifications, if any.

H3.3 MASTER PROGRAMME FOR TESTING AND COMMISSIONING WORKS

The A/C Contractor is required to submit a programme for testing and commissioning works within the first three months after acceptance of his Tender. The programme shall indicate the tentative dates of all tests and commissioning works that will be carried out throughout the Conditions and all necessary submissions and approval relating to testing and commissioning. The A/C Contractor shall ensure that the testing and commissioning programme matches the master programme for construction and that all testing and commissioning works are complete before the prescribed or extended date for completion of the Works. The programme shall also be updated as the Installations progress towards completion.

The programme shall detail the types of testing and commissioning works required, the breakdown of the programme into floor-by-floor and/or area-by-area basis, the tests that are required during construction and before completion of the Installations, the period of each test with float time allowed, the milestone dates for the key activities of works etc. Critical path programme shall be submitted. The A/C Contractor shall plan the programme so as to minimise the overlapping of different tests arranged simultaneously in different locations of the Site.

A detailed checklist of all the Installations to be commissioned and tested shall be submitted at the same time. The checklist will be used for progress monitoring and shall be updated from time to time as the Installations progress towards completion.

H3.4 DOCUMENTATION AND DELIVERABLES

The A/C Contractor shall submit full commissioning and testing report to the Supervising Officer within 14 days after completion of the commissioning and testing of the Installations. The report shall be in accordance with the requirements approved by the Supervising Officer.

H3.5 TESTING AND COMMISSIONING ENGINEER / SPECIALIST

Where specified in the Particular Specification, the A/C Contractor shall appoint a competent and experienced testing and commissioning engineer/specialist responsible for overall planning, organising, coordinating, supervising and monitoring of the testing and commissioning works and also certifying all results and reports from the testing and commissioning works. The A/C Contractor shall submit, after the acceptance of his Tender, information detailing the qualification and experience of the testing and commissioning engineer/specialist for the Supervising Officer's approval.

PART I – TRAINING, INSPECTION, ATTENDANCE, OPERATION AND MAINTENANCE DURING MAINTENANCE PERIOD

SECTION I1

GENERAL REQUIREMENTS

I1.1 GENERAL

Unless otherwise specified in the Particular Specification, the A/C Contractor shall provide training, inspection, attendance and operation and maintenance services for the Installations during maintenance period as specified in this General Specification.

The A/C Contractor shall supply and install, without additional cost to the Employer, replacements for any equipment or parts thereof, which may, in the opinion of the Supervising Officer, become unserviceable, especially where the causes are attributable to faulty materials, workmanship, or inadequate performance.

In the execution of servicing and maintenance, repair and operation work on site, apart from transportation, necessary labour, tools, equipment and testing instruments, the A/C Contractor shall also be responsible for keeping adequate stocks of spare parts/equipment and other items necessary to maintain all emergency repair in an efficient, satisfactory and safe operation condition at all time.

The interruption of electricity supply and functioning of the Installations during execution of works shall be kept to the minimum. Such interruption shall only be allowed with the prior approval of the Supervising Officer or his Representative.

The A/C Contractor shall provide all the Level One Services as specified in this General Specification for all installation works.

Level Two Services detailed in this General Specification shall only be carried out if specified in the Particular Specification. The specified Level Two maintenance responsibilities shall be priced separately in the Tender with cost for each individual item.

I1.2 COMPLETION OF OUTSTANDING AND DEFECTIVE WORKS

After receiving the list of defects and outstanding works issued with the Certificate of Completion, the A/C Contractor shall complete the outstanding works and rectify the defects concerned to the satisfaction of the Supervising Officer within the agreed time frame during the Maintenance Period. The A/C Contractor shall also rectify as soon as practicable any defects identified within the Maintenance Period.

The A/C Contractor shall submit periodic report on the progress of outstanding and defective works to the Supervising Officer and attend inspection with the

Supervising Officer's Representatives to verify satisfactory completion of the outstanding and defective works.

I1.3 REPAIR AND MAINTENANCE RECORDS

The A/C Contractor shall be responsible for maintaining a log book in each of the specific locations (e.g. switch room, plant room, etc.) as agreed with the Supervising Officer or his Representative. Every attendance and details of work done for the Installations including but not limited to repair, servicing and maintenance shall be entered into the log book by the A/C Contractor so as to form a comprehensive record of attendance and works done. The log book may be completed in either English or Chinese. In addition, the A/C Contractor shall also keep repair and maintenance records for the Installations in his own office and shall be required to forward such records for checking if so requested by the Supervising Officer.

SECTION I2

TRAINING TO USERS AND OPERATION AND MAINTENANCE AGENTS

I2.1 GENERAL

Training for the operation and maintenance of system and equipment shall be provided and arranged by the A/C Contractor. The training shall include all training facilities, material and handouts etc. The A/C Contractor shall submit a "Training Schedule" at least 3 months prior to the prescribed or extended date for the completion of Works for the Supervising Officer's approval. The schedule shall include but not limited to the following requirements:

(i) The A/C Contractor shall provide facilities and training programme to ensure that the Employer's operation and maintenance staff acquire full knowledge and operation, breakdown and routine maintenance, diagnosis and hence operate and maintain reasonably effectively and efficiently the system/equipment including Central Control and Monitoring System offered. The training proposal shall include all aspects of operation and maintenance of the plant including the use of special tools. Besides, equipment portfolio for the installations offered shall be submitted together with the training proposal. The equipment portfolio shall include quantity of equipment, equipment cost, recommended serviceable life by the manufacturer and cycle of major overhaul;

(ii) A training proposal for such service shall be included in the Tender;

(iii) The training proposal shall also include details and duration of the training course(s), qualifications of the instructor and the qualification requirements for the trainee(s);

(iv) Whenever possible, the training courses shall be held before or during the commissioning period and shall be in Hong Kong.

The A/C Contractor shall submit full details of the training syllabus for approval by the Supervising Officer;

(v) To reach the required depth of appreciation, the principles and theory and practical "hands-on" demonstration shall be lectured; and

(vi) The operation and maintenance training of the IAQ equipment shall also be included in the training programme. Any manual for the IAQ equipment shall be prepared by qualified personnel.

I2.2 OTHER TRAINING REQUIREMENTS

The training course shall contain, but not limited to, the following:-

(i) General description of the system and its associated equipment as a whole;

(ii) Start-up and shut-down procedures;

(iii) Safety precautions during start-up and shut-down;

(iv) A detailed description of the functions of all switches and indicators on control console;

(v) Trouble shooting procedures;

(vi) Preventive and corrective maintenance requirements to ensure proper operation of a system or equipment under the maintenance programme;

(vii) Identification of all the operating parameters which affects the performance of the plant;

(viii) Adjustment of the operating parameters to achieve optimum operating conditions;

(ix) Check-list of all the periodic inspection and servicing of the plant;

(x) Illustration of the construction of major components of the plant by sectional views;

(xi) Dismantling and reassembling procedures during a major repair;

(xii) Critical dimensions such as bearing clearance, wearing ring clearance, thrust clearance, torque table for bolts and nuts, etc.;

(xiii) The use of special tools;

(xiv) Calibration for testing equipment, measurement, record and performance assessment; and

(xv) Any other items as found necessary.

SECTION I3

INSPECTION, ATTENDANCE, OPERATION AND MAINTENANCE REQUIREMENTS

I3.1 RESPONSE AND ATTENDANCE TO EMERGENCY AND FAULT CALLS

The A/C Contractor shall attend to emergency, fault and complaint calls arising from defective work materials and/or system operation within one hour at any time during the Maintenance Period and rectify all defects leading to fault or breakdown of the equipment and/or system within the time as specified in contract documents. The costs for the attendance, labour, materials and spare parts for repair, submission of fault/breakdown reports, etc. are deemed to have been allowed for in the Tender.

I3.2 MAINTENANCE SCHEDULE

The A/C Contractor shall prepare and submit the maintenance programme before the commencement of the Maintenance Period for the approval of the Supervising Officer.

Upon the approval of the above maintenance programme and before the commencement of the Maintenance Period, the A/C Contractor shall prepare a comprehensive maintenance schedule for all installations and indicate dates for routine and periodic inspection, servicing and maintenance of the installations.

I3.3 INSPECTION DURING MAINTENANCE PERIOD

The A/C Contractor shall, in addition to the routine servicing and maintenance, make further inspections for the Installations to check and, if necessary, re-adjust the equipment/systems to meet the actual operation conditions and to test the installations to meet statutory requirements including the submission of test reports and certificates.

I3.4 JOINT INSPECTION AT THE END OF MAINTENANCE PERIOD

The A/C Contractor shall attend inspections to the Installations at the expiry of the Maintenance Period in order to facilitate the acceptance and handing over of the Installations to the Employer's operation and maintenance agents. The A/C Contractor shall conduct site checking and make necessary adjustments to the equipment/systems one month before expiry of the Maintenance Period to ensure that the Installations are in good working order, safe and satisfactory operation condition for handover. If the Installations are unacceptable by the Supervising Officer, the works covered in above Clauses I3.3 and I3.4 may have to be repeated at the A/C Contractor's expenses.

I3.5 LEVEL ONE SERVICES – MANDATORY RESPONSIBILITIES DURING MAINTENANCE PERIOD

The A/C Contractor shall also be fully responsible for the following within the Maintenance Period, in addition to the related aspects as stipulated in other clauses under Part I:-

(i) Instruction to Employer's Operation and Maintenance Staff

After the Works has been successfully handed over and put into operation, the A/C Contractor shall provide full time attendance for a period of at least 20 consecutive days or as stated in the Particular Specifications, by a qualified operator(s) who shall be fully conversant with the operation and maintenance of the plant. Their duties shall be to operate the systems and to guide and instruct the Employer's operation staff such that they will become fully conversant with the operation of the complete Installations.

Note: This commitment shall be carried out where the operational responsibilities are to be immediately transferred to the Employer's own staff or at the end of Levels Two Services operational arrangements.

(ii) Completion of Any Outstanding Work

The A/C Contractor shall complete all outstanding works listed thereon and rectify any defects that have arisen up to that time according to time frame as specified in the list of defects and outstanding works issued together with the letter of substaintial completion.

(iii) Servicing, Replacement and Replenishment

During the Maintenance Period, the A/C Contractor shall supply and install, without additional charge to the Employer, replacements for all and any equipment or parts thereof or liquids or gases, which may, in the opinion of the Supervising Officer, became unserviceable, especially where the causes are attributable to faulty materials, workmanship, or inadequate performance. The A/C Contractor shall, at his own cost, cover replacement of liquids or gases, oils and refrigerant which may be lost by leakage or become contaminated or in other respects unserviceable.

(iv) Supervising Officer to be informed

No replacement of plant or parts of plant shall be carried out at any time unless the Supervising Officer has previously been notified and approved.

(v) Annual inspection and submission of maintenance certificate

Before the expiry of the Maintenance Period, the A/C Contractor shall carry out and submit the annual inspection and submission of ventilation certificate for the ventilating system as required under Building (Ventilating Systems) Regulations to the Director of Fire Services of the completed Installations.

I3.6 LEVEL TWO SERVICES – SPECIFIED CONTRACTOR'S MAINTENANCE RESPONSIBILITIES DURING MAINTENANCE PERIOD

Where specifically required in the Contract, the A/C Contractor shall allow for and carry out full and comprehensive maintenance of the Installations during the Maintenance Period. The works shall in addition to those required under the LEVEL ONE SERVICES include also the followings: -

I3.6.1 The A/C Contractor shall be fully responsible for the following within the Maintenance Period: -

(a) Inspection, checking, servicing, maintenance and repair including replacement of parts and components due to normal tears and wears;

(b) Emergency inspection, checking and servicing, repair and rectification work;

(c) Provide skilled craftsmen to assist the start-up, control, performance monitoring and shut-down of the plant;

(d) Test and commissioning of the Installations after the completion of services, maintenance and repair; and

(e) Submission of services record and test report.

I3.6.2 The A/C Contractor shall provide labour, minor spare parts, components and consumable materials in the following services during the Maintenance Period: -

(a) Consumable materials such as re-filling of refrigerant and lubricant, renewal of v-belts for blower motor as and when required/necessary;

(b) All cutting and waste, packing, carriage, risk, moving, hoisting and fixing at the required position;

(c) Repairs including first line attendance, emergency and miscellaneous repairs, plants, tools, vehicles for transportation of material for purposes of execution of work; and

(d) Preparation and submission of records/reports, in compliance with miscellaneous requirements.

Upon substantial completion of the Works being certified by the Supervising Officer, the A/C Contractor shall provide competent, experienced and qualified staff and workshop facilities to undertake the Level Two maintenance works during the Maintenance Period. Detailed information of the organisation, workshop facilities and list of contact persons of the A/C Contractor's maintenance team shall be

submitted to the Supervising Officer one month before the anticipated substantial completion.

I3.6.3 A/C Contractor's Responsibilities for Breakdown Call-out

(a) The A/C Contractor shall offer efficient and prompt response to breakdown call-out for the installation/equipment failure. The expedition of response shall be in accordance with the following categories: -

(i) VERY URGENT for Installations breakdown including failure of chiller, compressor, circulation pump, pipe burst, water dripping, fire alarm and electricity power failure, the A/C Contractor shall respond and attend to the Very Urgent calls within 30 minutes;

(ii) URGENT for abnormality of equipment operation, the A/C Contractor shall respond and attend to the Urgent calls within 1 hour from the receipt of the calls; or

(iii) NON URGENT for abnormal room air condition, the A/C Contractor shall respond and attend the fault within 4 hours.

Investigation report and proposal for repair/improvement/ modification shall be submitted timely with time frame as instructed by Supervising Officer or his Representative.

(b) The A/C Contractor shall promptly complete any repair necessary for resuming the breakdown installation. In case immediate permanent repair is not possible due to safety related reason, the following "time for repair" targets counted from the receipt of breakdown or fault call shall be complied with: -

(i) Complete temporary repair for resumption of the suspended or breakdown services to a safe operating condition within 24 hours; and

(ii) Complete permanent rectification works within 3 working days unless long component and parts delivery time is required.

I3.6.4 Maintenance Programme and Schedule

The A/C Contractor shall prepare, submit and seek endorsement on the maintenance program before the anticipated commencement of the Contract Maintenance Period. The maintenance programme should include Monthly Routine Service, Half-Yearly Service and Annual Maintenance.

Upon the approval of the above maintenance program, the A/C Contractor shall prepare a comprehensive maintenance schedule for all installations and indicate dates for routine maintenance of the Installations before the anticipated substantial completion.

I3.6.5 Co-ordination

The A/C Contractor shall co-operate and co-ordinate with the Supervising Officer's Representatives, user department, user department's maintenance agent or EMSD, utility supply companies and the public authorities for the smooth execution of maintenance works.

I3.6.6 Plant Log and Breakdown/Fault Call Report

The A/C Contractor shall submit daily record of the following documentation and reports at three months intervals: -

(a) Record of current status of plant and major equipment, all services, maintenance and repair/replacement carried out for the plant and equipment including the following details: -

(i) supply and return chilled water temperature;

(ii) lubrication oil pressure gauge readings;

(iii) refrigerant pressure gauge readings;

(iv) system chilled water flow rate and its percentage against designed value;

(v) circulation pump suction and discharge pressure;

(vi) refrigerant compressor suction and discharge pressure;

(vii) dry and wet bulb temperature of supply air at designed offices, function and conference rooms and that of return air at system return and outdoor air condition; and

(viii) IAQ audit report with monthly measurements of all IAQ parameters.

(b) Equipment Breakdown Report

Equipment breakdown report shall be submitted after the rectification work and shall have full details of findings during investigation/examination on cause of breakdown, account of repair/replacement work needed, suggested precaution and/or action required to prevent the recurrence of similar incident.

I3.6.7 Monthly Works

(a) General

(i) To check the general condition of the plant and equipment such as chillers, compressors, condensers, heat recovery equipment, heat pumps, IAQ equipment, coils, chilled water pumps, make-up water tanks, air handling units, fan coil units, water treatment equipment and the associated electrical, electronic, mechanical controls and circuit boards. To ensure that the plant and equipment are satisfactorily operating within design conditions;

(ii) To drain and clean the pre-filter and after-filter of the pneumatic control system, and clean the refrigerated drier and after-cooler, if any;

(iii) To check the lubricating system of all running pumps, cooling fans, fan blowers, compressors, control mechanisms and any other running parts; cleaning, greasing and oiling where necessary;

(iv) To check any water leakage from the pipework and to repair if required;

(v) To keep all supply and return grilles and louvers clean;

(vi) To check the corrosion of metal surface, framework and support/mounting brackets, etc., and to reinstate the surface by removing rust and repaint if necessary;

(vii) To check the operating conditions of water cooling tower including the running current, water refilling rate, water quality and other important operating parameters; to conduct water quality and bacterial test; and to make all necessary submission to the regulating authority (including monthly operational records in Form CT3 to EMSD); and

(viii) To check and ensure that the operation conditions of the water treatment system are in accordance with the Specifications and recommendation by the manufacturer.

(b) Refrigerant Compressors, Chillers, Condensers and Heat Pumps

(i) To check for proper operation of the refrigeration machines and related controls, control circuit, and detect any abnormal noise and vibration, repair or adjust as necessary;

(ii) To check and record on log sheets and where appropriate on system performance sheet the refrigerant compressor suction and discharge pressures, chilled water inlets and outlet temperature, condenser air inlet and outlet temperature and motor current;

(iii) To check condition of operating refrigerant, liquid level and lubrication level, refill or renew as necessary;

(iv) To examine the condition of joints, stop valves, covers and seals for leaks, repair as necessary;

(v) To remove debris and maintain the condenser in clean and tidy condition;

(vi) To check driving belts for proper tension and correct alignment, adjust and renew belts and lubricate bearings; and

(vii) To check the vibration of machines as compare to the recommendations by the manufacturer for future baseline monitoring and maintenance.

(c) Motors for all motorised devices and equipment

(i) To clean motor casing, grease and lubricate;

(ii) To check and report any abnormal running noise and vibration. Replace the bearings, perform megger test on motor and repair as necessary; and

(iii) To check, adjust and rectify/repair defect on circuit protective devices such as starters, control relay and indicators.

(d) Pumps

(i) To visually inspect the pumps, check for abnormal running noise and vibration;

(ii) To check and record on log sheets and where appropriate on system performance sheet the water pump suction and discharge pressure and motor current;

(iii) To check condition of gland for excessive wear. Replace if necessary;

(iv) To check drains are not clogged and rectify if necessary;

(v) To check pump bearing temperature thermostat and repair if necessary;

(vi) To operate the vent valves once;

(vii) To check for proper operation of flow switch control system and safety device, rectify if necessary;

(viii) To clean suction strainer;

(ix) To check for proper function of makeup system to the chilled water or hot water circuit, rectify if necessary; and

(x) To check for correct alignment of the motor and pump, rectify if necessary.

(e) Air Handling Units

(i) To check that the air handling units and related controls and control circuits are operating properly. Repair or renew if necessary;

(ii) To check and record on log sheets and where appropriate on system performance sheet the air handling units operating conditions including motor current, chilled or hot water inlet and outlet temperatures, return and mix air temperatures, off coil, and supply air temperature and humidity;

(iii) To check condensing water drain pan, drain pipe and floor drain to ensure no clogging and flooding. Rectify if necessary;

(iv) To clean and renew air filter as required;

(v) To check driving belts for proper tension and correct alignment, adjust and renew belts and lubricate bearings as required;

(vi) To check the operation of control valves and isolating valves, rectify as required;

(vii) To clean the fresh air inlet, exhaust air louvers, air dampers, accessible internal ductwork surfaces and fan blades; and

(viii) To check the heaters for proper operation. Rectify if necessary.

(f) Fan Coil Units

(i) To check that the fan coil units and its control/sensing devices are functioning properly and inspect drain pipes to ensure no clogging and flooding. Rectify if necessary;

(ii) To check and clean the condensing water drain pan, drain pipes to ensure no clogging and flooding. Rectify if necessary;

(iii) To clean the supply and return air grilles and filters; and

(iv) To check the heaters and their control/protective devices for proper operation. Rectify if necessary.

(g) Heat Exchanger (include calorifier)

(i) To check on all joints for leak. Rectify if necessary;

(ii) To examine all mountings (gauge, pressure relief valve, etc.) to see that they are not damaged or leak and ensure that they are in working order; and

(iii) To check the temperature settings and functioning of the controls and ensure compliance with manufacturers' standards.

(h) Mechanical Ventilation System

(i) To clean fan blade and blades for wear and damage;

(ii) To check and if necessary to lubricate fan and motor bearings;

(iii) To check the fan belt and to adjust and replace it, if necessary;

(iv) To check flexible connections and that anti-vibration mountings are free to move, and function properly;

(v) To clean the air filters, supply and return air grilles and to renew air filters if necessary;

(vi) To check the operation and function of the control devices;

(vii) To check all electrical wiring and connections and circuit protection devices including switchgears and starters. Rectify if required; and

(viii) To clear the vanes in the ductwork.

(i) Equipment

(i) To check and service all IAQ equipment including air cleaner, UV light chambers and other filtration and sterilising system and equipment for IAQ; and

(ii) The A/C Contractor shall take measurements of IAQ parameters and submit records to the Supervising Officer.

I3.6.8 Half-Yearly Works

Half-yearly service and maintenance shall include the following items: -

(a) To inspect the condition of pipe fittings, supports, ductwork, hangers, etc., for sign of corrosion. Remove the rust and repaint with primer and finish coating as necessary;

(b) To check the performance of controls and safety cut-outs and check all control panel indication lamps, rectify as required;

(c) To clean electrical panels including wiring terminals and connection points;

(d) To touch up with finish-coating where there is any rust or sign of corrosion of the equipment by first removing the rust/corrosion;

(e) To check and adjust, if necessary, the air flow in the air-ductwork system;

(f) To clean all the air-cooled condenser coils by high-pressure water or steam jet with approved cleaning detergent to ensure that high heat transfer efficiency is maintained;

(g) To clean the cooling/heating coils (excluding fan coil units) by high-pressure water or steam jet with approved cleaning detergent to ensure that high heat transfer efficiency is maintained;

(h) To check and serve all IAQ control and sensing equipment including CO_2 sensors, air movement sensors, thermostat, humidifiers, dehumidifiers, humidistat, pressurestat and volume control dampers;

(i) To inspect all components of ventilation system for cleanliness and microbial growth and clean them as; and

(j) To clean, dislodge and disinfect cooling towers as per requirements stipulated in the Code of Practice for Fresh Water Cooling Towers published by the EMSD.

I3.6.9 Annual Works

(a) To inspect the condition of pipe fittings, supports, ductwork, hangers, etc., for sign of corrosion. Remove the rust and repaint with primer and finish coating as necessary;

(b) To check the condition of pipe work and ductwork. Recondition and if instructed, replace the deteriorated portion in accordance with the Specification, acceptable engineering practice and standard;

(c) To refit the isolating valves, change the valve gland and gasket, and recondition the globe valves, etc. if necessary;

(d) To examine, check and maintain the proper operation of associated electrical panels in the plant room. Repair and renew as appropriate;

(e) To check, test and recalibrate or replace as necessary, all control and safety devices;

(f) To check inlet guide vane of centrifugal compressor;

(g) To check, test, adjust, clean and repair/rectify defects if required for all electronic circuit boards and control/ sensing/ detection devices including building automation system if available in the system;

(h) To inspect and clean all internal surface of ductwork including the supply and return air plenums. The cleaning of ductwork shall not affect the normal operation of the building. The A/C Contractor shall arrange the cleaning work after the building office hour;

(i) To inspect aluminium foil, paints or other concrete sealing layers and wall surface which meant to stop radon gas emission and provide all necessary touch up work;

(j) To check and re-tighten any loose bolts and nuts in proper sequence; and

(k) To arrange conducting of an annual operation and maintenance audit for fresh water cooling towers by an independent auditor as per requirements stipulated in the Code of Practice for Fresh Water Cooling Towers published by the EMSD prior to expiry of the 12 months Maintenance Period, and ensure submission of an annual audit report to EMSD.

I3.7 SPARE PARTS AND SPECIAL TOOLS

For plant and/or equipment included in the Contract, the A/C Contractor shall provide the types of spare parts generally wherever these are appropriate to the plant and/or equipment involved plus any additional items for the particular plant and/or equipment.

Unless otherwise specified, within four months of the acceptance of the Tender, or in such period of time as has been agreed by the Supervising Officer in writing, the A/C Contractor shall submit in respect of the proposed plant and/or equipment a list of the manufacturer's recommended spare parts that are likely to prove necessary to service the plant and/or equipment during the first year's operation and parts required immediately following the expiry of the Maintenance Period.

The spare parts submission shall include diagrams or catalogue details of the parts concerned. Unless specified in detail, the criteria by which the A/C Contractor shall judge the need for spare parts to be included in the list shall be any part or component of the plant or equipment that is subject to frictional wear, vibration or temperature fatigue, rupturable to safety (or otherwise), corrosion, erosion, unacceptable deposits and/or saturation by contaminants (such as for filters), normal fair wear and tear and is likely to fail or reach an unacceptably low performance level within a period of three years or less from its commencement of operation.

The list shall include at least the following items where they are part of the Installations: -

- Springs, valves, valve rings, valve plates, etc.;
- Bearings or bearing bushes;
- Electric carbon brushes;
- Electrical main and arcing contacts;
- Driving belts in matched sets;
- Standard and special replaceable type air or liquid filter media;
- Gaskets and jointing;
- Seals, gland packings, etc.;
- Rupturable safety devices;
- Replaceable heat exchanger tubes;
- Sight glasses;
- Plug in relays;
- Indicator light lamps;
- Non-standard fuse cartridges;
- Overload heaters/coils; and
- Flexible hoses and similar.

Any of the above spare parts and/or disposable items which are required to replace defective or prematurely worn out parts that arise during the Maintenance Period

shall be replaced by the A/C Contractor at no cost to the Employer before the Maintenance Certificate is issued. The above items shall not be exhaustive. The A/C Contractor shall be responsible for the replacement of other parts and components for normal operation of the Installations.

Additionally, the A/C Contractor shall submit within the same period a priced schedule for the supply of any special tools necessary for servicing and maintenance of any part of the Installations.

Instructions for purchase of any special tool shall be issued separately but the basis for charging shall be similar to that for the A/C Contractor's equipment manufacturer's recommended spare parts.

The purchase of the needed spare parts and tools shall be secured by Supervising Officer's instruction.

The exact types and quantities shall be determined by the Supervising Officer based on the A/C Contractor's best advice and at the most appropriate time during the Contract Period when requirements can be most realistically assessed taking account of the Installations as installed or still being installed.

ANNEX I

LIST OF TECHNICAL STANDARDS QUOTED IN THIS GENERAL SPECIFICATION

Standard	Description	Part and Clause No.
AHRI 210/240:2017	Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment	C6.22.4
AHRI 410:2001	Forced-Circulation Air-Cooling and Air-Heating Coils	C3.6.3(b), C3.2.10(f), C3.2.13(c)
AHRI 550/590: (I-P/2018)	Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle	C6.1
AHRI 560:2000	Absorption Water Chilling and Water Heating Packages	C6.1
AHRI 575:2017	Method of Measuring Machinery Sound Within an Equipment Space	C6.1
AHRI 1060(I-P/2018)	Performance Rating of Air-To-Air Exchangers for Energy Recovery Ventilation Equipment	D5.1.1(d)(v)
ANSI/AMCA Standards 210-16	Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating	C3.3.2, C3.5.3
ANSI/AMCA Standards 300-14	Reverberant Room Method for Sound Testing of Fans	C3.3.2, C3.5.3, C3.14.2
ANSI/ASHRAE 15-2016 and ANSI/ASHRAE 34-2016	Safety Standard for Refrigeration Systems, and Designation and Classification of Refrigerants	B6.1, B6.2, B6.14.1, C6.1, C6.21.1
ANSI/ASHRAE 52.2-2017	Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size	C1.1.1, C1.2.1(a), C1.3, C1.4, C1.5, C1.6, C1.7, C1.8, C1.9, C1.10, C1.12, C1.14, D5.1.1(e)(ii), D5.4
ANSI/ASHRAE 70-2006	Method of Testing the Performance of Air Outlets and Air Inlets	C3.18.1(a), C3.17.4(b)

Standard	Description	Part and Clause No.
ANSI/ASHRAE 84-2013	Method of Testing Air-to-Air Heat Exchangers	D5.1.1(d)(v)
ANSI/ASHRAE 90.1-2016	Energy Standard for Buildings Except Low-Rise Residential Buildings	C6.1
ANSI/ASHRAE 135-2016	BACnet(r): A Data Communication Protocol for Building Automation and Control Networks	B5.1.2(c), C5.3(a)
ANSI/ASHRAE 189.1-2017	Standard for the Design of High-Performance Green Buildings	C6.1
ANSI/ASME Code B31.5: 2016	Refrigeration Piping and Heat Transfer Components	C6.20.3
ANSI C12.1:2014	American National Standard for Electric Meters – Code for Electricity Metering	B6.5.5 (c),
ANSI C12.20:2015	Electricity Meters 0.1, 0.2 and 0.5 Accuracy Classes	B6.5.5(c), B6.5.5 (d)
ANSI/CEA-709.1-B:2002	Control Network Protocol Specification	C5.3(c)
ANSI/EIA 310-D: 1992	Mechanical Core Specifications for Microcomputers Using IEC 603-2 Connectors	C5.4(a)
ANSI/IIAR Standard 2-2014	American National Standard the Safe Design of Closed Circuit Ammonia Refrigeration Systems	B6.14.1, B6.14.4, C6.20.3
AS 3498:2009	Authorization requirements for plumbing products - Water heaters and hot-water storage tanks	C6.28.4
AS/NZS 1301.403s: 2006	Methods of test for pulp and paper - Bursting strength of paper	C11.4.2 (c)
AS/NZS 2712:2007	Solar and Heat Pump Water Heaters - Design and Construction	C6.28.3(a)
ASHRAE 62.1-2016	Ventilation for Acceptable Indoor Air Quality	C6.3
ASHRAE Guideline 14-2014	Measurement of Energy, Demand and Water Savings	B6.5.5
ASHRAE Guideline 22-2012	Instrumentation for Monitoring Central Chilled-Water Plant Efficiency	B6.5.5

Standard	Description	Part and Clause No.
ASME Boiler and Pressure Vessel Code: 2017	2017 ASME Boiler and Pressure Vessel Code, Section II - Materials	B6.14.1, C6.20.3
ASTM A278/ A278M-01: 2015	Standard Specification for Grey Iron Castings for Pressure-Containing Parts for Temperatures Up to 650 °F (350 °C)	C13.13
ASTM A436-84: 2015	Standard Specification for Austenitic Grey Iron Castings	C13.13
ASTM B124/ B124M-18a	Standard Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes	C9.3.2(d)
ASTM C423-17	Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method	C8.7, C8.12.5
ASTM C916-14	Standard Specification for Adhesives for Duct Thermal Insulation	B8.7
ASTM C1071-16	Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material)	C8.7
ASTM C1371-15	Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers	C11.2.1(h)
ASTM D579/D579M-15	Standard Specification for Greige Woven Glass Fabrics	B11.6.3(c)
ASTM D882-18	Standard Test Method for Tensile Properties of Thin Plastic Sheeting	C11.4.3(b)
ASTM D3330/ D3330M-04(2010)	Standard Test Method for Peel Adhesion of Pressure-Sensitive Tape	C11.4.3(c)
ASTM E84-18b	Standard Test Method for Surface Burning Characteristics of Building Materials	B11.6.4(d), C6.13.4, C8.7, C8.9, D5.1.1(d)(viii)
ASTM E90-09 (2016)	Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements	C8.8, C8.12.5, C8.10
ASTM E96/E96M-16	Standard Test Methods for Water Vapour Transmission of Materials	C11.4.2(d)

Standard	Description	Part and Clause No.
ASTM E408-13	Standard Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques	C11.2.1(h), C11.4.2(e), C11.4.3(e),
ASTM G21-13	Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi	C2.6.2
BS 417-2:1987	Specification for galvanized low carbon steel cisterns, cistern lids, tanks and cylinders. Metric units	C13.14.2(a)(i)
BS 476-4:1970	Fire tests on building materials and structures. Non-combustibility test for materials	C1.2.2(a), C8.7, C8.9, C3.17.1(d), C3.18.3(b)
BS476-6:1989 +A1:2009	Fire tests on building materials and structures. Method of test for fire propagation for products	C1.2.2(b), C2.4, C2.7, C3.17.1(d), C3.18.3(b), C11.1.2(a)
BS 476-7:1997	Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products	B2.4, C1.18, C2.8, C2.15, C3.17.1(d), C3.18.3(b), C11.1.2(a)
BS 476-12:1991	Fire tests on building materials and structures. Method of test for ignitability of products by direct flame impingement	C2.4, C3.17.1(d), C3.18.3(b),
BS 476-20:1987	Fire tests on building materials and structures. Method for determination of the fire resistance of elements of construction (general principles)	B2.4, C2.11.1, C2.11.2, C8.10, C8.12.2, C11.2.9
BS 476-21:1987	Fire tests on building materials and structures. Methods for determination of the fire resistance of loadbearing elements of construction	C2.11.1, C8.10, C8.12.2
BS 476-22:1987	Fire tests on building materials and structures. Methods for determination of the fire resistance of non-loadbearing elements of construction	C2.11.1, C2.11.2, C8.10, C8.12.2
BS 476-23:1987	Fire tests on building materials and structures. Methods for determination of the contribution of components to the fire resistance of a structure	C2.11.1,
BS 1564:1975	Specification for pressed steel sectional rectangular tanks	C13.14.2(a)(ii)

Standard	Description	Part and Clause No.
BS 1710:2014	Specification for identification of pipelines and services	B11.8.3
BS 2502:1979	Specification for manufacture of sectional cold rooms (walk-in type)	C6.3
BS 3790:2006	Specification for belt drives. Endless wedge belts, endless V-belts, banded wedge belts, banded V-belts and their corresponding pulleys	B3.1
BS 3928:1969	Method for sodium flame test for air filters (other than for air supply to I.C. engines and compressors)	C3.2.8
BS 4213:2004	Cisterns for domestic use. Cold water storage and combined feed and expansion (thermoplastic) cisterns up to 500 l. Specification	C13.14.2(a)(iii)
BS 4766:1989 +A1:2009	Fire tests on building materials and structures. Method of test for fire propagation for products	C1.2.2(b), C2.4, C2.8, C3.13.1(d), C3.14.3(b), C11.1.2, C11.1.2(a)
BS 4800:2011	Schedule of paint colours for building purposes	B11.8.2, G3, G4
BS 4856-2:1975	Methods for testing and rating fan coil units, unit heaters and unit coolers. Thermal and volumetric performance for cooling duties: without additional ducting	C3.6.1
BS 4857-1:1972	Methods for testing and rating terminal reheat units for air distribution systems. Thermal and aerodynamic performance	C3.17.1(a)
BS 4857-2:1978	Methods for testing and rating terminal reheat units for air distribution systems. Acoustic testing and rating	C3.17.1(a)
BS 4954-1:1973	Methods for testing and rating induction units for air distribution systems. Thermal and aerodynamic performance	C3.17.1(a)
BS 4954-2:1978	Methods for testing and rating induction units for air distribution systems. Acoustic testing and rating	C3.17.1(a)
BS 5141-2:1977	Specification for air heating and cooling coils. Method of testing for rating of heating coils	C3.2.13(c)

Standard	Description	Part and Clause No.
BS 5315:1991	Hose clamps (worm drive type) for general purpose use (metric series)	B2.5
BS 5422:2009	Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range -40°C to +700°C	B11.6.3, C11.1.1, C11.1.2, C11.2.4, C11.4.4
BS 5733:2010 + A1: 2014	Specification for general requirements for electrical accessories	H1.7
BS 5970:2012	Thermal insulation of pipework, ductwork, associated equipment and other industrial installations in the temperature range of -100°C to +870°C. Code of practice.	C11.1.1
BS 6387:2013	Test method for resistance to fire of cables required to maintain circuit integrity under fire conditions	C3.1.5
BS 7116:1990	Specification for double sided pressure sensitive adhesive tapes	C11.4.3(d)
BS EN 197-1:2011	Cement. Composition, specifications and conformity criteria for common cements	C9.5
BS EN 378-1: 2016	Refrigerating systems and heat pumps. Safety and environmental requirements. Basic requirements, definitions, classification and selection criteria	H1.7
BS EN 378-2: 2016	Refrigerating systems and heat pumps. Safety and environmental requirements. Design, construction, testing, marking and documentation	B6.2, C6.21.1, H1.7
BS EN 378-3: 2016	Refrigerating systems and heat pumps. Safety and environmental requirements. Installation site and personal protection	B6.1, B6.2, H1.7
BS EN 378-4: 2016	Refrigerating systems and heat pumps. Safety and environmental requirements. Operation, maintenance, repair and recovery	H1.7
BS EN 545:2010	Ductile iron pipes, fittings, accessories and their joints for water pipelines. Requirements and test methods	C9.5
BS EN 598: 2007+A1:2009	Ductile iron pipes, fittings, accessories and their joints for sewerage applications. Requirements and test methods	C9.5

Standard	Description	Part and Clause No.
BS EN 779:2012	Particulate air filters for general ventilation. Determination of the filtration performance	C3.2.8, C3.6.1(b)
BS EN 837-1:1998	Pressure gauges. Bourdon tube pressure gauges. Dimensions, metrology, requirements and testing	C10.5
BS EN 969:2009	Ductile iron pipes, fittings, accessories and their joints for gas pipelines. Requirements and test methods	C9.5
BS EN 1057:2006 + A1: 2010	Copper and copper alloys. Seamless, round copper tubes for water and gas in sanitary and heating applications	C9.5,
BS EN 1092-1:2018	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Steel flanges	C8.5.2, C13.11, C13.14.2(d)
BS EN 1092-2:1997	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Cast iron flanges	C13.11
BS EN 1287:2017	General technical specification for sanitary tapware, low pressure thermostatic mixing valves	C9.9
BS EN 1515-1:2000	Flanges and their joints. Bolting. Selection of bolting	C13.11
BS EN 1561:2011	Founding. Grey cast irons	B9.15.3, C9.4, C13.1.3(a), C13.1.3(d), C13.2.3(a), C13.13
BS EN 1751:2014	Ventilation for buildings. Air terminal devices. Aerodynamic testing of dampers and valves	C2.8, C2.12
BS EN 1822-1:2009	High efficiency air filters (EPA, HEPA and ULPA). Classification, performance testing, marking	C1.2.1(d)
BS EN 1886:2007	Ventilation for buildings. Air handling units. Mechanical performance	C3.2.1, C3.2.7
BS EN 1982:2017	Copper and copper alloys. Ingots and castings	C13.1.3(b), C13.1.3(c), C13.2.3(b)(i)
BS EN 10029:2010	Hot-rolled steel plates 3 mm thick or above. Tolerances on dimensions and shape.	B9.3.2

Standard	Description	Part and Clause No.
BS EN 10051:2010	Continuously hot-rolled strip and plate/sheet cut from wide strip of non-alloy and alloy steels. Tolerances on dimensions and shape	B9.3.2
BS EN ISO 16890-1:2016 to BS EN ISO 16890-4:2016	Air filters for general ventilation	C1.2.1(e)
BS EN ISO 683-3:2018	Heat-treatable steels, alloy steels and free-cutting steels. Case-hardening steels	C13.1.3(c), C13.2.3(d), C13.13
BS EN ISO 683-4:2018	Heat-treatable steels, alloy steels and free-cutting steels. Free-cutting steels	C13.1.3(c), C13.2.3(d), C13.13
BS EN 10226-1:2004	Pipe threads where pressure tight joints are made on the threads. Taper external threads and parallel internal threads. Dimensions, tolerances and designation	B 9.8.1
BS EN 12975-1:2006 +A1:2010	Thermal solar systems and components. Solar collectors. General requirements.	C6.28.3(a)
BS EN ISO 9806:2017	Solar energy. Solar thermal collectors. Test methods	C6.28.1, C6.28.3(a)
BS EN 12976-1:2017BS EN 12976-1:2017	Thermal solar systems and components. Factory made systems. General requirements	C6.28.3(a)
BS EN 12976-2:2017	Thermal solar systems components. Factory made systems. Test methods	C6.28.3(a)
BS EN 13835:2012	Founding. Austenitic cast irons	C13.2.3(b)(ii)
BS EN 14511-1: 2018	Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling and process chillers. Terms and definitions	C6.1, C6.5.2(p)
BS EN 14511-2: 2018	Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling and process chillers. Test conditions	C6.1, C6.5.2(p)
BS EN 14511-3: 2018	Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling and process chillers. Test methods	C6.1, C6.5.2(p)

Standard	Description	Part and Clause No.
BS EN 14511-4: 2018	Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling and process chillers. Requirements	C6.1, C6.5.2(p)
BS EN 16798-3: 2007	Energy Performance of Buildings – Ventilation for Buildings	C1.2.1 (c)
BS EN 60034-1: 2010	Rotating electrical machines. Rating and performance	H1.7
BS EN 60073:2002	Basic and safety principles for man-machine interface, marking and identification. Coding principles for indicators and actuators.	G5
BS EN IEC 60079-0: 2018	Explosive atmospheres. Equipment. General requirements	C13.4.3
BS EN 60079-1: 2014	Explosive atmospheres. Equipment protection by flameproof enclosures “d”	C13.4.3
BS EN 60335-1: 2012 + A13: 2017	Household and similar electrical appliances. Safety. General requirements	H1.7
BS EN 60529:1992 + A2: 2013	Specification for degrees of protection provided by enclosures (IP code).	F.5.3(a)
BS EN 60669-1: 2018	Switches for household and similar fixed electrical installations. Part 1: General requirements	H1.7
BS EN 60670-22: 2006	Boxes and enclosures for electrical accessories for household and similar fixed electrical installations. Particular requirements for connecting boxes and enclosures	H1.7
BS EN 60939-2: 2005	Passive filter units for electromagnetic interference suppression. Sectional specification: passive filter units for which safety tests are appropriate. Test methods and general requirements	C6.5.2(g)
BS EN 61000-6-1: 2007	Electromagnetic compatibility (EMC). Generic standards. Immunity for residential, commercial and light-industrial environments	C1.16, C10.8
BS EN 61000-6-2: 2005	Electromagnetic compatibility (EMC). Generic standards. Immunity for industrial environments	C1.16, C10.8
BS EN 61000-6-3: 2007+A1:2011	Electromagnetic compatibility (EMC). Generic standards. Emission standard for residential, commercial and light-industrial environments	C1.16, C10.8

Standard	Description	Part and Clause No.
BS EN 61000-6-4: 2007+A1:2011	Electromagnetic compatibility (EMC). Generic standards. Emission standard for industrial environments	C1.16, C10.8
BS EN ISO 844: 2014	Rigid cellular plastics -- Determination of compression properties.	C11.2.1(d), C11.2.9(c)
BS EN ISO 1452-1: 2009	Plastics piping systems for water supply and for buried and above – ground drainage and sewerage under pressure –Unplastized poly (vinyl chloride) (PVC-U) – Part 1: General	C9.5
BS EN ISO 1452 – 2: 2009	Plastics piping systems for water supply and for buried and above –ground drainage and sewerage under pressure – Unplastized poly (vinyl chloride) (PVC-U) – Part 2: Pipes	C9.5
BS EN ISO 1452 – 3: 2010	Plastics piping systems for water supply and for buried and above –ground drainage and sewerage under pressure – Unplastized poly (vinyl chloride) (PVC-U) – Part 3: Fittings	C9.5
BS EN ISO 1452 – 4: 2009	Plastics piping systems for water supply and for buried and above –ground drainage and sewerage under pressure – Unplastized poly (vinyl chloride) (PVC-U) – Part 4: Valves	C9.5
BS EN ISO 1452 - 5: 2009	Plastics piping systems for water supply and for buried and above –ground drainage and sewerage under pressure – Unplastized poly (vinyl chloride) (PVC-U) – Part 5: Fitness for purpose of the system	C9.5
BS EN ISO 4590: 2016	Rigid cellular plastics. Determination of the volume percentage of open cells and of closed cells	C11.2.1 (f), C11.2.9(e)
BS EN ISO 5136: 2009	Acoustics -- Determination of sound power radiated into a duct by fans and other air-moving devices -- In-duct method	H1.7
BS EN ISO 5659-2: 2017	Plastics -- Smoke generation -- Part 2: Determination of optical density by a single-chamber test	C2.7.1.3, C2.7.2.3, C11.2.4(h)
BS EN ISO 6708: 1996	Pipework components -- Definition and selection of DN (nominal size)	C9.5
BS EN ISO 9445-1:2010	Continuously cold-rolled stainless steel. Tolerances on dimensions and form. Narrow strip and cut length	B9.3.2

Standard	Description	Part and Clause No.
BS EN ISO 9445-2:2010	Continuously cold-rolled stainless steel. Tolerances on dimensions and form. Wide strip and plate/ sheet	B9.3.2
BS EN ISO 9906: 2012	Rotodynamic pumps. Hydraulic performance acceptance tests. Grades 1, 2 and 3.	B13.1, H1.7
BS EN ISO 29463-2:2018 to BS EN ISO 29463-5:2018	High-efficiency filters and filter media for removing particles in air	C1.2.1(d)
BS ISO 1922:2018	Rigid cellular plastics. Determination of shear properties	C 11.2.1, C11.2.9
BS ISO 3966:2008	Measurement of fluid flow in closed conduits. Velocity area method using Pitot static tubes	C 10.6
BS ISO 7194:2008	Measurement of fluid flow in closed conduits. Velocity-area methods of flow measurement in swirling or asymmetric flow conditions in circular ducts by means of current-meters or Pitot statics tubes	C 10.6
BS ISO 20816-1:2016	Mechanical vibration. Measurements and evaluation of machine vibration. General guidelines	C3.1.4(b)
CSA C22.2 No. 8	Electromagnetic interference (EMI) filters	C6.5.2(g)
CTI- STD-201 RS:2017	Performance Rating of Evaporative Heat Rejection Equipment	C6.13.1
DIN 50154:1980	Tensile test without extensometer on foils and strips of aluminium and wrought aluminium alloys with a thickness up to 0.179 mm	C11.2.8(c), (d)
DIN 53438-3:1984	Testing of combustible materials; response to ignition by a small flame; surface ignition	C1.2.2(d)
DW/143:2013	Guide to good practice - Ductwork Air Leakage Testing	B2.1, B2.9, B2.10, C2.14
DW/144:2016	Specification for Sheet Metal Ductwork	C2.3(a), C2.8, C2.14, C2.15, C2.17, C3.2.1, C3.5.1, C3.17.1(b), C3.17.4(b), B2.1, B2.3, B2.10, B11.8.3

Standard	Description	Part and Clause No.
DW/154:2000	Specification for plastics ductwork	C2.3(b), C2.5
DW/191:1973	Code of practice for resin-bonded glass fibre ductwork	C2.3(c), C2.6.2
Eurovent Document 2/2 1996	Air Leakage rate in Sheet Metal Air Distribution Systems	C3.20, 1(c)
IEC60034-30-1	Rotating Electrical Machines – Part 1: Rating and Performance	C3.14.6,C13.1. 1 (c)
IEC60072-1:1991	Dimensions and output series for rotating electrical machines - Part 1: Frame numbers 56 to 400 and flange numbers 55 to 1080	H1.7
IEC60072-2:1990	Dimensions and output series for rotating electrical machines - Part 2: Frame numbers 355 to 1000 and flange numbers 1180 to 2360	H1.7
IEC60072-3:1994	Dimensions and output series for rotating electrical machines - Part 3: Small built-in motors - Flange numbers BF10 to BF50	H1.7
IEC60076-1:2011	Power transformers – Part 1: General - Edition 3.0	C6.5.2(f)
IEC61000-4-11:2004/A1:2017	Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests	C6.5.2(g)
IEC61000-4-34:2007+A1:2009	Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with mains current more than 16A per phase	C6.5.2(g)
IEC 61439-1:2011	Low-voltage switchgear and control gear assemblies - Part 1: General rules	H1.7
IEC 62053-21:2003+A1:2016	Electricity metering equipment (a.c.) Particular requirements Part 21: Static meters for active energy (classes 1 and 2) - Edition 1.1	B6.5.5(d)
IEC 62053-22:2003+A1:2016	Electricity metering equipment (a.c.) Particular requirements Part 22: Static meters for active energy (classes 0,2 S and 0,5 S) - Edition 1.1	B6.5.5(c)
IEC 62058:2008	Electricity metering equipment (AC) – Acceptance inspection	B6.5.59(c), B6.5.5(d)
IEC 62271-100: 2008 + A1:2012+A2:2017	High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers	H1.7

Standard	Description	Part and Clause No.
IMO MSC 307(88)	Smoke and toxicity test	C11.2.4(i)
ISO 7-1: 1994/Cor 1:2007	Pipe threads where pressure-tight joints are made on the threads -- Part 1: Dimensions, tolerances and designation	B9.8.1, C8.5.2, B9.3.2, C9.5, B9.15.3
ISO 65:1981	Carbon steel tubes suitable for screwing in accordance with ISO 7-1	C9.5
ISO 185:2005	Grey cast irons -- Classification	B9.15.3, C9.4, C13.1.3(a), C13.1.3(d), C13.2.3(a), C13.13
ISO 197-4:1983	Copper and copper alloys -- Terms and definitions -- Part 4: Castings	C9.4, C13.1.3(b), C13.1.3(c), C13.2.3(b)(i)
ISO 254:2011	Belt drives -- Pulleys -- Quality, finish and balance	B3.1
ISO 1081:2013	Belt drives -- V-belts and V-ribbed belts, and corresponding grooved pulleys -- Vocabulary	B3.1
ISO 1182:2010	Reaction to fire tests for products. Non-combustibility test	C3.17.1(d), C3.18.3(b)
ISO 1663:2007	Rigid cellular plastics -- Determination of water vapour transmission properties	C11.2.1(g)
ISO 1813:2014	Belt drives -- V-ribbed belts, joined V-belts and V-belts including wide section belts and hexagonal belts -- Electrical conductivity of antistatic belts: Characteristics and methods of test	B3.1
ISO 21940-11:2016	Mechanical vibration – Rotor balancing-- Part 11: Procedures and tolerances for rotors with rigid behaviour	H1.7
ISO 2016:1981	Capillary solder fittings for copper tubes -- Assembly dimensions and tests	B9.9.1, C9.5
ISO 2892: 2007/Cor 1:2009	Austenitic cast irons -- Classification	C13.2.3(b)(ii)
ISO 3864-1:2011	Graphical symbols -- Safety colours and safety signs -- Part 1: Design principles for safety signs and safety markings	G.3

Standard	Description	Part and Clause No.
ISO 4183:1995	Belt drives -- Classical and narrow V-belts -- Grooved pulleys (system based on datum width)	B3.1
ISO 4184:1992	Belt drives -- Classical and narrow V-belts -- Lengths in datum system	B3.1
ISO 5149-1:2014	Refrigerating systems and heat pumps - Safety and environmental requirements - Part 1: Definitions, classification and selection criteria	C6.1
ISO 5149-2:2014	Refrigerating systems and heat pumps - Safety and environmental requirements - Part 2: Design, construction, testing, marking and documentation	C6.1
ISO 5149-3:2014	Refrigerating systems and heat pumps - Safety and environmental requirements - Part 3: Installation site	C6.1
ISO 5149-4:2014	Refrigerating systems and heat pumps - Safety and environmental requirements - Part 4: Operation, maintenance, repair and recovery	C6.1
ISO 5151:2017	Non-ducted air conditioners and heat pumps -- Testing and rating for performance	B12.1.2
ISO 5167-1:2003	Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full -- Part 1: General principles and requirements	C10.7
ISO 5187:1985	Welding and allied processes -- Assemblies made with soft solders and brazing filler metals -- Mechanical test methods	B9.18.5
ISO 5208:2015	Industrial valves -- Pressure testing of metallic valves	C9.3.2(a)
ISO 5209:1977	General purpose industrial valves -- Marking	C9.3.2(h)
ISO 5292:1995	Belt drives -- V-belts and V-ribbed belts -- Calculation of power ratings	B3.1
ISO 5457:1999+A1: 2010	Technical product documentation -- Sizes and layout of drawing sheets	A4.3.2, A4.2.2
ISO 5801: 2017	Industrial fans -- Performance testing using standardized airways	C3.3.2, C3.5.3, C3.14.2, H1.7
ISO 6453:1985	Polymeric materials, cellular flexible -- Polyvinylchloride foam sheeting -- Specification	C2.5

Standard	Description	Part and Clause No.
ISO 7005-1:2011	Pipe flanges -- Part 1: Steel flanges for industrial and general service piping systems	B9.3.2, B9.3.3, B9.8.2, B9.9.1, B9.15.3, C13.11, C13.14.2(d)
ISO 7005-2:1988	Metallic flanges -- Part 2: Cast iron flanges	B9.9.1, B9.15.3, C9.7, C13.11, C13.14.2(d)
ISO 7005-3:1988	Metallic flanges -- Part 3: Copper alloy and composite flanges	B9.9.1, B9.15.3, C9.7, C13.14.2(d)
ISO 7268: 1983/ Amd 1:1984	Pipe components -- Definition of nominal pressure	C9.5
ISO 8079:1984	Aerospace process -- Anodic treatment of aluminium alloys -- Sulfuric acid process, dyed coating	C11.2.8(a)
ISO 8302:1991	Thermal insulation -- Determination of steady-state thermal resistance and related properties -- Guarded hot plate apparatus	C11.2.1(e)
ISO 9001: 2015	Quality Management systems -- Requirements	A3.17.5, B9.3.2, C3.2.1, C3.6.1, D5.1.2(a)
ISO 9330-1:1990	Welded steel tubes for pressure purposes -- Technical delivery conditions -- Part 1: Unalloyed steel tubes with specified room temperature properties	C9.5
ISO 9330-2:1997	Welded steel tubes for pressure purposes -- Technical delivery conditions -- Part 2: Electric resistance and induction welded unalloyed and alloyed steel tubes with specified elevated temperature properties	C9.5
ISO 9330-3:1997	Welded steel tubes for pressure purposes -- Technical delivery conditions -- Part 3: Electric resistance and induction welded unalloyed and alloyed steel tubes with specified low temperature properties	C9.5

Standard	Description	Part and Clause No.
ISO 9692-1:2013	Welding and allied processes -- Types of joint preparation -- Part 1: Manual metal-arc welding, gas-shielded metal-arc welding, gas welding, TIG welding and beam welding of steels	B2.7, B9.3.3, B9.18.3, B9.18.4
ISO 10294-1:1996/ Amd 1:2014	Fire resistance tests -- Fire dampers for air distribution systems -- Part 1: Test method	C2.11.1, C2.11.2
ISO 20816-1:2016	Mechanical vibration -- Measurement and evaluation of machine vibration -- Part 1: General guidelines	C3.1.4(b)
ISO 13253: 2011	Ducted air-conditioners and air-to-air heat pumps -- Testing and rating for performance	B12.1.2
ISO 13256-1:1998	Water-source heat pumps -- Testing and rating for performance -- Part 1: Water-to-air and brine-to-air heat pumps	B12.1.2
ISO 13256-2:1998	Water-source heat pumps -- Testing and rating for performance -- Part 2: Water-to-water and brine-to-water heat pumps	B12.1.2
ISO 13261-1:1998	Sound power rating of air-conditioning and air-source heat pump equipment -- Part 1: Non-ducted outdoor equipment	B12.2
ISO 13261-2:1998	Sound power rating of air-conditioning and air-source heat pump equipment -- Part 2: Non-ducted indoor equipment	B12.2
ISO 14644-1:2015	Cleanrooms and associated controlled environments -- Part 1: Classification of air cleanliness by particule concentration	C1.11
ISO 15609-1:2004/ Corr 1:2005	Specification and qualification of welding procedures for metallic materials welding procedure specification - Part 1: Arc welding	B9.18.3
ISO 15609-2:2001	Specification and qualification of welding procedures for metallic materials welding procedure specification - Part 2: Gas welding	B9.18.4
ISO 21940-14:2012	Mechanical Vibration – Rotor Balancing Part 14: Procedures for assessing balance errors	H1.7
ISO/IEC 1989: 2014	Information technology -- Programming languages -- COBOL	B5.1.2(i), C5.3(h)

Standard	Description	Part and Clause No.
ISO/IEC 8802-3: 2017	Telecommunications and information exchange between systems – local and metropolitan area networks – specific requirements – part 3: Standard for Ethernet	B5.1.2(j), C5.3(i), C5.5
ISO/IEC 9075-9: 2016	Information technology -- Database languages -- SQL -- Part 9: Management of External Data (SQL/MED)	B5.1.2(a), C5.3(b), C5.13
ISO/IEC 9075-10: 2016	Information technology -- Database languages -- SQL -- Part 10: Object Language Bindings (SQL/OLB)	B5.1.2(a)
ISO/IEC 9075-13: 2016	Information technology -- Database languages -- SQL -- Part 13: SQL Routines and Types Using the Java TM Programming Language (SQL/JRT)	B5.1.2(a)
NAIMA Publication AH-122	Cleaning Fibrous Glass Insulated Duct Systems - Recommended Practices	C2.6.2
(NES) 713 (Issue 3)	Determination of the Toxicity Index of the Products of Combustion from Small Specimens of Material	C11.2.4(i)
NFPA-90A:2018	Standard for the Installation of Air-Conditioning and Ventilating Systems	B11.5.4, B11.6.4(d), C2.6.2, C2.11.1, C3.17.1(d), C3.18.3.(b), D5.1.1(d)(viii)
NFPA-90B:2018	Standard for the Installation of Warm Air Heating and Air-Conditioning Systems	C2.6.2
NFPA 220:2018	Standard on Types of Building Construction	B11.6.4(d)
NFPA 255:2006	Standard Method of Test of Surface Burning Characteristics of Building Materials	C8.7, C8.9
PD 5500:2018+A1:2018	Specification for unfired fusion welded pressure vessels.	B8.5.5, C6.28.4, C8.5.2
TIA/EIA 232-F	Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange	B5.1.2(e), B5.3, C5.3(d), C5.5

Standard	Description	Part and Clause No.
TIA/EIA 485-A	Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems	B5.1.2(f), B5.3, C5.3, C5.5
TIA/EIA 568-.1-D	Commercial Building Telecommunications Cabling Standard	B5.1.2(g), B5.3, C5.3(f)
UL 58:2018	Standard for Steel Underground Tanks for Flammable and Combustible Liquids	C6.5.2(g)
UL 153:2014	Standard for Portable Electric Luminaires	C1.17
UL 181:2013	Factory-Made Air Ducts and Air Connectors	C2.6.2, C3.17.1(d), C3.18.3(b)
UL 555S:2014	Smoke Dampers	C2.11.2
UL 586:2009	High-Efficiency, Particulate, Air Filter Units	C1.2.1(b), C1.11, C1.13
UL 710:2012	Exhaust Hoods for Commercial Cooking Equipment	C1.14
UL 723:2018	Test for Surface Burning Characteristics of Building Materials	C8.7, C8.9
UL 867:2011	Electrostatic Air Cleaners	C1.14, C1.16
UL 900:2015	Safety Air Filter Units	C1.2.2(c)
UL 1283:2017	Standard for Electromagnetic Interference Filters	C6.5.2(g)
UL 1598:2018	Luminaires	C1.17
UL 1995:2015	Heating and Cooling Equipment	C1.17

Year	Title of Codes of Practice / Guideline	Part and Clause No.
2007	Code of Practice on the Handling, Transportation and Disposal of Asbestos Waste	A2.1.2(o)
2007	Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes	A2.1.2(p)
2008	Design Manual Barrier Free Access 2008	A2.1.2(i)
2018	Code of Practice for Energy Efficiency of Building Services Installation	A2.1.2(f), C5.55, C6.1, C6.25, C11.5, C12.19
2012	Codes of Practice for Minimum Fire Service Installations and Equipment and Inspection, Testing and Maintenance of Installations and Equipment	A2.1.2(d)
2017	ASHRAE Fundamentals SI Handbook 2017	B8.1
2015	Code of Practice for the Electricity (Wiring) Regulations	A2.1.2(c), A3.12, C6.1, H1.9
2016	Code of Practice for Fresh Water Cooling Towers published by the EMSD	A2.1.2(b), F1, I3.6.8(j), I3.6.9(k)
2016	Code of Practice for Prevention of Legionnaires' Disease issued by Prevention of Legionnaires' Disease Committee, the Government of HKSAR	A2.1.2(j), F1
2016	Fresh Water Cooling Towers Scheme (FWCT Scheme) published by the EMSD.	A2.1.2 (a)