PART III

AIR - CONDITIONING AND VENTILATION

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CHAPTER 1

INTRODUCTION TO SPECIFICATIONS FOR AIR CONDITIONING AND VENTILATION SYSTEMS

1.1 Specifications and Standards

This part of the specifications refers to the standards of American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), Charted Institution of Building Services Engineer (CIBSE) and British Standards. Systems could be designed to one of these standards and where one standard does not cover the complete aspect of the system design, other standards could be referred to. Any other equivalent standards could be used in designs and constructions with the approval of the Engineer.

In adopting the recommendations of this part of the specifications attention shall always be placed on the need to optimize the energy consumption and the need to reduce hazards and minimize effects detrimental to the environment.

All designs and construction works shall follow the latest standards of specification and regulations. In every respect this specification should be considered as a 'General Specification' and any conflicts of interpretation of any particular area of the specification shall be referred to the Engineer for final decision.

1.2 Scope of Work

This part of the specifications generally covers all works related to the supply, installation, commissioning, testing and maintenance of air conditioning and ventilation systems as described. The intent of these specifications is that with the completion of the Contract the whole of the works described will be ready for full time commercial service. The scope of work shall therefore include all such plant and services obviously necessary to meet this requirement whether or not particularly described in these specifications.

1.3 Design Criteria

Outdoor Design conditions; Dry bulb temperatures and wet bulb temperatures, Indoor Design

Conditions; Dry bulb temperature and RH% of respective Zones shall be specified. The recommended noise criteria for each occupancy type shall be specified. Relative Humidity of the Indoor Conditions for Human Comfort air conditioning, except Precision Air-conditioning, is un-controlled & should be maintained below 60%RH, between 55%to 60%RH. Indoor conditions for human comfort shall comply with ASHARE Standard 55-2017, thermal Environmental Conditions for Human Occupancy.

Indoor Air Quality (IAQ)

All types air-conditioning systems designed for human comfort applications shall provide adequate ventilation for IAQ as per ASHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality. Minimum air volume of outdoor air shall be calculated using Volume breathing zone (V_{bz}) equation as per ASHRAE Standard 62.1.

As an energy conservation measure, energy recovery shall be utilised as per designer's requirement, by utilising Energy Recovery Ventilators (ERV). ERV shall be with Recuperaters, however ERVs with energy recover wheels shall be used for high latent loads.

Ventilation Controls for High Occupancy Areas

Demand control ventilation shall be utilised for high occupancy areas as per ASHRAE Standard 90.1 Energy Standard for Buildings Except Low-rise Residential Buildings, for spaces larger than 50 m^2 with a design occupancy for ventilation 25 people for 100m^2 of floor area.

1.4 References to other Document Etc

This specification shall be referred together with the Part I, 'General Requirements for Electrical and Mechanical Works' and Part II 'Electrical Installations' in this document, 'Conditions of Contract' - SCA/1 and any particular conditions of the contract.

CHAPTER 2

HYDRONIC SYSTEM

2.1 Pipework and Fittings above Ground

2.1.1 General

Pipework shall be supplied and installed generally as shown on the drawings and as detailed below to provide a complete working installation.

Standard fittings shall be used in the installation as detailed below.

Flanges or unions, the latter of the spherical bronze seat type shall be fitted to facilitate installation and maintenance at not more than 20m intervals and at all connections to equipment.

Screwed joints shall be made with the approved PTFE tape up to 40mm size and hemp/jointing compound for 50mm size and above and each screwed joint shall be in accordance with the appropriate British Standard.

All flanges shall be in accordance with BS 4504 and joints shall be made with full faced bonded asbestos fibre sheet rings.

Any copper alloy used in fittings, brazing rods, etc., shall be capable of withstanding dezincification.

Runs of piping shall be supported so that a clear space of not less than 50 mm is left between the pipes or lagging and the nearest wall ceiling or other surface.

All reductions in pipe sizes shall be made using standard reducing fittings. Changes in direction shall be made with standard bends.

All pipes, fittings, etc., are to be cleaned of any foreign matter, open ends plugged during erection and the complete system flushed out or blown through before putting into service.

2.1.2. Chilled Water Pipework

Chilled water piping within the plant room area up to 150 mm diameter shall be in black heavy-weight steel conforming to BS 1965 or with screwed joints and malleable iron fittings to BS 1387 with welded joints and welding fittings to BS 143 and 1256. Flanges shall conform to PN 16.
Pipes over 150mm diameter shall be in black heavy-weight steel conforming to BS 806 with welded joints and welding fittings to BS 1965.

All other chilled water supply and return pipes to air handling units shall be in black heavy weight steel conforming to BS 1387, with screwed joints and malleable iron fittings to BS 143 and 1256 or in unplasticised PVC conforming to SLS 147, Type 1000.

When maximum system pressure in the application exceeds 10 bar, for high rise installations, complete piping system shall be in black heavy-weight steel conforming to BS 1965.

As an alternative to black heavy-weight steel piping GI, PPR & HDPE shall be used.

2.1.3. Refrigerant Pipework

All copper tubing shall be of refrigeration quality (sealed ends). Joints shall be avoided but where required and approved by the Engineer shall be interconnected (or expanded) or by means of copper solder fittings and silver solderes using Bakers soldering flux or Silfos 15 Alloys solder. Bends shall have an inner radius of not less than five times the diameter of the tube to avoid crimping. If copper solder fittings are used, the bend radius should be according to the standard radius. Tubing shall be installed neatly and shall be supported in the following manner:

In vertical runs, clamps shall consist of hard wooden clamping blocks cut in half and provided with holes for the tubing. Alternatively proprietary piping fixtures may be used subject to the approval of the Engineer. The maximum distance between clamps shall be 1.00 m and the distance from a bend in the tubing to a clamp shall be not more than 300mm.

All tubing shall be leak tested before the commissioning of the unit.

The compressor suction line shall be insulated by means of appropriate insulating sleeves to be approved by the Engineer. In cases where this sleeve is exposed to mechanical damage in outdoor locations an adequate aluminium sheathing protection shall be installed.

Where metal clamps are used, the tubing shall be insulated from these or protected, short wrappings of plastic tape shall be used to prevent chaffing and galvanic action.

2.1.4 Condenser Water Piping

Condenser water piping may be un-plasticised PVC pipes conforming to SLS 147; Type 1000 or to BS 3505, Class E with solvent cement joints and injection moulded rigid PVC fittings conforming to SLS 147; or BS 4348 or black heavy weight steel to standards specification in 2.1.2 above. All condenser water pipes within plant rooms and pipes in other areas (if diameter exceeds 100 mm) shall be of black heavy weight steel or Galvanized Iron (GI) to BS 1387 heavy gauge.

As an alternative to steel piping PPR & HDPE shall be used

2.1.5 Condensate Drains

Condenser drains shall be in un-plasticised PVC conforming to SLS 147 or BS 3505, with solvent cement joints and injection moulded rigid PVC fittings conforming to BS 4348.

2.2 Grading, Venting and Draining

Wherever possible, piping shall be graded to permit natural venting and draining to a minimum number of points in the system.

Manual air vents shall be fitted at high points and at all potential air pockets on all chilled water pipes and cooling coils.

20 mm diameter drain valves suitable for hose coupling shall be fitted to all low points in the piping system.

Grading of all drain and vent lines shall be in the direction of flow and not less than 1 in 200. All vents and drain valves shall be mounted outside the insulation.

2.3 Welding

Welding of mild steel pipework shall be carried out by either the oxy-acetylene method in accordance with BS 1821 or the metal arc method in accordance with BS 1856.

Brazing of copper pipelines shall be carried out by the self-bronze process.

Galvanised pipework shall not be welded.

All workmen carrying out welding on the site shall be in possession of a valid welding certificate.

The Engineer reserves the right to carry out the tests as detailed in the appropriate British Standard on one percent of the welds in the installation. All weld joints unless otherwise specified shall be subject to at least a dye penetrant check after welding.

2.4 Pipe Hangers and Supports

All pipework shall be adequately supported by means of standard or purpose made clips so that no movement or distortion of the pipe takes place except that necessary to take up the expansion of pipework.

Pipe supports shall be constructed generally in accordance with BS 3974.

All clips, brackets, supports, etc., in contact with the pipe wall shall be of the same material as the pipe, otherwise an approved non-metallic packing material is to be inserted between the clip and pipe.

Straight pipework shall be supported at centres not less than those given in Table B 16.3 of the IHVE Guide 1970 or to manufacturer's recommendations.

Supplementary supports shall be provided at changes of direction, valves or similar pipeline equipment.

Pipework shall be supported as indicated on the drawings or, if not specifically detailed, in accordance with the following:

Horizontal main shall be supported on rollers and chairs or by standard mild steel hangers and clips from lengths of channel iron or "Unistrut" type channel either built-in or bolted to the structure.

Branch mains shall be supported as above or by means of standard munsen ring clips, built-in

screwed to the adjacent structure.

Vertical mains shall be supported from anchor points fixed rigidly to one intermediate floor slab with guide supports at the remaining floor slabs.

Small diameter run-outs shall be supported by standard school-board pattern clips, built-in or screwed to the adjacent structure or by means of standard double saddle clips.

All ferrous brackets or parts thereof shall be painted two coats of red lead primer before fixing.

Chilled water pipework operating at a temperature below ambient dew point shall have supports arranged to fit around the outside of the pipe insulation. A vapour sealing, a 1.5mm thick galvanised sheet steel half sleeves, two diameters in length or machine cut timber support blocks shall be fitted over the insulation to spread the load at every support point. Heavy density expanded polystyrene or cork shall be fitted round the pipe as insulation under the sleeves.

Supports on horizontal and vertical piping shall be spaced as follows, unless otherwise specified.

Pipe Diameter (mm)	Pipe Support Centres Maximum (m)		Minimum Support Rod Diameter (mm)
	Steel	PVC	
15	2.0	1.25	10
20	2.4	1.50	10
32	2.7	2.00	10
40	3.0	2.00	10
50	3.4	2.20	10
65	3.7	2.40	15
80	3.7	2.40	15
100	4.1	3.00	15
150	4.8	3.25	20
200	4.8	3.25	20
250	4.8	3.25	20

2.5 Expansion of Pipe work

All pipework shall be erected, and on completion be left in such a manner that expansion and contraction is taken up without excessive stress on the pipe to the building structure. Where this cannot be achieved with the normal run of pipework, special expansion loops or expansion joints shall be provided.

Expansion loops shall be made up from pipe of the same quality as the main, either with welded elbows or fabricated from a single length of pipe with pulled or fire-set bends.

Expansion joints shall be of the stainless steel bellows type adequately supported, in accordance with the manufacturer's instructions and with guides on the mains adjacent to the joints.

Anchors shall be provided at intervals to ensure expansion is absorbed at the determined places, and shall consist of a short length of pipe, flanged at each end and positively fixed to the building structure by heavy mild steel angle or channel iron.

"Cold draw" shall be applied, suitable to the pipe work and service, by pulling up through long bolts on the expansion loop/joint flanges. The long bolts shall afterwards be replaced by normal or expansion unit bolts.

The provision for expansion is to be checked before and after any enclosure of the pipework.

2.6 Valves and Cocks

2.6.1 Drain Cocks

Drain Cocks 32 mm and over, shall be bronze gland cocks complete with malleable iron levers and hose unions.

Cocks 25mm and under, shall comply in all respects with BS 2879, Type A, bronze draining taps, screw down pattern, lock-shield design with loose key.

2.6.2 Air cocks

All air bottles on low pressure systems shall have 6 mm, air cocks fitted with loose key, as detailed on the drawings.

2.6.3 Terminal Units

Isolating valves for chilled water fan coil units, etc., shall comply in all respects with BS 2767, bronze union valves, angle or straight patterns, with proportional flow characteristics, plastic cover hand wheel type. Regulating valves shall be of the double regulating and orifice type as specified above.

The connection to the unit shall be of the metal to metal union pattern and the opposite end appropriate to the pipework.

The flow valve shall be of the wheel type and the return valve of the lockshield type.

Where visible, valve bodies shall have a polished finish.

A Valve kit comprising two shut-off valves, pressure independent commissioning valve (PICV), flexible couplings, complete with commissioning by pass valve & Insulated covering for valve kit shall be used wherever possible.

2.6.4 Ball Float Valves

Ball float valves 28mm and over, shall be of the equilibrium (balanced pressure) type gunmetal brazed copper ball and with flanges conforming to PN 16 or with screwed BSPT ends as required.

Ball float valves 22mm and under shall comply in all respects with BS 1212 Portsmouth type and the plastic floats with BS 2456.

2.6.5 Isolating Valves

Isolating valves on flow connections to equipment shall be as indicated with hand-wheels. Valves on return connections shall be of the double regulating type incorporating a facility to prevent opening beyond pre-set limits.

2.6.6 Check Valves

Check valves shall be installed as indicated and be in accordance with either BS 5153 for cast iron valves or BS5154 for copper alloy valves.

2.6.7 Regulating and Double Regulating Valves

2.6.7.1 Regulating valves complying with BS 5152 or BS 5154 as relevant shall have characterised plugs to give a linear or equal percentage Characteristics and micrometre indicators of the type where a pointer moves over a scale permanently fixed to the main structure of the valve.

2.6.7.2 Double regulating valves shall comply with clause 2.6.7.1 and incorporate a facility to prevent opening beyond pre-set limits

2.6.7.3 All regulating valves shall be sized for the pressure drop as indicated.

2.6.8 Pressure Independent Control Valves (PICV).

PICV shall have constant control characteristics at all flow settings and control flow rates at differential pressure up to 350 kPa.

Flow rates shall be externally adjustable and set point recordable.

Integral test points shall be fitted to verify setting pressure allowing pumps to be set at optimum speed to maximise energy savings.

The PICV valves complying with BS EN 1265

2.6.9 Safety Valves

Safety valves 55mm and under, shall comply in all respects with BS 759 and have a bronze body with flat seating surface, precision lapped to give positive closure and screwed BSPT ends.

2.6.10 Automatic Air Vents (AAV)

Suitable type air vents shall be provided at high points of water lines and wherever required to allow air to vent from system. Each vent shall have a drain.

2.7 Pipe Sleeve and Floor Plates

Except where specified otherwise, all pipes passing through any walls of floors shall be provided with PVC sleeves having an internal diameter at least 50mm larger than the outside of the pipe (or pipe with insulation, in case of insulated services), suitably packed and finished not less than 2mm proud or the finished surface. The annular space between the pipes and sleeves shall be adequately

caulked with asbestos rope to reduce noise transmission.
In wet areas, sleeves through floors are to be extended 30mm above the finished floor.

A chromium plated rolled steel hinged cover plate shall be provided and fixed to all exposed pipes at each end of each sleeve and to every exposed pipe rising through floors.

Where pipes pass through trench covers, specially approved flanged sleeves shall be provided to form watertight seals.

2.8 Strainers

Strainers shall be installed to protect heat exchanger apparatus, automatic control valves and other sensitive fittings or circuits as indicated.

Strainer shall be suitable for the working pressure and service of the piping system in which they are installed and shall be readily accessible for cleaning.

Strainers shall be supplied and installed in the pipework as indicated on the drawings or, if not specifically indicated, to provide at least one strainer for each water circuit.

Isolating valves shall be provided on each side of the strainer or the strainers to be fixed relative to equipment isolating valves so that the strainer can be opened and cleaned without draining down the circuit.

Strainers, 65mm and over, shall be of the `Y' pattern with cast iron body, 1.5mm stainless steel screen and flanges conforming to PN 16.

Strainers, 50mm to 32mm, shall be of the `Y' pattern with gunmetal body, 1mm brass screen and screwed BSPT ends.

Strainers, 25mm and under shall be of the `Y' pattern with pressed brass body, 1mm brass screen and screwed BSPT ends.

Strainers in external pipework, 65mm diameter and larger shall be of the bucket type with flanges conforming to PN 16.

Strainer for bodies for pipe lines up to 50 mm size shall be of copper alloy to BS 1440 and otherwise of cast iron to BS 1452 Class180. Strainer pressure ratings shall be at least 150% of maximum system pressure in the application.

2.9 Plugs for Open Pipes and Ducts

Any open-ended pipe or duct left overnight or for any considerable period shall be protected from the entry of dust, sand, etc., by the fixing of approved type plugs.

2.10 Flushing and Cleaning

In case of piping and fittings for `refrigeration' system the interior shall be thoroughly cleaned with an alkaline solution and capped tightly until installed. The actual cleaning procedure shall be that recommended by the manufacturers of the equipment, and approved by the Engineer.

The piping system shall be thoroughly flushed out with water. Strainers of not less than 0.7 mm (number 40) mesh shall be installed during this period. The strainers shall be cleaned and inspected after flushing has been completed.

After draining of flushing water, each system shall be filled with softened fresh water from the lowest point, de-aerated and checked for full water flow, in each system. All subsequent fillings and toppings shall be softened water.

Corrosion Treatment Passivation process for Black Steel pipe work

2.11 Protection of Pipework

All mild steel pipework whether insulated or not, shall be thoroughly wire brushed and painted with red lead paint immediately after installation and again before the finishing treatment is applied.

2.12 Painting

Items of equipment shall be provided with the manufacturer's standard finish, which, on completion of installation, shall be in good condition or brought up to original standard.

Ferrous pipework, brackets, etc., shall be painted two coats of red lead primer. Alternatively, where

steelwork is completely enclosed a proprietary anti-rust coating may be used.

Pipework, brackets, etc., in public spaces shall be painted two coats of red lead primer, and a decorative finish coat as specified elsewhere or otherwise in accordance with the colour code, conforming to BS 1710.

2.13 Testing of Pipework

All sections of pipework shall be hydraulically tested during installation of the works to avoid the necessity for disturbing the building programme at the later stages. No pipes must be lagged, covered in or otherwise made inaccessible before they have been tested.

Hydraulic pressure testing with water should be carried out immediately before the commencement of chemical cleaning or disinfection, which in turn should be carried out immediately before system commissioning.

The entire pipe testing to should be completed within 48 hours to minimise the opportunity for bacteria to develop n pipe surfaces.

2.13.1 Filling the system

It may be necessary to keep parts of the system or individual components isolated and dry whilst other parts of the system are tested. This might be necessary if;

A. The required test pressure is greater than 1.5 times the normal pressure ratings of any system components. These items should be kept isolated to avoid potential damage.
B. The system incorporates plastic pipe which is to be left dry until the steel parts of the system are chemically cleaned and treated (keeping plastic pipes dry in this way should avoid the need to include them in the chemical cleaning process).

2.13.2 Test Procedure for All Metal Piping Systems

2.13.2.1 For all metal pipework systems, a test pressure of at least 1.5 times the maximum working pressure of the systems shall be applied.

2.13.2.1 Test procedure shall be:

A. when the system is full of water, raise the pressure to the test pressure and seal the system.
B. Monitor the pressure. If pressure falls, walk around the system to check for leaks
C. If the test pressure holds steady for one hour, system deemed to be satisfactory.
D. When it is concluded that the system is sound, have the appropriate witnessing authority witness the test and sign off the relevant test sheet.

2.13.3 Test Procedure for Systems Containing Plastic Pipes

2.13.3.1 Plastic pipes used in buildings include Poly Vinyl Chloride (PVC), Polyethylene (PE), or Cross-linked Polyethylene (PEX) and Polybutylene (PB). System comprising plastic pipes differ from all metal systems in that:

A. There is likely to be greater expansion of the pipe material when pressure or temperature is increased causing any test pressure to fall over a period of time.
B. Plastic pipes have specialised jointing techniques which, if faulty or poorly installed, may not fail immediately under pressure but may leak over a period of time

2.13.3.2 For these reasons, plastic pipes may require a higher test pressure which must be sustained ver longer period.

2.13.3.3 As a general rule, test pressure equivalent to the maximum working pressure plus 5 bar shall be applied. This pressure shall be maintained within limits over a 2-hour period.

2.13.3.4 Test procedure shall be:

A. when the system is full of water, raise the pressure to the test pressure and seal the system.
B. After 10 minutes check the test pressure. If it has fallen, re-pressure the system so that the test pressure is restored.
C. After a further 10 minutes, check the test pressure again. If it has fallen, re-pressure the system so that the test pressure is restored
D. After a further 10 minutes record the test pressure in the system, but do not re-pressure.
E. If the loss in pressure is less than 0.6 bar over the following 30 minutes and less than 0.2 bar over the following 2 hours after this, the system deemed to be satisfactory.
F. When it is concluded that the system is sound, have the appropriate witnessing authority witness the test and sign off the relevant test sheet

2.14 Valve and Equipment Labels

All valves shall be clearly labelled. The labels shall be rectangular, 100mm x 40mm of multi-layer, colour/black/colour, laminated plastic with each side showing a number, the name of the service and purpose. Each label shall be attached by a short length of chain having at one end a link opened, passed through a hole in the label and then closed, and at the other end a key passed through the end and around the valve spindle or pillar. All labels shall be coloured in accordance with the colour code applicable to the service controlled. The colour code shall comply in all relevant respects with BS 1710.

All equipment shall be clearly labelled. The labels shall be of multi layer, white and black plastic similar to that previously specified, front engraved, securely fixed to the equipment by means of stainless steel screws or blind rivets. All equipment labels shall be engraved with a number, name of the equipment and service as previously specified but with the legend on the face only.

A valve chart indicating the duty and position of all valves shall be fitted into a glazed frame and fixed in an agreed position.
Identical copies shall be handed over to the Engineer as a part of the record drawings.

CHAPTER - 3

AIRSIDE SYSTEM

3.1 Sheet Metal Duct Work

3.1.1 General

Ductwork shall be supplied and installed generally as shown on the drawings to provide a complete working installation and in accordance with the details stated hereafter.

Dimensions of ductwork shall be as given on the drawings, except where site measurement necessitates variation, in which case the specified cross-sectional areas to be adhered to and the change in section made with tapered transfer pieces. Sizes given on the drawings are internal sizes and where internal insulation and/or acoustic lining is provided the duct is to be increased in size to give the specified free internal dimensions.

Ductwork shall be cleaned out as erection takes place and all openings blanked off until the whole system is in operation.

All raw edges of ductwork shall be painted with one coat of aluminium paint before leaving the works and again prior to erection.

All ductwork passing through plant room floors and walls shall be provided with a sleeve and the space between the duct and the sleeve shall be packed with suitable sound insulation material to reduce the noise transmitted to other parts of the building from the plant room.

Where there is a possibility of the transmission of vibration the ductwork shall be isolated from the building structure.

Where ducts pass through the structure, holes shall be provided with 50mm x 50mm timber frames around the perimeter by the Contractor. Angle flanges to be secured around the perimeter of the ducts shall be supplied and fixed to the timber frames.

The material used shall be selected with service in mind, and special consideration shall be given when equipment has to handle corrosive gases, dust and similar contaminants. Galvanised steel,

shall be used for all metal duct work, unless otherwise specified. All

structural supports and parts shall be of structural steel conforming to BS 449 or ASTM A 36. In other cases, where material in ducts are different to supports etc., materials used shall be well insulated so as to avoid direct metal to metal contact.

3.1.2 Design Criteria

The duct design shall be in accordance with the HVAC Duct Work Specifications, Published by Heating and Ventilation Contractors Association or in accordance with the ASHRAE Hand Book published by American Society of Heating, Refrigerating and Air Conditioning Engineers. OR SMACNA (USA) or DW/144 of HVCA (UK).

The Duct design shall be such that it will supply the specified volume of air to each area within the facility, at a specified pressure and velocity. Low-pressure ducts shall have static pressures up to 500 Pa and a velocity of 13 m/s. High pressure ducts shall have pressures of 0.75 to 25 kPa static pressure and velocities above 10 m/s.

Each duct system shall be constructed for the specific duct pressure classifications shown on the contract drawings. Where no pressure classes are not specified by the designer, the 250 pa pressure class is the basis of compliance with these standards, regardless of velocity in the duct, except when the duct is variable volume: All variable volume ducts upstream of VAV boxes has a 500 pa basis of compliance when the designer does not give a pressure class.

The duct design shall ensure that the noise levels are low and tolerable.

The sections of the duct may be rectangular or circular conforming to the preliminary drawings and the recommended section shall be used for the fabrication of ductwork.

The duct assembly shall be air tight as to allow leakage of not more than 1.0 percent of the total flow rate. Any leak in the system shall not create any audible noise.

Pressure relief controls shall be provided to overcome problems due to excessive pressure loads, and fire dampers provided shall have a minimum of 1.5 hour, standard fire protection rating.

Ductwork classification

3.1.3 Low Pressure Ductwork

Ductwork shall be erected as indicated on the drawings, complete with all hangers and supports, control and fire dampers, plant, grilles, access doors, etc., all in accordance with the Specification for sheet metal ductwork, SMACNA (USA) or DW/144 metric, low velocity, low pressure, air systems published by HVCA.

Joints, except for those made on site, shall be of the lock form type.

Site erection joints up to 600mm size shall be drive cleats or slip joints, the latter lapped in direction of flow secured with self tapping screws sealed with mastic and/or taped with plastic tape not less than 75mm wide.

Site erection joints over 600mm size shall be as above but further reinforced with the relevant size of angle stiffener. Alternatively, large ducts may be jointed by means of angle iron flanges and suitable gaskets and /or mastic.

Apart from painting requirements specified elsewhere, all stiffeners and angles, if not galvanised after manufacture, shall be painted with red oxide undercoat and aluminium paint finish before fixing to duct. All screws, fastenings etc. are to be sheradised.

Back draft dampers shall be of the same material as the ductwork, and multiblade type. Blades shall have felt strips riveted or crimped in place and shall be joined using suitable connection bars. Each blade shall be attached to the pivot rod, and the pivot rod shall extend into an oil impregnated bronze bushing located in the frame.

Acoustical duct lining shall be flexible or rigid mineral fibre. The lining shall not be less than 25mm thick. When acoustic lining is used duct size shall be adjusted to compensate for the thickness of lining.

In lieu of acoustical lining, factory fabricated sound attenuators may be provided. Factory fabricated attenuators shall be constructed of galvanised steel sheets. The outer casing of which shall be not less than 0.9 mm and the pressure drop through the attenuator is not more than 15 percent of total

external static pressure of the air handling system. When sound attenuators are to be site fabricated, construction details and behaviour shall be similar to the factory fabricated units.

Low-pressure ductwork will not normally be pressure tested but if inspection and/or air flow tests suggests air loss, a pressure/smoke test will be called for by the Engineer.

Wherever mitred bends are indicated on the drawings, radius bends shall be installed in accordance with SMACNA (USA) or HVCA Specification DW 144, unless space limitations require square bends, in which case air turn vanes shall be provided.

Details given in Table 1 shall be used in the construction of low-pressure class rectangular ductwork unless otherwise specified.

Table 1

Galvanized Steel Thickness (mm)	Maximum duct size	Type of Transverse Joint connections	Brazing
0.55	up to 310mm	S, drive, pocket or bar slips on 2.40m centres	None
0.70	up to 330 mm	S, drive, pocket or bar	None
	480 mm to 760 mm	S, drive, 25mm pocket or 25 mm bar slips on 2.40 m centres (2-3) joints	25x25x3mm angle midway between joints
0.85	780 mm to 1070	S, drive, 25mm pocket or 25 mm bar slips on 2.40 m centres (2-3) joints	25x25x3mm angle midway between joints
0.95	1090 mm to 1370 mm	38mm angle connections or 38mm pocket, or 38 mm bar	38x28x3mm angle midway between joints
1.00	1400mm to 1520mm	Slips with 35x3mm reinforcing bar on 2.40m centres (2-4) Joints	38x28x3mm angle midway between joints
1.20	1500mm to 2140mm	38mm angle connections or 38mm pocket, or 38 mm bar slips on 1.14 max. centres with 35x3mm with reinforcement bar	38x28x3mm angle or 38x28x3mm diagonal angle midway between joints
1.20	2160mm to 2440mm	50mm angle connections or 38mm pocket, or 38 mm bar slips on 1.14 max. centres with 53x3mm with reinforcement bar	38x28x3mm angle or 38x28x3mm diagonal angle midway between joints

3.1.4 High Pressure Ductwork

Joints between sections of rectangular ducts and between ducts and fittings shall be made with gasketed flange connections or welded flange joints.

Sound traps shall be provided on the discharge and suction duct of each high pressure fan operating at pressure above 1 kPa. Maximum permissible pressure drop across a sound trap shall not exceed 150 Pa. The traps shall be air tight when operating under an internal pressure of 2 kPa**.**

Sound trap shall be site or factory fabricated. In case of site fabricated sound trap, it shall be contained in an oversized section of duct constructed of galvanized iron not thicker than 1.3 mm or of 1.6 mm thick aluminium, having a suitably sealed joint. Each trap shall be constructed of No. 2 mesh galvanised wire cloth or 1.6mm galvanised expanded metal, and shall have a nett inside dimension not less than the connecting discharge duct. The layers of 25 mm or thicker acoustic blanket shall be installed between the duct and the wire cloth to provide the required sound reduction.

3.2 Flexible Ductwork

Connections to units, and where suitable to small diameter diffusers, may be made with flexible ducting, and shall be jointed to the unit/grille and rigid duct with universal type non-corrodible hose clips. The maximum length of flexible ductwork shall be 750mm and be fully supported.

The ducting shall be subject to the relevant fire resistance requirements of the enclosing space and shall be insulated.

Ducts shall be fabricated with material suitable to handle the type of contaminants in the air and shall withstand the design air flows and pressures.

3.3. PVC Duct Work

The construction of PVC ductwork shall be in accordance with the HVCA Specification DW / 151.
Pre-insulated ductwork

3.4 Hangers and Supports

Ducts shall be permanently fixed from rigid supports at not more than 2.5m centre for horizontal runs at each floor level for vertical runs. Additional supports should be fixed at bends, dampers, etc., where standard spacing leaves these unsupported.

Horizontal runs shall be fixed by means of mild steel brackets connected onto a mild steel band encircling the duct or fixed to the stiffening angles for larger duct sizes. The brackets shall be suspended from the structure by flexible hangers or supported on cantilevers.

Low level ductwork shall in general, be supported as above or otherwise on special mild steel frames.

One anchor type support shall be provided for each main run of ductwork, or each 20m, either by fixing rigidly to the structure or by cross braced hanger supports.

Vertical runs shall be fixed rigidly to and completely encircling the duct and be arranged so that the whole weight of duct is transferred to the support.

In insulated ducts where the dew point of the enclosing space is below the duct air temperature, brackets shall be of standard size and the insulation carried over the bracket. Where the dew point is above duct air temperature, the brackets are to be oversized and fitted with rigid insulation between the duct wall and the bracket.

3.5 Dampers

3.5.1 Volume Control Dampers

Adjustable dampers shall be installed generally as indicated on the drawings, but at all main branches in the ductwork, the fresh air inlet, the recirculation main duct, and also where necessary for correct balancing of the system.

Dampers shall be single blade type or multi blade type and all multi blade type dampers shall be Opposed Blade type.

Dampers shall be of the manually adjustable type with indicating quadrant and lockable lever and are to be of rigid construction, free from noise or rattle under operating conditions.

Dampers with side dimensions less than 300mm shall be of the single blade type of thickness not less than 1.6mm with 10mm diameter pivot rods and rigid bearings.

Dampers with side dimensions over 300mm shall be of the multi-leaf type of thickness not less than 1.6 mm and no blade shall be more than 250mm wide. They shall be provided with 10mm diameter pivot rods, aerofoil section set in rigid bearings and linked externally to a single quadrant and lever.

After final commissioning, the position of the dampers should be indicated with durable paint.

Unless access is feasible through adjacent equipment, hand access panels shall be provided to enable full inspection of the blades.

3.5.2 Fire Dampers

Fire dampers shall be provided in all positions as shown on the drawings and as necessary to meet the requirements of the Fire Officer.

Fire dampers shall be located within the thickness of a fire barrier. Where this is not possible, the section or ductwork between the damper and fire barrier shall have a fire resistance equal to that of the damper itself, and not less than 6mm thick mild steel plates.

Each fire damper assembly shall be held in the open position by a fusible link, generally set to release at a temperature of 70^0C and all blades must be weighted to ensure immediate closure on release of the link.

Access doors shall be provided at all fire dampers to enable full inspection of the blade and fusible link.

Access doors shall not be less than 450mm x 450mm clear, unless this effects the duct dimensions.

Fire dampers shall be of the type having the shutter outside the normal airstream.

3.6 Access Holes and Doors

Access doors and other openings in ductwork shall be provided as indicated below:

(i) Access for personnel for maintenance and replacement of plant items, where appropriate.

(ii) Access for routine maintenance, lubrication and adjustment of items not requiring full access.

(iii) Access for cleaning, where indicated on the drawings.

(iv) Access for inspection of items concealed in ductwork such as dampers, fusible links, thermostats, etc..

Access doors shall be not less than 450mm x 450mm clear, unless this affects the duct dimensions. They shall be hinged and fitted with felt seals, secured to prevent stripping and provided with cam lock fasteners. Holes cut in the duct walls for the access doors shall be provided with stiffening frames.

Where hinged doors cannot be included due to space limitations, bolted-on type with quick release fittings shall be employed.

Access holes shall be 200mm x 200mm clear, unless this affects the duct dimension. They shall be of the bolted-on type and be fitted with felt seals.
Access doors on insulated ducts are to be insulated and a retaining frame is to be provided for the duct insulation where it abuts the door opening.

3.7 Test Holes

Test holes for instruments shall be provided where indicated on the drawings and in any case to enable fan ducts to be tested and the performance of regulating dampers to be assessed. All holes shall be 25mm diameter and provided with an effective seal.

Test holes shall be made up of a brass nipple and cap welded to the duct or casing adjacent to each temperature-sensing device. On low-pressure system and on fan suction sides of all casings an instrument test hole with cap may be used in lieu of a welded brass nipple.

3.8 Plenums and Casings

Plenums and casings shall include all enclosures for, and air passages between, the air intakes, filters, heating and cooling coils and fans. The floors of structural platforms under casings shall serve as bottoms and the sides, and tops shall be constructed of sheet metal of 1.0 mm minimum thickness.

Casing shall be reduced or increased in dimensions to connect each piece of apparatus.

Wherever necessary casings shall be reduced or increased in dimensions to connect to each piece of apparatus.

Sheet metal thicknesses and reinforcements shall be selected so that under normal operating pressures the casing wall shall not deflect excessively. The strength of panels under normal operating pressures shall be so as to limit the deflection to 1/240th of the unsupported panels span.

Access doors shall be provided in each section of the casing and shall be of air tight construction. Each door shall have a neoprene or similar type gasket. When doors are provided, the hinge mechanism and fastening mechanism shall be constructed of corrosion free material such as brass. The fastening shall have provisions for opening from inside or outside. Doors shall swing so that the fan suction or the pressure holds the doors in closed position.

3.9 Eliminators

Each cooling coil in the field fabricated casings and duct work having an air velocity of over 2m/s. through the net face area shall be equipped with moisture eliminators, unless the coil manufacturer guarantees that no moisture will be carried beyond the drip pans under actual operating conditions.

Eliminators shall be constructed so that they are removable through the nearest access door in the casing or ductwork.

3.10 Drip Pans

Drip pans shall collect, confined dispose of all condensate from cooling coils and attachments including headers, return bends, distributors and un-insulated pipe and fittings. Where individual eliminator blades are made in sections, auxiliary drip through shall be provided at the bottom of each section with drains and drip pans. Material used in drip pans shall resist corrosion for long times and shall be removable easily for replacement.

3.11 Diffusers, Registers, Grills and Troffers

Diffuser, registers, grills and troffers shall be factory fabricated of steel or aluminium and shall be compatible with the ceiling system selected by the Architect. Complete details including manufacture and types shall be submitted for approval of the Engineer and Architect.

3.11.1 Diffusers

Diffusers shall distribute the correct quantities of air and flow pattern over the space intended, without causing noticeable drafts, air movements in occupied zones, or dead spots any where in the conditioned area.

Ceiling diffusers shall be circular, square, rectangular perforated face, perforated plate or linear type. Diffuser shall be sized in accordance with the recommendations of the manufacturer, and shall be equipped with baffles or other devices required to provide proper air distribution pattern. Factory fabricated turning vanes furnished by the manufacturers shall be provided at each diffuser, branch duct or take off except where flexible duct is used. Volume dampers and separate pattern adjustments shall be fixed so that it could be removed through the diffuser neck for access into the duct. Diffusers used for the exhaust or return shall be similar to diffusers used for supply, except that, elements used for air pattern control is only eliminated.

3.11.2 Registers

Registers shall be provided with factory fabricated volume dampers, furnished by the register manufacturer. Volume dampers shall be group operated, opposed blade and adjustable type. Exhaust and return registers shall be similar to supply registers except that they shall have a single set of non directional face bars or vanes having the same appearance as the supply register. Registers shall be factory primed ready for finish, painting.

3.11.3 Grills

Grills shall be manufactured and finished as registers except that the volume dampers shall be omitted.

3.11.4 Troffers

The air handling portion of the combination light and air handling troffer shall be provided with a method of balancing the air in the supply troffer, which shall be accessible for adjustment without requiring the removal of troffer components or ceiling panels after installation. Supply air shall be delivered in uniform adjustable pattern along the entire length and/or width of the troffer. The return air handling section shall vent room air and attenuate room noise passing into the ceiling plenum. Return and supply air handling sections shall be interchangeable except that distribution plenums are not required for return sections discharging into the ceiling plenums.

3.12 Louvres

Louvres, which are connected directly by the ductwork to air handling equipment, shall be made of galvanised steel or aluminium unless otherwise specified. All louver shall have 50 percent free area and shall be constructed to withstand a wind pressure of 1.5 kPa. They shall be designed and manufactured with accurately fitted blades with folded edges to exclude driving rain

In case of adjustable louvers they shall be operated by manual means.

3.12.1 Bird Screens

Outdoor air intake louvers must include a corrosion resistant screen designed to prevent penetration by a 13mm diameter probe.

3.13 Sound Attenuators

Sound attenuators shall be supplied and installed as indicated and scheduled on the drawings and also as necessary to achieve the sound levels in accordance with design criteria specified in Clause 3.1.2.

It shall be the Contractor's responsibility to ensure that the sound attenuators provided are capable of reducing the sound power level of the fans and system, as installed, to the design room conditions as noted.

The sound attenuator casing shall be manufactured from pre-galvanised steel to the appropriate thicknesses and shall be pocket lock formed to ensure a constant seal.

The acoustic lining material of the sound attenuators shall be of inorganic incombustible fibreglass having a minimum density of 32kg/m3 protected from air stream erosion by a reinforced glass fibre mesh and be contained within a 0.91mm thick pre-galvanised metal splitter on each side of which shall be an exposed face of material.

The splitters shall be arranged within the casing to provide a number of airways, the width of each being determined by the required acoustic performance. A half width splitter shall be fixed on the attenuator side walls for minimising flanking problems. Splitters shall be secured to the casing by pop rivets or self-tapping screws.

Where zinc galvanising is destroyed during the manufacturing process, all such places shall be thoroughly cleaned and treated with a zinc rich paint.

The sound attenuators shall be installed with suitable transformation pieces to adjacent ductwork.

Sound attenuators handling saturated air shall be manufactured generally as above but in lieu of the reinforced glass fibre mesh, the acoustic infill shall be inserted behind scrim and be of 0.55 mm thick perforated sheet steel having 50 percent free area and hot dipped galvanised after perforation.

3.14 Flexible Connections

Flexible connections shall be provided at all connections onto plant and/or fans and are to be of flame resistant, non-organic flexible sheet secured with flat galvanised steel band to the duct and be fixed so that a smooth internal surface is presented to the air flow.

3.15 Connections to Builder's Work

Where metal ducts, fan inlets and outlets connect to builder's work, connections shall be by built-in timber frame or built-in companion ring or flange. Built-in timber frames are preferred, except for connection to fire barrier walls or fixing fire dampers. Timber frames shall be constructed in hardwood of suitable section. Companion rings shall be provided with an adequate number of suitably sized rag bolts or similar fixing devices.

In all cases the duct end shall finish with a mating flange and where this is fixed to a timber frame the flange should be wide enough to overlap the joint between timber and masonry by at least 15mm.

3.16 Fans

3.16.1 Roof Extract Fans

Roof extract fan units shall be of the axial/mixed flow type, as indicated and scheduled on the drawings.

The weather skirt, cowl and impeller shall be constructed in glass fibre reinforced resin, with polypropylene shutters and aluminium fittings. The motors shall have ball bearings and be of the totally enclosed type.

All fan units shall be mounted on suitable acoustic curb.

Each fan shall be provided with a suitable flush or surface mounted starter/switch unit with red indicating light.

3.16.2 Window / Wall Mounted Extract Fans

Window/wall mounted extract fans shall be of the axial flow type with balanced pressed steel or moulded plastic impellers, totally enclosed motor and resilient mountings fully rust proofed or of non ferrous construction. The fans shall have electrically operated automatic shutters.

3.16.3 Duct Mounted Extract Fans

Duct mounted extract fans shall be supplied and installed as indicated on the drawings. Motor shall be manufactured conforming to BS 5000 and the assembly shall be provided with a sufficient length of mains lead terminating in 3 pin 13A plug. Impellers and casing shall be constructed from non-ferrous alloy. The fan assembly shall be mounted on anti-vibration supports.

Flexible connections, not less than 75mm, shall be fitted on both inlet and outlet.

Extract fan with twin fan system shall be equipped with auto-changeover facility to ensure continuous operation, in the event of failure of the duty fan and the facility to indicate the faulty condition on the control box accordingly.

Extract fans connected to extract hoods in kitchens shall be bifurcated (motor located outside the air stream) type. Impellers shall be of non-ferrous construction and suitable for air laiden with grease from cooking area.

3.17 Other Systems of Ventilators

3.17.1 Hoods

Unless otherwise specified hoods shall be constructed of galvanised steel with welded or soldered seams. They shall be ceiling mounted and shall be 150 mm. larger than the equipment it covers. The hoods shall be designed for handling and venting of air without much turbulence and disturbance. When hood ventilators are provided they shall be of a permanent type as recommended by the manufacturers. Hoods in areas like kitchens, where grease is likely to be handled, grease trays shall be fitted just under the filters. Grease filters shall be baffle type Such trays shall be removable in sections for cleaning purposes.

3.17.2 Roof Exhausters and Ventilators

Natural ventilation in factory building etc., shall be provided by installing ridge and box type

ventilators. They shall be fitted in accordance with the designers instructions and in locations specified. This is particularly important in the case of box type ventilators which also act as fire regulators in ware houses etc.,

The ventilators shall be capable of venting through the type of contaminants and the material and construction of the ventilators must be such that they are able to withstand any vapours, corrosive gases, dust etc., for long periods without regular maintenance.

All roof mounted ventilators shall be designed and installed in a manner that will withstand the maximum wind velocities expected under cyclone conditions and such velocities must be equivalent to those used in the building design.

Screen protection provided against birds, insects etc., shall not restrict the air movement and they shall be fitted in such a way that cleaning or replacement of same could be done without any difficulty.

Dampers/covers shall be provided if the ventilators are open to the atmosphere. Such systems shall have means for operating manually or by sensors and automatic controls to detect rain etc.. Dampers/covers should be designed to withstand heavy tropical rains and should be provided with water tight seals.

3.17.3 Rotary Turbine Ventilators, Wind Actuated

Rotors should be constructed out of light materials. All rotating parts of the rotor should be properly balanced and this type too should be constructed to withstand high wind velocities.

3.18 Air Cleaning Devices

Particular type of devices to be used shall depend on the nature of impurities and the thoroughness of air cleaning necessary.

3.18.1 Dry Type Filters

Filters shall be constructed in such a way that they contain frames or cells to carry filter media which could be easily detachable for removal or replacement of filter media.

Filter media may be wool, felts, specially woven fabrics, glass wool synthetic fibres or cellulose. These materials must be rot proof, vermin proof, fire proof, and odourless. Adhesive or viscous

materials should not be used as coatings on the cleaning surfaces. The filter as a whole should be a leak proof construction and should carry indicators to show when the filter is clogged.

Two complete sets of spare filtering pads shall be supplied along with the filter, and complete technical information including filter efficiencies, air flow rates and resistance offered by the filtering media should be provided.

3.18.2 Spray Type Air Washer

The scrubber/eliminator plates which are fitted shall be fitted with a high pressure spray jet system to keep the scrubber/eliminator plates wet at all times. High pressure water should be supplied through a suitably rated electrical centrifugal pump which draws water from the collecting tank located at the bottom of the air washer.

Scrubber/eliminator plates shall be manufactured of copper, glass, mild steel galvanised after manufacture or treated with a similar corrosive resistant material. Spray nozzles shall be of non corrodible material such as gun-metal. Construction shall permit easy disassembly for cleaning and replacement purposes.

The collecting tank shall be fitted with a primary water filter/and a `ball valve' of not less than 9mm bore with a visible over-flow with a connection from the permanent water supply.

Access doors should be provided for routine maintenance of the washer. They should be fitted with water tight seals and non corrodible hinges.

Where dust loading is light, "cellular air washers" consisting of multiple cells fitted with glass

filaments can be used. Low pressure water could be used in these systems and all cells shall be kept wetted at all times.

3.18.3 Viscose Type Filters

The frame of the cell shall be steel or cardboard and the inside may be filled with materials such as steel shavings, vegetable fibres, spun glass fibres, animal hair or bristles. A suitable oil shall be applied to the surface and the oily effect must be retained for long times.

In viscous filters where the surfaces are kept continuously or periodically moved a properly designed

drive mechanism should be incorporated. Means must be provided to remove excess oil from the filters prior to coming into contact with the main air stream.

3.19 Test Points and Instruments

Test points shall be provided and installed, generally as given below and as further indicated on the drawings, to allow in-operation temperature and/or pressure readings to be taken. (The test points are supplementary to instruments specifically detailed in equipment clauses).

Pressure test points for pipework shall comprise of a 10mm F x F brass gauge cock and brass plug.

Temperature test points for pipework shall comprise of a 100mm long x 15mm BSPT brass pocket.

Pressure and temperature test points in pipework systems shall be provided at all main branches and on flow and return of all cooling coils.

Temperature test points shall be provided on all three connections to mixing valves.

Pressure gauges for pipework shall be of the Bourdon type with 100mm dial, black case, chrome bezel and 10mm BSPT connection. The scale shall be marked in N/m^2.

Thermometers for pipework shall be of the bi-metal type with a 100mm dial, black case, chrome bezel, 100mm long stem and 15mm BSPT connection. Scale range shall be 0 to 120^0C.

Pressure and temperature test points for ductwork shall be 25mm diameter holes provided with an effective seal.
Pressure and temperature test points in ductwork systems shall be provided before and after all air handling units, cooling coils and at the fresh air and recirculation inlets.

Pressure gauges for ductwork shall be of the diaphragm actuated type with 100mm dial, black case and bezel and 3mm BSPT connections. The scale shall be marked in N/m^2.

Thermometers for ductwork shall be of the bi-metal type with a 100mm dial, black case, chrome bezel, 300mm long stem. The scale range shall be 0 to 50^0C.
Supply instruments and leave in such of the above test points as agreed with the Engineers.

3.20 Kitchen Extract Systems

3.20.1 Kitchen canopy Hoods

Shall be based on specifications DW/172 of HVCA UK

Kitchen hoods shall be built of stainless steel or aluminium sheet of 1.6 mm (SWG 16) thickness.

Unless restricted by walls, plan dimension of the canopy shall always exceed the plan dimension of the catering equipment by a minimum of 250mm on each free side, and by 250mm at the front & rear.

Height of the canopy shall be 400mm and installed 2000mm to 2100 mm higher from the finished floor level.

3.20.1 Duct Work

All ductwork shall be low-pressure class A and be in accordance with HVCA specification number DW/144 with a minimum thickness of 0.8 mm.

Where it is not possible to immediately discharge the captured air within the confines of the kitchen fire zone, fire rated ductwork must be used to comply with BS 3476 part 24/BS 5588 part 9.

Where total 'grease tightness' is required within the kitchen fire zone, all ductwork within the kitchen compartment and not discharging directly to atmosphere shall be constructed from either 1.2mm stainless steel or 1.6mm zintec, be of fully welded construction with welded angle iron flanges and use full faced gaskets. Gaskets shall be non porous, impervious to grease and cooking oils and capable of withstanding the higher temperatures experienced in kitchen extract systems. Mild steel ductwork should also be painted externally with 2 coats of protective paint before leaving the manufacturers works.

Steam line duct sections shall be fabricated with Stainless Steel or Aluminium sheets with Pittsburg lock or Acme lock grooved longitudinal seams. Snap locks shall not be used. Ductwork shall be braced and stiffened so that they do not bend, rattle or vibrate. Laps shall be in the direction of air flow and no flanges shall be projected into air flow.

Segmented 90 degree bends shall be of five section elbows. Segmented 45 degree bends shall be of three section elbows. Bends shall have a ratio of centre line radius to diameter of at least 1.4 to 1. All tees shall have conical or tapered branches. Where no details have been given, duct designs shall be in accordance with Ductwork Specifications published by Heating and Ventilation Contractors' Association or in accordance with the Hand Book of American Society of Heating, Refrigerating and Air conditioning Engineers.

Flange joints shall have angles welded on to the ductwork to make the mating surfaces. Mating surfaces shall be ground smooth and be punched for 8mm bolts at not more than 150 mm centres.

All joints shall be chalked or gasketted to make airtight.

Where necessary in the ductwork or in the casings, access doors shall be provided to permit inspection, operation and maintenance of all fans, dampers, controls or other apparatus concealed behind the metal work. Access door shall be 450 mm x 450mm clear or larger to suit the size of the equipment fitted adjacent to the same, and where the above size is not permitted, 50mm narrower than the duct width.

3.20.2 Volume Dampers

Volume control dampers shall not be used in grease laden air removal in canopy extract systems. Air flow balancing of multiple canopies should be addressed as a manifold system with duct fittings pressure loss is used for controlling the air flow balancing without utilizing volume control dampers. If it is really necessary but should be kept to a minimum and incorporate the following features:

1. For extract systems, the damper blades shall be fabricated from stainless steel.
2. The operating mechanism shall be outside the airstream and be capable of withstanding the higher air temperatures associated with kitchen extract systems

Adjustable volume dampers shall be provided as shown in the Drawings in the various branches of the duct work and on the down stream of the exhaust supply.

Volume dampers shall be of the quadrant type of heavy construction, pivoted with approved operating and locking devices, mounted on the out side of the duct in an accessible place. Fully open and fully closed positions of the device shall be clearly marked. Dampers in ducts over 450 mm deep shall be of the multi-blade parallel type. Multi-blade dampers shall be provided in large ducts.

3.20.3 Fire rated ductwork

Where it is not possible to immediately discharge the captured air within the confines of the kitchen fire zone, fire rated ductwork must be used to comply with BS 3476 part 24 / BS5588 part 9.

No fire dampers are to be installed in the extract ductwork.

3.20.4 Hangers

Hangers shall be provided generally in accordance with Clause 3.4. The work shall be securely anchored to the structure. Suspension from the ceiling work is not permitted. Hangars shall be located suitably and shall be adjustable in the vertical plane. Cadmium or galvanized fasteners shall be used in exposed, areas.

3.20.5 Ductwork Construction Details

3.20.5.1 For the distribution of supply air to canopy, the ductwork has no special requirements other than minimum F6 filtration level for incoming air. Bird mesh screens to the rear of any inlet louver shall be incorporated. Insect mesh shall not be used as it can become easily blocked.

3.20.5.2 Under normal circumstances and provided it runs within the fire compartment of the kitchen itself, extract ductwork shall also have no special requirements.

3.20.5.3 All ductwork described in 3.20.5.1 & 3.20.5.2 shall be low pressure Class A and be in accordance with HVCA Specification DW/144 with minimum thickness of 0.8 mm.

3.20.5.3 All interior surfaces of the ductwork shall be accessible for cleaning an inspection process. Access doors shall be installed at 3 m centres.

3.20.5.3 On horizontal duct runs, access doors should be installed on the side of the duct, with under side of the at least 40 mm above the underside of the duct. On vertical ducts, cleaning doors shall be provided at each floor level.

3.20.6 Grease Eliminator

Each kitchen hood shall be provided with grease eliminators to ensure that no grease enter the main duct. Grease eliminators shall be of stainless steel.

3.20.7 Lighting

Kitchen hood shall be illuminated with heat, dust and moisture proof GCE valiant lamp (catalogue No. 64110) or equivalent.

CHAPTER 4

AIR CONDITIONING PLANT

4.1 General

This chapter covers all equipment that shall be used to provide chilled water or direct air cooling. The performance characteristics of the system shall meet the requirements of the areas to be air conditioned. All calculations and design data used in the selection of equipment shall be submitted to the Engineer for approval, unless otherwise is stated.

All equipment shall be in the form of packaged units manufactured in a reputed establishment. The Contractor shall ensure that each individual piece of equipment in the plant has been tested and certified before delivery and that all items in the plant are covered under the guarantees required.

NOISE

Mechanical and electrical plant shall be selected or suitably silenced to achieve the specified noise levels as measured 1m from air inlets and/or outlets.

If these noise levels cannot be achieved by the plant then attenuators shall be installed to achieve the recognized levels. Where no noise levels have been specified the Contractor shall be guided by the NC, decibel levels recommended in the AMERICAN NATIONAL STANDARD ANSI/ASA S12.2-2008, Criteria for evaluating Room Noise.

Table 2 NC DECIBEL LEVELS

Table-1 Recommended NC and RNC Criteria

Occupancy	Recommended NC and RNC criteria curve
Concert halls, opera houses, and recital halls (listening to faint musical sounds)	15-18
Small auditoriums (≤500 seats)	25-30

Large auditoriums, large drama theaters, and large churches (for very good speech articulation) (>500 seats)	20-25
TV and broadcast studios (close microphone pickup only)	15-25
Legitimate theaters	20-25
Private residences:	
Bedrooms	25-30
Apartments	30-40
Family rooms and living rooms	30-40
Schools:	
Lecture and classrooms core learning space with enclosed volume <566 cu m(≤ 20,000 cu ft)	25-30
core learning space with enclosed volume >566 cu m(> 20,000 cu ft)	30-35
Open-plan classrooms	25-30
Hotels/motels:	
Individual rooms or suites	30-35
Meeting/banquet rooms	25-35
Service support areas	40-50
Office buildings:	
Offices executive	25-35
small, private	35-40
large, with conference tables	30-35
Conference rooms	
large	25-30
small	30-35
Open-plan areas	35-40
Business machines, computers	40-45
Public circulation	40-50
Hospitals and clinics	
Private rooms	25-30
Operating rooms	25-35
Laboratories	35-45
Corridors	35-45
Public areas	40-45

Movie theaters	30-40
Churches, small	30-35
Courtrooms	30-35
Libraries	35-40
Restaurants, kitchens, and laundries	40-45
Shops and garages	50-60

4.2 Refrigerant

Refrigeration machines shall be selected which work on ozone friendly refrigerant.

When selecting Refrigeration machines, consider equipment with minimal Ozone Depletion Potential (ODP) and Global Warming Potential (GWP). The use of Refrigeration machines containing Chlorofluorocarbon (CFC) & Hydrochlorofluorocarbons (HCFC) refrigerants are prohibited.

In case of common refrigerants sue for vapour compression cycle refrigeration machines, the selection shall conform to publications by the `ASHRAE' standards, Guides & Handbook published by the `American Society of Heating, Refrigerating and Air Conditioning Engineers'. All relevant information of the refrigerant used in the system together with any special requirement against leaks and safety measures to be adopted shall be clearly indicated in the `Instruction Manuals'. Refrigerant safety shall comply with ANSI/ASHRAE Standard 34-2007, Designation and Safety Classification of Refrigerants

4.3 Water Chilling Packages

4.3.1 The water chilling packages shall be vapour compression cycle air-cooled or water-cooled, electrically operated, positive displacement or water-cooled centrifugal or water-cooled/air-cooled centrifugal oil free magnetic bearing type or Absorption cycle water-cooled single effect/double effect absorption type. The water chilling packages on vapour compression cycle supplied in package units comprising of compressors, condensers, expansion device, cooler or evaporator and the automatic control panel. The unit shall be fixed on a base frame ready to be mounted on a suitably designed foundation. When several chiller units are used, a suitable central control system such as Chiller Plant Manager (CPM) shall be provided.

Each chiller shall have a minimum of 2 No fully independent refrigeration circuits.

Designer may select single circuit chillers when there is N+1 redundancy available.

When chillers are equipped with variable speed drives (VSD), Harmonic Suppression Filters or Line Reactors shall be fitted as a standard accessary.

Harmonic voltage limits for individual voltage distortion & Total voltage distortion (THD) shall be as per Table-1 IEEE Standrad519-1992 Harmonic Voltage Limits.

Harmonic current limits for current distortion shall be as per Table-2 IEEE Standrad519-1992 Harmonic Current Limits.

Chiller shall have BMS interface card with BACnet or Modbus protocol as a standard accessary for BMS integration work.

4.3.2 Water Chiller Types

Individual chiller	Electric chiller
Plant capacity	Type
≤ 100 Tons	Scroll
> 100 Tons <300 Tons	Screw
≥ 300 Tons	Centrifugal

4.4 Compressor

Water chiller packages shall use compressor types such as Scroll, Screw, Centrifugal or centrifugal oil free magnetic bearing types. Compressor configuration shall be fully hermetic for scroll type, serviceable hermetic for screw and open & serviceable hermetic type for Centrifugal. Compressors of scroll, screw type shall be equipped with automatically reversible oil pump, operating oil charge, suction and discharge shut-off valves and insert type crankcase heater. Motors shall be cooled by the suction gas passing around the windings and shall be provided with over temperature protection, a contactor and a calibrated manual re-start, ambient-insensitive overload protectors and all other required protectors for the proper and safe operation of the compressor. The overload protector shall open all three phases in the event of overload in any one of the three phases.

The controls shall include under/over voltage protection, so that, in the event of the occurrence of a

power supply fluctuation that could be harmful to the motors, the equipment is shut down, with automatic reset occurring following a preset delay after power restoration. The complete unit shall be a robust and compact construction and shall be mounted on spring type vibration isolators.

Selection of a suitable type from the two types of compressors shall depend on the condenser pressure. In high pressure systems reciprocating type shall be incorporated. When selecting the chiller, appropriate redundancy shall be taken into consideration by the designer.

All exposed nuts and bolts shall be made of stainless steel and exposed surfaces shall be painted with anti-rust paint to prevent possible deterioration under salty and humid atmosphere conditions.

4.5 Refrigerant Circuit Components

Refrigerant circuit components shall be factory supplied and piped. The circuit shall incorporate high side pressure release valves, liquid line shut off valves, hot gas valves, filter dryers, liquid and moisture indicating sight glasses, liquid line solenoid valves and thermal expansion valves. Any other components that shall be necessary for proper operation of systems shall be incorporated in addition to what is mentioned.

4.6 Condensers

Condensers shall be either air-cooled or water-cooled type and shall be designed to match the refrigeration components of entire plant.

4.6.1 Air -Cooled Type Condensers

Air cooled type condensers shall be of aluminium/copper finned copper tubes or coils with low speed propeller type fans in a packaged type construction on a base frame for installation at a suitable location.

Condenser find shall be coated with HYDROPHOBIC protective coating of 2 microns and withstand to Salt Spray Humidity Endurance Test for 1000 hrs., for installation locations such as coastal areas, polluted areas and corrosive areas.

4.6.2 Water-Cooled Type Condensers

Water-cooled type condensers shall be mechanically cleanable shell and tube type with integrally finned copper tubes having removable heads. In case of Unitary packaged equipment oir split units application, water-cooled condenser shall be shell and coil type, Tube-in-Tube type as specified.

Condensers shall be constructed to provide sub cooling of liquid refrigerant by having separate sub-cooling coil bundle. High-pressure relief valves for safety shall be incorporated to the condenser and shall comply with AHARE Standard 15. A fusible plug shall be sued in tube-in-tube or shell & coil condensers only.

Shells shall be made out of carbon steel plate. The condenser shall be designed, tested, and stamped in accordance with ASME Code for refrigerant-side/ working-side pressure of 200 psig. All tube sheets shall be of carbon steel; tubes shall be mechanically expanded into tube sheets and mechanically fastened to tube supports. Condenser tubes shall be 19.05 mm diameter. Both types can be individually replaced

The selection of the type of condenser media shall be the responsibility of the designer by taking into consideration of the availability and the quality of water to be used in the condenser. Surfaces in constant contact with water shall be constructed out of corrosion resistant materials.

The Condenser shall be tested in accordance with ASME code for refrigerant side working pressure of 15-bar minimum. The altitude shall be taken as sea level

All water-cooled condensers shall be coupled to water re-circulating systems with chemical treatment.

Water cooled condenser vessel shall have Underwriters Laboratory UL certification.

4.7 Cooler or Evaporator

Cooler (Evaporator) shall be rated according to AHRI Standards 590-86 for evaporators, total water side fouling factor as defined in AHRI rating standard 590-92, shall be taken as 0.000044 m °C/W, and shall be manufactured according to ISO 9002 quality standard.

Evaporators shall be either, shell-and-tube `dry expansion (DX) type' or the shell and tube "Flooded type". Shell and tube evaporator shall have adequate waterside baffles with internal fins for copper tubing. and the tube arrangement shall be accessible for maintenance and repair purposes.

Shells shall be made out of carbon steel plate. The cooler shall be designed, tested, and stamped in accordance with ASME Code for refrigerant-side/ working-side pressure of 200

psig. All tube sheets shall be of carbon steel; tubes shall be mechanically expanded into tube sheets and mechanically fastened to tube supports. Cooler tubes shall be 25.4 mm diameter. Both types can be individually replaced

Tubes shall be seamless copper suitably expanded into the tube sheets. Refrigerant side of the evaporator shall be manufactured in accordance with the ASME code for unfired pressure vessels. Insulation shall be polyvinyl chloride or similar approved material.

Evaporators and their pipe work connections shall be fully insulated with rubber-closed cell or polyurethane type insulation and suitably painted in order to avoid condensation forming at any time during the operating periods

Victaulic joints suitable for steel pipe work to BS. 1387 on evaporator inlet and outlet connections.

4.8 Cooling Towers

Cooling tower shall be of induced draught type for capacities below 100 TR and Cross flow type for capacities above 100 TR.

Cooling Tower Selection shall be based on CTI certified towers when chillers rated at AHIR conditions. If the chillers are rated at local conditions, then the cooling towers could be selected at local conditions.

When selecting cooling towers for varying load applications, 2 or more cells should be selected. If the operation is 24 hr, then fan motor of the each shell must have variable speed drives (VSD) to reduce energy waste.

In the design of the cooling tower adequate provisions should be made to ensure that no recirculation of vapours take place and the drift & evaporation losses do not exceed 0.2 percent of the circulating rate. Tower casing shall be made out of modular fibreglass polyester or similar material and the tower construction should be adequately protected to prevent corrosion. Noise level of the tower

should be kept to a minimum. Whilst the installation shall be capable of cooling the condenser water to specified levels the tower shall have provisions for easy installation in any convenient location in the building including the roof slab.

4.9 Air Cooled Liquid Chillers

The units shall be capable of the cooling duties scheduled when operating at design ambient conditions.

The unit shall be packaged factory assembled units, piped, wired and charged with refrigerant and comprise screw/reciprocating compressors and hermetically sealed motors, shell and tube evaporators, aluminium finned cooper condenser coils with vertical discharge low speed propeller type fans and complete control packaged to include starters, loading/unloading and cycling controls for compressors, all of which should be subject to the Engineer's approval. The units shall have anti-vibration spring type isolators with 75mm static deflection under load conditions as a minimum. The aluminium fins shall be treated suitably to prevent deterioration under saline atmospheric conditions.

Selection of chiller and compressor unit shall be according to the following criteria.

(i) SCROLL type (up to 100 TR)
(ii) Screw type (100 TR and above)
(iii) Centrifugal type (300 TR and above)

Chiller should work on 'ozone friendly refrigerant', which are easily available in the market.

4.10 Chilled Water and Condensed Water Circulating Pumps

Electrically driven chilled water and condenser circulating pumps shall be capable of the full load duty of the systems as installed.

The pumps shall be of the centrifugal, closed coupled end suction, Back-pull-out end suction or vertical in-line type with cast iron casing, gunmetal impeller, stainless steel shaft, mechanical seal

and flexible coupling drive to a totally enclosed industrially silent splash proof three phase motor. Wiring shall be tropicalized insulation Class F. Closed discharge head of pumps shall not exceed working head by more than 25 percent and pump motors shall be sized to operate continuously throughout the performance range of pump without exceeding the nameplate rating of motor. Pumps performance shall be not less than 5 percent below point of maximum efficiency.

Pump motor efficiencies shall comply ASHARE 90.1 Standard, Table 10.8.1 Minimum Nominal Full Load efficiency for General Purpose Electric Motors (Type-1 & 2)

Each pump shall be fitted with isolating valves on the suction and delivery connections, and where pumps are in parallel operation, a non-return (check) valve shall be installed at the discharge outlet.

Pressure gauge cocks shall be fitted to the pump casing on the suction and delivery connections.

The pressure gauge tapping shall be piped-up with a three way cock to enable the differential pressure to be taken by one pressure gauge which shall be a 100mm diameter flanged type rigidly fixed to adjacent structure and with a red pointer set at normal delivery pressure.

Each pump shall be works tested and characteristic curves of pressure and flow provided, related to the pressure gauge tapping on the pump casing. These charts shall be available at the time of commissioning and testing and copies are to form part of the instructions manual.

Vibration Isolation of Pumps

All Flexible coupled pumps such as end suction back pull-out types shall have Concrete Inertia Base, Type-C as per ASHRAE 2007 HVAC applications.

All closed couple pumps shall have Structural Bases, Type-B as per ASHRAE 2007 HVAC applications.

4.11 Absorption Refrigeration

Absorption refrigeration plants shall be only lithium bromide and water absorption refrigeration cycle package units completely assembled and delivered to the site. These equipment shall not be specified unless requested specifically, in situations where alternative sources of energy are not freely available.

Plant shall be a single shell hermetic design which will be completely assembled, leak tested and evacuated in the factory before shipment. Absorber, concentrator and evaporator shall be made of cupro nickel and other parts such as header shall be of copper. The arrangements shall enable easy access of tubes for repairs and all parts shall be tested to at least 150% of the working pressures. The pumps in the plant shall be designed and arranged so as to facilitate removal of drive motor without breaking the machine vacuum.

The plant shall be provided with a suitable control system either pneumatic or electrical, to control the temperature of chilled water, to modulate heat energy input to the machine etc., and controls for safety of plant, should the temperature in the evaporator becomes dangerously low over heating the pump during the operation of plant.

4.12 Fan Coil Units

Selection of fan coil units cooling capacities shall base on low speed setting of the fan motor. When selecting the fan coil unit, room criteria should be strictly complied with.

The finned coil cooler shall be of solid drawn copper tube with welded headers and non-ferrous bar fins, shall be tested to 700 kPa, and shall provide the cooling outputs as scheduled when operating at medium speed and low speed for noise sensitive applications.

Finned coil cooler shall have Hydrophilic coating for fins stock.

A bitumen coated drip tray with drain outlet and connection to a uPVC drain pipe shall be provided under the element, with the discharge so arranged to be run to the nearest convenient drain or as shown on the drawings.

The fans shall be double inlet, centrifugal type fully balanced with a totally enclosed, factory lubricated, sealed sleeve bearing, three speed motors, all assembled as an easily withdrawable unit for inspection and cleaning. Anti-vibration mountings shall be incorporated in the unit to ensure that no vibration from the fan/motor combination is transmitted to the structure.

Each unit shall be provided with air cocks, union lock shield valves, on the returns and union wheel valves on the flow as specified.

Each unit shall be fitted with a washable filter of flame retardant material, with an efficiency of 55% when tested using No 2 test dust to comply with the test requirement specified in BS 2831. Filter shall be easily removable through the access panel.

All internal wiring shall be integral with the unit and connected to the adjacent single phase supply through a terminal block.

Each unit shall be provided with a four position switch giving high, normal, low and off positions. Thermostatic control shall be provided in the form of control packages consisting of three port control valves and associated wiring. Fan coil units in common areas are to be interconnected to a common thermostat as indicated on the drawings.

Units mounted in plant rooms or in false ceilings shall have a remote mounted combined four position switch and thermostat mounted in room as shown in the drawings.

4.13 Air Handling Units

Draw-through air handling units shall be either Horizontal or Vertical packaged factory assembled models as manufactured by an approved manufacturer. Units shall be of double skinned construction, insulated with thermal breaks and painted white externally and shall be sized according to the schedule of physical dimensions.

Fan Power & Efficiency

The units shall be capable of providing the required air flow against the total air resistance of the system as installed and be capable of the required cooling duties, with chilled water, as scheduled and shall be selected to achieve the required sound levels without additional duct attenuators.

The casings shall be double skinned and constructed of heavy gauge galvanised sheet steel reinforced with mild steel angle or channel members. Access panels and hand holes shall be provided underneath the units to give easy access to all parts of the unit.

The cooling coils shall be of non-ferrous construction and provided with a condensate drain pan, the discharge arranged to be run to the nearest convenient drain or as shown on the drawings. Maximum velocity of airflow through coil shall be 2.5m/s. All sections outside the internal airflow shall be

insulated and vapour sealed.

The fans shall be of the belt driven centrifugal, Plug Fans (Plenum fans) & EC motors. Fan Impellers shall be dynamically balanced at the factory. The motors shall be mounted inside the unit on adjustable mountings and be supplied complete with vee rope drive and adjustable pulleys. Fan motors shall be capable of operating margin of not less than 25% above the theoretical BHP & use of a VFD as per designers requirements. The duty of the fans shall be related to the resistance of the system as actually installed.

Filters shall be of the types as scheduled and specified hereafter.

A mixing box with multi-leaf dampers on both inlets shall be fitted to the air handling units where scheduled.

The fan units shall be fixed on flexible mountings suited to the characteristics of the unit, so that no perceptible vibration is transmitted to the surrounding structure. Flexible sleeves shall be provided on the inlet and outlet air conditioning connections to the Units to prevent vibration been transmitted to the ductwork. These sleeves shall be approximately 150 mm wide, of air proof non-organic flexible fabric or sheet and shall be held in place with heavy metal bands or flanges. Supports shall be arranged to prevent any static loading being carried by the flexible connection.

Anti-vibration mountings shall be installed to the air handling units (AHU) as per the following requirements:

AHU/Fan speed up to 800 rpm - spring type 50 mm deflection.

AHU/Fan speed up to 1400 rpm - spring type 25 mm deflection.

AHU/Fan speed above 1400 rpm - rubber type 8 mm deflection.

High efficiency filters shall be provided within each air handling unit.

The filters shall be of the extended surface type with glass/synthetic fibre media, protected on both sides with scrim positively located in steel holding frame with supporting wire mesh bag. All metal

parts shall be rust proofed and located in a steel installation frame providing for easy withdrawal and shall be completely sealed with mastic or foam strip.

Each unit shall consist of elements which in total give the required air flow at an initial resistance of not more than 50 N/m2 at a filtration efficiency of 99.2% for when tested using No 2 dust in compliance with tests detailed in BS 2831.

Air Handling Units for variable air volume (VAV) applications, fan motor should be able to operate on variable speed drive (VFD).

4.14 Split Type Air-conditioning Units

The air-cooled condensing units shall have self-contained compressors mounted in an anti corrosive rust resistant, galvanized steel plate and double backed acryl resin finished casing.
Each condensing unit shall be suitably mounted on an angle iron structure with an air guide louvre in the service area.

The fan coil units shall be of the direct expansion type with the cooling capacity scheduled when operating with its associated condensing unit. The unit shall comprise of a cooling coil of non-ferrous construction, double inlet centrifugal fan with totally enclosed motor and condensate drain pan. The casing shall be of heavy gauge steel, insulated and vapour sealed throughout. Fan coil units shall be either cassette type or wall mounted type as detailed and scheduled on the drawings.
Refrigerant connection between remote condenser and fan coil unit shall be made together with all necessary valves, controls, wall mounted thermostat/fan switches, control wiring, etc., to make a complete installation. All refrigerant pipes shall be insulated with 19mm thick closed cell, flexible foamed pipe sleeves. Condensate drains shall be insulated with 6 mm thick foam tape.

Unless otherwise specified the remote control thermostat/fan switch shall be mounted on the wall at the same height as the light switches.

Condensate drain pipes shall be in PVC, to conforming to SLS 147 type 1000 or BS 3505 Class E with solvent cement joints and shall be laid to falls discharge into nearest drain point complete with trap.

Refrigerant pipes on roof shall be properly supported and protected with solar resistant aluminium tapes.

Refrigerant pipes down walls shall be installed in uPVC flush mounted duct. The control unit for split units shall be wall mounted and shall have a rear entry cable entry suitable for wiring in a concealed conduit installation.

4.15 Package Rooftop Air-conditioning Unit

Self contained Draw through air handling units shall be packaged factory assembled rooftop models, complete with matching condensing units.

The air handling unit shall be capable of providing the required air flow against the total air resistance of the system as installed and be capable of the required cooling duties with refrigerant.

The casing shall be constructed of heavy gauge galvanised sheet steel reinforced with mild steel angle or channel members and with the cooling section adequately insulated. Access panels and hand holes shall be provided as required to give easy access to all parts of the unit. The unit shall be suitably weather proofed for rooftop installation.

The cooling coil shall be of non-ferrous construction and provided with condensate drain pan, with the discharge to be run to the nearest convenient drain. Maximum velocity of air flow through the coil shall be 2.5 m/s. All sections outside the internal air flow shall be insulated and vapour sealed.

The fan shall be of the belt driven centrifugal type with fully balanced impellers. The motor shall be mounted inside the unit on adjustable mountings and be supplied complete with vee rope drive and adjustable pulleys. Fan motors shall have an operating margin of not less than 25% above the theoretical BHP. The duty of the fan shall be related to the resistance of system as actually installed.

The primary filters shall be of the washable type and consist of de-membraned polyurethane, foam bounded around non-rusting internal reinforcement and contained in a frame made of 1.2 mm thick, rust-proofed mild steel finished in white stove enamel or of all plastic construction. The individual elements shall be easily withdrawable and mounted in a rigid rust free frame.

Each unit shall consist of elements which in total give the required air flow at an initial resistance of not more than $30N/m^2$ at a filtration efficiency of not less than 70% when tested using No.2 dust in

compliance with tests detailed in BS 2831.

Medium efficiency filters shall also be installed within the unit as shown on the drawing. The filters shall be of semi-cleanable/throw away type having a glass fibre filter medium with scrim facing and rustless perforated front and back.

4.16 Guards

Moving parts of all machines installed and supplied shall be protected by rust proofed permanent guards, including all parts fixed at high level to which there is no permanent means of access.

4.17 Holding Down Bolts

All plant equipment such as motors, pumps, fans, etc., shall be supplied complete with holding down bolts of approved type, put in correct alignment and position and grouted in.

CHAPTER 5

CONTROLS AND INSTRUMENTATION

5.1 General

A complete control system shall be supplied and installed in the building as approved to meet the control requirements and functions of the system as detailed on the drawings, schematics and as specified. It shall include instruments for monitoring, adjustment and calibration of various sections of the system described below. The Contractor shall submit detailed wiring diagrams for the electrical control system together with a detailed valve schedule giving reference numbers, duty and pressure drops all of which shall be approved by the Engineer prior to manufacture or delivery. Control system may be powered by pneumatic or by other suitable arrangement, provided the source of energy employed is the most economical.

5.2 Sensors

5.2.1 Temperature Sensors (Thermostats)

Thermostats provided shall suit the application and shall be of a commonly used types such as

(i) bi-metal

(ii) rod and tube

(iii) sealed bellows

(iv) remote bulb

(v) resistance (electrical)

Room thermostats shall be of a concealed adjustment type with concealed indicators. Unless otherwise specified thermostats shall be installed at a height of 1.6m from the ground. Colour of thermostat cover shall suit the room and its hardware.

5.2.2 Humidity Sensing Elements

Hygroscopic or electrical type of humidity sensors shall be used for the purpose.

5.2.3 Pressure Sensors (Pressure Gauges)

Pressure gauges shall be bellow, diaphragm or Bourdon tube type suitable for the work. System pressure gauges shall be mounted directly at the point of sensing and are to be located at a remote position. Pressure shall be transmitted via a stainless steel diaphragm seal attachment fitted on the

pipe lines.

A gauge cock shall be provided in the sensing lines between the piping system and the pressure gauge and pulsation dampers shall be provided for gauges used with reciprocating compressors.

5.2.4 Water Flow Meters

When water flow rates are to be measured suitable flow meters shall be provided. The type of flow meter to be used shall be selected on the range accuracy. Literature concerning the flow meters shall indicate the range of working flow rates and accuracy of the instrument in this range.

5.3 Controls

5.3.1 Control Valves

Electrically activated control valves shall regulate the pressure in the circuit it controls. Valves shall be at the closed position when power supply is removed. The valve body, moving components, seats etc., shall be of material suitable for the service requirements.

5.3.2 Chilled Water Control

The chilled water control circuit shall be either constant flow, or variable flow as designer's choice. Variable circuits shall be either primary variable, de-coupled system with primary constant & secondary variable or both circuits are variable as designer's choice. For variable flow circuits, chiller by-pass shall be fitted with 2-way modulating valve with differential pressure controller to maintain the pressure between the flow and return headers. For decoupled systems with a decoupler, no control valves are necessary in the de-coupler line. In addition to the controls integral with the packaged chillers, return sensors coupled with a suitable controller and duty selector switch shall be provided on return headers to -

(i) turn chillers off at times of low load, and

(ii) bring chiller on line progressively as the temperature of the return water increases.

5.3.3 AHU/FCU Start-Up and Controls : Recirculation Plant

Once the supply fan has started and an airflow has been proven via an airflow sensor in the supply duct, the automatic control system shall be energized.

A temperature sensor located in the common return of the recirculating plants from the controlled space shall work in conjunction with the chilled water cooling coils and the two-port modulating control valves to maintain the required temperature in the space, however temperature adjustment

shall be at the unit for the AHU's.

Each air handling unit shall be complete with locally mounted on/off switch and a controller. Each fan coil unit shall be complete with locally mounted combined thermostat/ three speed controller and on/off switch.

5.3.4 Indicating Panels

Large installations where controls are automatic, separate indicating panels shall be provided giving a schematic representation of the system with its major components. Various circuits shall be colour coded. Indicator panels shall be designed and manufactured in accordance with the principles laid down by the 'Institution of Electrical Engineers' Regulations for Equipment within Buildings with all controls and control setting indicators mounted thereon. Panels shall be located at an accessible area near the central equipment. Panels shall be factory constructed generally as per specification given under Control Panels in Part II of these specifications, Electrical Installations. With Best quality mild steel not less than 2 mm in thickness shall be used for floor standing panels and wall mounting panels larger than 1 meter square shall be , factory wired, connected and delivered to site as one unit. For smaller panels lighter gauge material may be used with the approval of the Engineer.

5.4 Auxiliary Controls

Auxiliary controls shall depend on the type of control system.

5.4.1 Electrical Controls

In the case of electrical control system, the control panel shall incorporate all safeguards against failures due to mechanical and electrical faults generally as described in Part II, of these specifications and as specified below. The system shall as also comply with the associated tender drawings and equipment schedule.

The panel board shall be constructed weather proof using steel and/or timber. The panel shall be installed with adequate space all round for easy access during repairs and maintenance.

The following provisions shall apply to all electrical cupboard type control panels containing motor starter equipment, etc.

The selection of all electrical equipment shall be based on the recommendation laid down by the British Standards Institute, unless otherwise agreed by the Engineer. The control panels shall be

designed and manufactured in accordance with principles laid down by the 'Institute of Electrical Engineers' Regulations for Equipment within buildings.

The Automatic Controls Specialist shall take full responsibility for the integration of the automatic control system equipment to ensure correct operation and interlocking between devices and equipment.

The Automatic Controls Specialist shall provide a Senior Specialist Engineer to witness and supervise where necessary the complete commissions of all motor starter and temperature control equipment supplied with the system. This work shall be carried out on site during the progress of the Contract and the cost shall be included for within the tender figure. The purpose of the control panels is to centralise the control of various motor starter equipment for fans, pumps etc., automatic temperature control equipment and to centralise the distribution to various environmental package units.

Each of the water chillers shall have its own separate starter panel. These shall be in accordance with the Cupboard type specification. Each of the panels shall have an individual feed from the appropriate switchboard.

These panels shall form an integral part of the packaged refrigeration machine supplied by the refrigeration machine manufacturer.

5.4.2 Pneumatic Controls

This system when incorporated shall include all compressed air supply system including the compressor, connecting air line and electrical gear required for the system. Other than electrical switch gear required for the system as outlined elsewhere the controls shall include-

(i) electro pneumatic relays
(ii) pneumatic - electric relays
(iii) pneumatic relays
(iv) positioning relays
(v) switching relays
(vi) gradual switches etc.

5.5 Pressurised Expansion Tank

Open type expansion tank or Packaged pressurised, diaphragm type expansion tanks and pump unit for the chilled water circuits, manufactured by an approved manufacturer shall be supplied and installed as indicated on the drawings. Use of open type expansion tanks is not recommended due its corrosion effects, however when system operating pressure exceeds the diaphragm tank pressure limits for high rise applications, open type tanks shall be used.

For large central systems, a dirt & air separator shall be installed as per the designer's wish.

The size of the unit shall be checked before ordering against the system as installed. The installing, filling and commissioning procedure shall be in accordance with the manufacturer's recommendations.

5.6 Water Treatment

Prior to design of plant a typical water sample shall be tested in a reputed laboratory such as in the Industrial Technology Institute (the successor to Ceylon Institute for Scientific and Industrial Research) or in the National Building Research Organisation for impurities and contaminants that may foul water lines, condensers etc., If water is found to contain undesirable impurities and contaminants the plant shall incorporate a suitable water treatment unit or the plant shall be designed to withstand adverse effects of contaminants. If in an unavoidable situation untreated water is to be used the system shall be designed to overcome such effects and the Contractor shall outline in full , the procedure and frequency of cleaning and repairing of water lines.

CHAPTER 6

THERMAL INSULATION

6.1 General

The entire system including components that carry heated or chilled fluid shall be insulated from the atmosphere. Vapour barriers in addition to insulations shall be used in areas that are liable to cause condensation. In selecting a suitable insulating material other than the ones specified, following characteristics shall be checked and agreed with the Engineer:

(i) fire properties

(ii) property to withstand rotting fungal growth and vermin attacks

(iii) possible health hazards.

All insulation material and adhesives used shall comply with the requirements stipulated by the relevant authorities.

All adhesives, vapour barriers and coatings shall have the following indices (tests as defined in BS 874 and BS 2972):

Ignitability	-	Zero
Heat Evolved	-	Zero
Smoke developed	-	Not greater than three

6.2 Thermal Insulation for Air-Conditioning Ductwork

6.2.1 General

Thermal insulation shall be provided on all surfaces operating at a surface temperature below the surrounding air and when the surface temperature is below the dew point of the surrounding air an impervious vapour barrier shall encase the outer surface of the insulation.

The insulation material for cooled surfaces shall be 50mm thick CLOSED CELL MATERIAL such as Nitrile Rubber, EPDM or pre-formed sections with a thermal conductivity `K' value not greater than 0.04 W/m^0C.

Adhesives and sealers of approved manufacture shall be supplied. Slabs on ductwork 900 mm x

900 mm and over shall, in addition to an adhesive, be further held in position by means of stick-clips and washers.

Any combustible facing shall be not more than 0.8 mm thick and comply with the relevant regulations for flame spread.

As an alternative, foamed plastic slabs or preformed pipe sections may be used, only in situations acceptable to the relevant fire authority or provided in local regulations. Such materials shall have a `K' value not greater than 0.04 W/m^0C and be non-flammable or self extinguishing.

Insulation provided to ductwork shall be finished so as to satisfy the following criteria :

(i) Air Conditioned spaces

Surfaces of ductwork fixed in air conditioned areas shall be such that the differential temperature of the finished surface to the due point of the surrounding air is greater than 2^0C.

(ii) Non -Air Conditioned Spaces

Surfaces of ductwork fixed in areas where the differential temperature, air to surrounding air due point is less than 2^0C.

Vapour barriers shall be continued over the thermal insulation including branch connections, flanges, hangers and similar equipment and where of necessity the insulation is terminated the end shall be fully sealed.

Access doors in ductwork shall be fitted with purpose made, rigid fibre, removable covers with quick release bands or fasteners.

All insulation applied to any ductwork or plant shall be neatly cut around all dampers, test holes, thermometers, etc., to provide accessibility.

Alternative proposals for insulation, adhesives and finishes will be considered, but the standard produced shall not be less than that given in the detailed specification.

Details of the alternative proposal must be submitted to the Engineer and approved by him before

commencing work on site.

All insulation, finishes and adhesives employed must be acceptable to the local fire authority.
The Contractor shall submit samples of all types of insulation to the Engineer for approval.

6.2.2 Air Conditioned Spaces

Ductwork shall be insulated with CLOSED CELL MATERIAL such as Nitrile Rubber, EPDM or pre-formed sections faced with aluminium foil/paper laminate, securely fixed with an approved adhesive directly to the metal ductwork. Joints between slabs shall be covered with 75 mm wide plastic coated adhesive tape fixed to a tack coat of adhesive on the aluminium surface.

6.2.3 Non Air Conditioned Spaces

Ductwork shall be insulated with CLOSED CELL MATERIAL such as Nitrile Rubber, EPDM or preformed sections faced with aluminium foil/paper laminate, securely fixed with an approved adhesive directly to the metal ductwork. All joints between slabs shall be covered with 75 mm wide plastic coated adhesive tape fixed to a tack coat of adhesive on the aluminium surface. All raw edges shall be filled with reinforced expanding foam. The insulation shall be covered with a coat of sealer and whilst tacky, with a covering of heavy quality canvas, the whole then covered with a finishing coat of sealer finishing material.

6.2.4 Plant Rooms

Ductwork shall be insulated with CLOSED CELL MATERIAL such as Nitrile Rubber, EPDM or preformed sections faced with aluminium foil/paper laminate, securely fixed with an approved adhesive directly to the metal ductwork. On rectangular ductwork 50 mm x 50 mm angle aluminium shall be fitted as additional protection on all corners. The insulation shall be covered with a coat of sealer and whilst tacky, with a covering of heavy quality canvas, the whole then covered with a finishing coat of sealer, finishing material.

The insulation shall then be finished and protected with 0.55 mm ‘hammered’ aluminium sheeting, all joints being overlapped and secured with pop rivets. Bends shall be neatly formed with segments and tees gartered and bands shall be fitted at all termination points.

6.2.5 External Ductwork

Ductwork shall be insulated as for non- air conditioned spaces but shall be covered with final

protective coating of 0.55 mm 'hammered' aluminium sheeting, all joints overlapped and secured with pop rivets. Bends shall be neatly formed with segments and tees gartered and bands shall be fitted at all termination points.

6.2.6 Fittings

Fittings requiring insulation shall be covered with an insulation of thickness of equal to that of the adjacent duct and cut to shape. It shall then be fixed to the metal and to adjacent insulation with the appropriate adhesive and with any open joints filled in with a mixture of mastic and granulated insulation; thereafter the whole smoothed down by building up sharp corners with mastic, covered with reinforced expanding foam, a further coating of sealer and painted in accordance with the requirements for the adjacent ductwork.

6.2.7 Supports

Hangers and brackets supporting insulated services in non-air-conditioned spaces shall be fixed external to the thermal insulation and vapour barrier with a 1.6 mm thick galvanised sheet half sleeve with a length of not less than one twentieth of the circumference of the duct. Rigid insulating material is to be inserted between the sleeve and the duct of thickness equal to that of the normal insulation.

6.3 Thermal Insulation for Air Conditioning Pipework

6.3.1 General

Thermal insulation shall be provided on all surfaces operating at a surface temperature below the surrounding air and when the surface temperature is below the dew point of the surrounding air an impervious vapour barrier shall encase the outer surface of the insulation.

The insulating material for cooled surfaces shall be CLOSED CELL MATERIAL such as Nitrile Rubber, EPDM or preformed sections with a thermal conductivity (K) value not greater than 0.04 W/m^0C.

Any combustible facing shall not be more than 0.8mm thick and comply with the relevant regulations for flame spread.

If put forward as an alternative, foamed plastic slabs or preformed pipe sections may only be used

where acceptable by the Fire Authority or Local Regulations and shall have a `K' value not greater than 0.04W/m^{0}C and be non-flammable or self extinguishing.

The following are terms for the standards of finishes for different areas:

(i) Air conditioned space : surface or pipework fixed in areas where the differential temperature, water to surrounding air dew point is greater than 2^{0}C.

(ii) Non-Air Conditioned space : surfaces or pipework fixed in areas where the differential temperature, water to surrounding air dew point is less than 2^{0}C.

Vapour barriers shall be continuous over the thermal insulation including connections, flanges, valves, pumps, hangers and like equipment and where of necessity the insulation is terminated the end shall be fully sealed. Vents shall not be insulated within the building.

All insulated pipework shall be coloured in accordance with the colour code specified in BS 1710.

All insulation applied to any pipework or plant shall be neatly cut around gauge, thermostats, etc., to provide accessibility.

Alternative proposals for insulation and finishes will be considered, but the standard produced shall not be less than that given in the detailed specification.

Details of the alternatives must be submitted to the Engineer and approved by him before commencing work on site.

All insulation, finishes and adhesive employed shall have fire property must be class-O & acceptable to the local fire authority. The Constructor shall submit samples of all types of insulation to the Engineer for approval.

6.3.2 Chilled Water Pipework

The thickness of insulation shall be as follows:

15 mm to 50 mm pipework, 32 mm thick

65 mm pipework and over, 50 mm thick

Valves and flanges shall be insulated

All external pipework shall be insulated to 50 mm thick.

6.3.3 Air Conditioned Spaces

The insulation shall be CLOSED CELL MATERIAL such as Nitrile Rubber, EPDM or pre-formed sections faced with aluminium foil/paper laminate, securely fixed with an approved adhesive directly to the pipe surface. Joints shall be made with 75 mm wide plastic adhesive tape with a tack coat of adhesive on the aluminium surface.

6.3.4 Runouts

Runouts to individual room units, if not greater than 20 mm diameter, may be insulated with 19 mm thick, closed cell, flexible foamed pipe sleeves with a thermal conductivity (K) value not greater than 0.04 W/m^0C. Condensate drains shall be insulated with 6 mm thick closed cell, flexible foam tape.

6.3.5 Non-Air Conditioned Spaces

The insulation shall be CLOSED CELL MATERIAL such as Nitrile Rubber, EPDM faced with aluminium foil/paper laminate, securely fixed with an approved adhesive directly to the pipe surface. All joints between sections shall be covered with 75 mm wide plastic contact adhesive tape fixed to a tack coat of adhesive on the aluminium surface. All raw edges shall be filled with reinforced expanded foam. The insulation shall be covered with a coat of sealer, and whilst tacky with a covering of heavy quality canvas; the whole being then covered with a finishing coat of sealer, and finishing material.

6.3.6 Plant Rooms

The insulation shall be CLOSED CELL MATERIAL such as Nitrile Rubber, EPDM faced with aluminium foil/paper laminate, securely fixed with an approved adhesive directly to the pipe surface. All joints between sections shall be covered with 75 mm wide plastic contact adhesive tape fixed to a tack coat of adhesive on the aluminium surface. All raw edges shall be filled with reinforced expanded foam. The insulation shall be covered with a coat of sealer and whilst tacky a covering of heavy quality canvas; the whole then covered with a finishing coat of sealer and finishing material.

The insulation shall then be finished and protected with 0.55 mm `hammered' aluminium sheeting, all joints overlapped and secured with pop rivets. Bends shall be neatly formed with segments, tees gartered and bands shall be fitted at all termination points.

6.3.7 External to Building above Ground

The insulation shall be CLOSED CELL MATERIAL such as Nitrile Rubber, EPDM faced with aluminium foil/paper laminate, securely fixed with an approved adhesive directly to the pipe surface. All joints between sections shall be covered with 75 mm wide plastic contact adhesive tape fixed to a tack coat of adhesive on the aluminium surface. All raw edges shall be filled with reinforced expanded foam. The insulation shall be covered with a coat of sealer and whilst tacky with a covering of heavy quality canvas; the whole being then covered with a finishing coat of sealer, and finishing material.

The insulation shall then be finished and protected with 0.55 mm `hammered' aluminium sheeting, all joints overlapped and secured with pop rivets. Bends shall be neatly formed with segments, tees gartered and bands shall be fitted at all termination points.

6.3.8 External to the Building below Ground

Pipework and fittings below ground shall be of the pre-insulated 'pipe within a pipe' system. The inner pipe shall be steel with an outer casing of polyethylene securely bonded to the inner pipe with rigid polyurethane foam. Joints shall be carried out using specially developed plastic coated steel fittings and purpose made bends and tees. Expansion of the underground mains shall be checked by the specialist manufacturers and purpose made foam pads shall be installed in accordance with their recommendations.

6.3.9 Flanges, Valves and Fittings

Flanges, valves and fittings requiring insulation shall be covered with an insulation of thickness equal to that of adjacent pipe and cut to shape. It shall then be fixed to the metal and to adjacent insulation with the appropriate adhesive and with any open joints filled in with a mixture of mastic and granulated insulation; thereafter the whole smoothed down by hereafter building up sharp corners with mastic, covered with tape, and a further coating of sealer to be vapour sealed. The insulation shall be finished to match the adjacent pipework, except that all valves in plant rooms shall be finished with 0.91 mm thick `hammered' aluminium boxes which shall be designed for easy removal and access for maintenance without disturbing the insulation on the adjacent pipework.

6.3.10 Supports

Hangers and brackets supporting insulated services in non-air conditioned spaces shall be fixed external to the thermal insulation and vapour barrier with a 1.6 mm thick galvanised sheet half sleeve

of not less than twice the bore of the pipe. Rigid insulating material or timber rings shall be inserted between the sleeve and the pipe. On services in air conditioned spaces the bracket or support shall be fixed to the pipe and the thermal insulation and vapour barrier carried over and any gap filled in with mastic.

6.4. Hot Water Piping

Hot water piping shall be insulated using fibre glass blankets of not less than 25 mm thickness. Valves, pumps and strainers shall be neatly boxed in, using sectional styrene insulation with internal cavities filled, and external surface finished as specified for the piping. Boxes shall be trimmed around the top of the valves leaving the gland exposed for inspection and re-packing. Detachable boxes shall be provided for pumps.

6.5 Hot Water Pressure Tanks

Insulation of hot water pressure tanks shall be of fibreglass blankets of not less than 100 mm thick with aluminium paper covering.

CHAPTER 7

TESTING & COMMISSIONING OF PLANT AND SUBMISSION OF DOCUMENTS

7.1 Testing and Commissioning

Testing & commissioning process shall comply with ASHRAE Guideline 1-1996 The HVAC commissioning Process, CIBSE Commissioning Code M:2003, CIBSE Commissioning Code A : 1996 Air Distribution Systems.

The contractor shall upon completion commissioning and testing the system submit two copies of a comprehensive report on commissioning and testing to the Engineer for approval.

Prior to commencement of commissioning a detailed procedure schedule is to be provided by the Contractor for the approval of the Engineer.

Initial start-up and commissioning of the chiller unit shall be done by or in the presence of the approved supplier. Final commissioning report shall be approved and signed by the supplier.

Finally the Contractor shall demonstrate to the Engineer that the operation and the installation is in accordance with the specification.

All testing and commissioning records shall be bound into the operation and maintenance manuals when the system has been successfully completed and witnessed by the Engineer.

7.2 Record Drawings

The Contractor is expected to keep one set of white prints of his approved drawings on site throughout the contract. This set of prints shall be used solely to record the progress of works and the exact nature of any deviation in the installation from that detailed on the approved working drawings. The prints shall be kept up to date on a day to day basis and shall be available for inspection by the Engineer at any time during working hours.

At the completion of each section of the work a record drawing should be prepared by the Contractor for submission to the Engineer.

The record drawings shall show the position of every item of plant, all pipework runs, valves, drain cocks and all items requiring access for maintenance or cleaning and any other item of equipment forming part of the Mechanical Services Installation. Where relevant all sizes, capacities or ratings of equipment shall be given. All items buried or otherwise concealed shall be precisely located on the `as installed' drawings by means of dimensions taken on site from some readily identifiable point (ie. main walls of building or finished floor levels). Where necessary, the Contractor shall also produce sections, elevations and part plans.

When all record drawings have been submitted to the Engineer and have subsequently been approved, the Contractor shall supply copies of these drawings in the following forms:

(i) Three sets of prints on white paper.
(ii) One set of plastic copy negatives.
(iii) Three sets of `reduced' prints on A4 size card.
(Suitable for inclusion in operating and maintenance manual binder.)

7.3 Operating and Maintenance Manual

The Contractor shall submit for approval an Operating and Maintenance Manual.

Operating and Maintenance Manual shall comply with ASHRAE Guideline 4-1993, Preparation of Operating and Maintenance Documentation for Building Systems.

This should include following items.

(i) Brief description of the system and the list of all parties involved in the project; architects, consultants, contractors etc.

(ii) Equipment schedule with make and model

(iii) Manufacturer's catalogues for all items of equipment forming the mechanical services installation

(iv) Manufacturer's operating and maintenance instructions for any item of plant chillers, pumps, air handling units, tanks etc.

(v) Manufacturer's drawings and spare parts schedule for the major items of equipment.

(vi) List of local suppliers and manufacturers of all items of equipment forming the mechanical services installation with their addresses, telephone/telex/fax numbers, contact personnel etc.

(vii) Reduced prints of services installation on A4 size card.

(viii) A Copy of the commissioning report.

The Contractor having obtained the Engineer's approval for the Operating and Maintenance Manual shall supply three copies in PVC covered binders, PRIOR TO COMPLETION CERTIFICATES BEING ISSUED.

7.4 Maintenance Tools

Each plant room shall be provided with a set of spanners, gland keys and other special tools required for testing or dismantling such items of equipment as compressors, pumps, valves, fans, coolers, etc., together with suitable holding rack arranged for wall fixing for one set and a padlocked box for the other two sets.

Two keys shall be provided for each size of lock-shield regulating valve air cock, automatic air valve or other valve requiring special tools to operate, together with duplicate keys for any clockwork mechanism or locks or instruments, safety valves, etc., supplied under the Contract.

Two grease guns of the lever type with oiling heads to suit grease nipples on equipment should also be supplied.

7.5 Spare Parts

The Contractor shall supply sufficient spare parts for each item of the equipment to provide maintenance for two years all in accordance with the recommendations of the individual manufacturers of equipment and as agreed in the contract.