

Mechanical Services Design Standards



MACQUARIE
University

DOCUMENT HISTORY

Version	Description	Date Issued
V0.1	For Review	Jan 2014
V0.2	For Review	Mar 2014
V1.0	Comments incorporated	Apr 2014
V1.1	Minor Revisions	Nov 2014
V1.2	For Circulation	Dec 2015
V1.3	Minor Revisions	May 2016
V1.4	Revisions and Clarifications & Final Review	Jan 2018

CIRCULATION APPROVAL

Name	Position	Approved
Dennis Spicer	Engineering Project Manager	01/06/2017
Conor Kelly	Engineering Project Manager	24/08/2017
Damien McLynskey	Technical Services Manager	02/01/2018

Mechanical Services Design Standards

TABLE OF CONTENTS

1.	PURPOSE	1
2.	SCOPE	1
3.	Glossary of Terms	1
4.	Authorities and Responsibilities	4
5.	Technical Requirements	5
5.1.	INTRODUCTION	5
5.2.	STANDARDS	5
5.3.	DESIGN AND DOCUMENTATION	5
5.3.1.	DESIGN APPROACH	5
5.3.2.	DESIGN INPUTS AND PROCESS	6
5.3.3.	ENGINEERING FUNCTIONS REQUIRED FROM DESIGN CONSULTANTS	6
5.3.4.	CALCULATIONS	6
5.3.5.	DESIGN CONDITIONS	6
5.3.6.	EQUIPMENT SELECTION AND SIZING	7
5.3.7.	MINIMUM ENERGY EFFICIENCY AND HEAT RECOVERY REQUIREMENTS	7
5.3.8.	SYSTEM TYPES	8
5.3.9.	FUTURE ALLOWANCE	9
5.3.10.	OTHER DESIGN REQUIREMENTS	9
5.4.	TECHNICAL COMPONENTS	10
5.5.	AIR COOLED CHILLERS	10
5.5.1.	APPLICATIONS	10
5.5.2.	PREFERRED SUPPLIERS	10
5.5.3.	GENERAL REQUIREMENTS	11
5.5.4.	REFRIGERANTS	11
5.5.5.	COMPRESSORS	11
5.5.6.	LIQUID COOLERS	12
5.5.7.	CONDENSER COILS	12
5.5.8.	CONDENSER FANS	12
5.5.9.	CORROSION PROTECTION	12
5.5.10.	CONTROLS	12
5.6.	WATER COOLED CHILLERS	13
5.6.1.	PREFERRED SUPPLIERS	13
5.6.2.	GENERAL REQUIREMENTS	14
5.6.3.	COMPRESSORS	14
5.6.4.	LIQUID COOLERS	15
5.6.5.	CONDENSERS	15
5.6.6.	WATER BOXES	15
5.6.7.	CORROSION PROTECTION	15
5.6.8.	CONTROLS	15
5.7.	HEATING HOT WATER GENERATORS	16
5.7.1.	TYPE	16
5.7.2.	PREFERRED SUPPLIERS	16
5.7.3.	GENERAL REQUIREMENTS	17
5.7.4.	HHW GENERATOR FLUES	17

Mechanical Services Design Standards

5.8. COOLING TOWERS	19
5.8.1. PREFERRED SUPPLIERS	19
5.8.2. GENERAL	19
5.8.3. CONSTRUCTION	19
5.8.4. FAN	20
5.8.5. WATER DISTRIBUTION	20
5.8.6. DEAD LEGS AND BALANCE LINES	20
5.8.7. CAPACITY	20
5.8.8. ACCESS	20
5.9. PUMPS	21
5.9.1. PREFERRED SUPPLIERS	21
5.9.2. GENERAL	21
5.10.VARIABLE SPEED DRIVES (VSD'S)	22
5.10.1. PREFERRED SUPPLIERS	22
5.10.2. GENERAL	22
5.10.3. VSD MOTOR PROTECTION FEATURES	23
5.10.4. CONTROL PAD	23
5.10.5. PERFORMANCE	23
5.10.6. LOCATION	23
5.10.7. PROTECTION	23
5.10.8. COOLING	23
5.10.9. SOFTWARE, PROGRAMMING, PASSWORD AND O&M	23
5.10.10. HIGH LEVEL INTERFACE AND CONTROL	24
5.11.FANS	24
5.11.1. GENERAL	24
5.11.2. INSTALLATION	24
5.11.3. BELT DRIVEN FANS	25
5.11.4. KITCHEN EXHAUST FANS	25
5.11.5. ROOF MOUNTED FANS	25
5.12.AIR HANDLING UNITS AND FAN COIL UNITS	26
5.12.1. PREFERRED SUPPLIERS	26
5.12.2. INTERPRETATION	27
5.12.3. GENERAL	27
5.12.4. CONSTRUCTION	27
5.12.5. Fan Coil Units	28
5.12.6. RETURN AIR	29
5.12.7. Fresh AIR	29
5.12.8. COILS	29
5.12.9. DRIP TRAYS	29
5.12.10. ACCESS DOORS AND PANELS	29
5.12.11. SERVICE LIGHTS	30
5.12.12. FILTERS	30
5.12.13. MIXING PLENUMS	30
5.12.14. FACE BYPASS DAMPERS	30
5.12.15. LOCATION	30
5.13.HEAT RECOVERY	31
5.13.1. PREFERRED SUPPLIERS	31
5.13.2. GENERAL	31
5.14.CHILLED WATER/ HEATING HOT WATER/CONDENSER WATER PIPEWORK	31

Mechanical Services Design Standards

5.14.1.	DESIGN	31
5.14.2.	PIPE SIZING	32
5.14.3.	PIPE MATERIAL	32
5.14.4.	PIPE JOINTS	32
5.14.5.	PIPE SUPPORTS	32
5.14.6.	CLADDING AND INSULATION	33
5.14.7.	PRESSURE TESTING	35
5.14.8.	FLUSHING OF PIPEWORK	35
5.14.9.	USE OF AIR AND DIRT SEPARATORS	36
5.14.10.	Dead Legs and Flushing loops	36
5.15. VALVES		36
5.15.1.	GENERAL	36
5.15.2.	WATER VALVE TYPES	38
5.15.3.	SENSING POINTS	40
5.15.4.	VALVES IN THE CEILING SPACE	40
5.15.5.	VALVE UNIONS	40
5.15.6.	CONNECTIONS TO EQUIPMENT	40
5.15.7.	BINDER COCKS	40
5.15.8.	VENTS, AIR AND DIRT SEPARATORS	40
5.16. CONDENSATE DRAINS/SAFETY TRAYS		41
5.16.1.	GENERAL	41
5.16.2.	CONDENSATE PUMPS	41
5.16.3.	SIZING AND MATERIAL	41
5.16.4.	CONDENSATE WASTE DRAIN INSULATION	41
5.16.5.	CONDENSATE TRAP	41
5.16.6.	CONDENSATE DISCHARGE	41
5.16.7.	SAFETY TRAYS	41
5.17. SPLIT SYSTEMS		42
5.17.1.	PREFERRED SUPPLIERS	42
5.17.2.	GENERAL	42
5.18. VRV/VRF		43
5.18.1.	PREFERRED SUPPLIERS	43
5.18.2.	GENERAL	43
5.19. REFRIGERANTS & REFRIGERATION PIPEWORK		44
5.19.1.	REFRIGERANT TYPE	44
5.19.2.	REFRIGERANT RECOVERY	44
5.19.3.	REFRIGERANT PIPE WORK	44
5.19.4.	PIPES	44
5.19.5.	EXTERNAL TRUNKING	45
5.19.6.	PIPE JOINTS	45
5.19.7.	PIPE SUPPORTS	45
5.19.8.	THERMAL INSULATION	46
5.19.9.	Testing and Evacuation	46
5.20. DUCTWORK		47
5.20.1.	GENERAL	47
5.20.2.	Duct Leakage Testing:	47
5.20.3.	FLEXIBLE DUCT	47
5.20.4.	FLEXIBLE CONNECTIONS	48
5.20.5.	VARIABLE AIR VOLUME unit (VAV)	48

Mechanical Services Design Standards

5.20.6.	VOLUME CONTROL DAMPERS	49
5.20.7.	SPLITTER DAMPERS	50
5.20.8.	MOTORISED DAMPERS	51
5.20.9.	NON-RETURN DAMPERS	51
5.20.10.	FIRE DAMPERS	51
5.20.11.	ACCESS OPENINGS – LOCATION	51
5.20.12.	ACCESS PANELS	52
5.20.13.	ACCESS DOORS	52
5.20.14.	INSULATION	53
5.20.15.	DUCTWORK INSTALLATION	53
5.20.16.	LEAKAGE TESTING procedures	54
5.21.AIR GRILLES AND DIFFUSERS		55
5.21.1.	GENERAL	55
5.21.2.	EXHAUST GRILLES	55
5.21.3.	PLENUM BOXES	55
5.21.4.	DOOR GRILLES	55
5.21.5.	UNDERCUTTING OF DOORS	56
5.22.VIBRATION/ NOISE		56
5.22.1.	MACHINERY	56
5.22.2.	PIPING	56
5.22.3.	DUCTWORK	56
5.22.4.	FLEXIBLE CONNECTIONS FOR PIPEWORK	56
5.22.5.	FLEXIBLE CONNECTIONS FOR DUCTWORK	56
5.22.6.	PUMP INERTIA BASES	56
5.23.MECHANICAL SWITCHBOARDS AND CONTROL PANELS		57
5.23.1.	General	57
5.23.2.	Form of Separation	57
5.23.3.	Metalwork	57
5.23.4.	kWH Meters	57
5.23.5.	Finish	58
5.23.6.	Labels	58
5.23.7.	Fuses	58
5.23.8.	Approved Component Suppliers	58
5.24.MECHANICAL SERVICES WIRING		59
5.24.1.	Wiring General	59
5.25.PAINTING		60
5.26.LABELLING		62
5.26.1.	GENERAL	62
5.27.SERVICE ACCESS/ SAFETY REQUIREMENTS		64
5.27.1.	GENERAL	64
5.28.REDUNDANT EQUIPMENT		64
5.29.PRODUCT SUPPORT/ EXPERIENCE REQUIREMENTS		64
5.30.COMMISSIONING		66
6. QUALITY CONTROL		67
6.1. DESIGN STANDARD COMPLIANCE		67
6.2. DESIGN STANDARD CERTIFICATION		67

Mechanical Services Design Standards

7.	REFERENCES	68
7.1.	STANDARD DRAWINGS	68

Mechanical Services Design Standards

1. PURPOSE

This Mechanical services standard sets out Macquarie University's minimum requirements for the design, construction and maintenance of Mechanical systems. The objective of this standard is to provide guidance and minimum standards of compliance to ensure that systems are designed, constructed, commissioned, and maintained to achieve energy efficiency, fitness for purpose, quality and durability, design performance in operation, maintainability and safety for access and operation, low environmental impact, and low life cycle cost.

Applicable requirements documented in Work Health and Safety legislation, Disability Discrimination legislation, State Environmental Planning legislation, Commonwealth and State legislation, National Construction Codes (NCC), Macquarie University Design Guides and Australian Standards (AS) are the minimum and mandatory compliance requirements. British Standards shall be used where no Australian Standard exists.

Reference is also made to CIBSE commissioning codes, ASHRAE and their associated standards and references.

Where any ambiguity exists between this standard and the above mandatory requirements then:

- a. The highest performance requirements must apply
- b. Applicable requirements must follow this order of precedence
 - i. Work Health and Safety legislation
 - ii. Disability Discrimination legislation
 - iii. State Environmental Planning and Assessment legislation
 - iv. All other Commonwealth and State legislation
 - v. This Standard and Macquarie University Design Guides
 - vi. NCC and BCA
 - vii. AS/NZS

Mechanical Services Design Standards

2. SCOPE

These Standards describe the minimum, requirements for the design, construction and maintenance of all mechanical services throughout all buildings owned, operated and managed by Macquarie University Property.

The Standard applies to planners, project managers, consultants, contractors, sub-contractors, tenants, managing agents and University staff involved in the design, construction, commissioning and maintenance of existing, new and proposed University buildings and facilities.

The Mechanical Services Standard provides:

- A reference document to enable consistency with the design and engineering objectives;
- Guidance on design considerations;
- Details of the minimum performance requirements;
- Details of the minimum quality requirements;
- Guidance on provisions for maintenance and access;
- Commissioning requirements for acceptance by the University.

The maintenance Standard Guide provides detail on the service requirements for maintenance within the University.

Mechanical Services Design Standards

3. GLOSSARY OF TERMS

Mechanical Services Design Standards

Consultant	The mechanical design consultant/engineer
Designer	The engineer carrying out the design process including a D & C contractor
AHU	Air Handling Unit
AS	Australian Standard
BCA	Building Code of Australia
BMCS	Building Management Control System
CCW	Condenser Cooling Water
CHW	Chilled Water
Consultant	The mechanical design consultant/engineer
D&C	Design and Construct
FCU	Fan Coil Unit
FIP	Fire Indicator Panel
HCFC	Hydro-chlorofluorocarbons
HDG	Hot Dip Galvanised
HHW	Heating Hot Water
HLI	High Level Interface
HVAC	Heating Ventilation Air Conditioning
LCD/LED	Liquid Crystal Display/Light Emitting Diode
MSDS	Material safety data sheets
MUP	Macquarie University Property
NATA	National Association of Testing Authorities
NCC	National Construction Code
ODP	Ozone Depletion Potential
O&M	Operations and Maintenance
PC	Practical Completion
RAC	Room Air Conditioner (window mounted)
RPZD	Reduced Pressure Zone Device

Mechanical Services Design Standards

SMACNA	Sheet Metal and Air Conditioning Contractor's National Association
VAV	Variable Air Volume
VOC	Volatile organic compound
VRV	Variable Refrigerant Volume
VRF	Variable Refrigerant Flow
VSD	Variable Speed Drive
VCD	Volume Control Damper
WHS	Work Health and Safety

Mechanical Services Design Standards

4. AUTHORITIES AND RESPONSIBILITIES

This standard is owned by MUP. MUP is responsible for maintaining the standard and keeping it up to date. Always check to see if there has been an update to this standard before committing to its use. It is the responsibility of the user to ensure they are using the latest version.

5. TECHNICAL REQUIREMENTS

5.1. INTRODUCTION

The aim of this manual is to assist consultants, Project managers, D & C Contractors and Builders to understand the requirements of the University. Generally, the relevant Australian standards are to be complied with unless the University requires that a higher standard be met. Variations from this standard are to be approved by MUP. For the avoidance of doubt the Mechanical system of a University building may include structural/building elements, or any other trade works other than the mechanical trade which are contingent on the functioning of the mechanical system. (E.g. Building Trade – Louvre's, plenums, etc). In some cases, components of the Mechanical system will be installed or are to be installed in other buildings. In these cases, the word building in this document is to be interpreted as inclusive of these structures, annexes and components.

It should also be noted that the University is a long-term owner of the property and so appropriate considerations are to be made in terms of quality of installation, efficiency in operation, ease of maintenance and safety, long term reliability, and flexibility for change of use (where feasible).

The Technical Services Manager shall be consulted if any confusion arises before applying this Standard Guide. Approved variations must always be in writing or they will not be accepted. Consultants and Designers must advise and seek approval for any variation of these Guides or this document will take precedence.

5.2. STANDARDS

At the time of design and construction as a minimum the current Building Code of Australia and National Construction Codes that are current at that time must be strictly adhered to.

The design and installation shall consider all relevant standards required under legislation or authority requirements, and consider international codes and standards if required to satisfy the technical, operational and functional requirements of the brief.

5.3. DESIGN AND DOCUMENTATION

5.3.1. DESIGN APPROACH

The University expects consultants and designers to provide designs that meet the project brief and this Guide. The following are priorities that consultants and designers must be aware of and consider in their design:

- a. A consultant's return brief shall be provided for approval that confirms all aspects of the project brief, design allowances, building fabric, usage and operating conditions, environmental criteria, design approach and options to be considered as part of the concept design process;
- b. Provide environmental conditions that meet the project brief;
- c. Take a long term balanced view of capital costs, energy costs, maintenance costs and longevity of equipment;
- d. As educational and research progresses at rapid rates, usage of buildings and areas within a building can change many times within its life. Where possible, systems must be designed to be adaptable for fit out alterations, change of use, extension & expansion;
- e. Accessibility, ease of operation, and ease of maintenance;
- f. Control systems shall be designed with simplicity and reliability in mind. Often controls are made overly complicated, which can lead to issues in commissioning, multiple points of failure and an overly onerous maintenance burden;
- g. Allowance for adequate space for installation and maintenance of machinery, whether it be in designated plant rooms, ceiling spaces or otherwise. Lack of space is not considered an acceptable excuse for poor access provisions. Where insufficient space has been provided due to factors beyond the consultant's control, it shall be notified in writing to MUP for instructions to be made;
- h. Provision of fixed access platforms, walkways, stairs and ladders in accordance with AS.1657 to allow service/maintenance access to all items of equipment in ceiling spaces, roof spaces and on

Mechanical Services Design Standards

- roofs;
- i. Roof access ways exposed to the elements shall be aluminium alloy 6063 -T6 Temper, engineered to support the heaviest piece of installed equipment including service loads, and attached to roof decking with approved weatherproof fixings isolating the access way from the roof material;
 - j. Walkways are to be provided in roof spaces, protected from the weather and shall be integrated with ductwork, pipework and conduit layouts at the design stage so that all serviceable items of equipment can be accessed from the fixed walkway;

5.3.2. DESIGN INPUTS AND PROCESS

The University expects consultants and designers to proactively inform, advise and contribute to the design process and in particular the following aspects:

- a. Building Physics – provide advice to the project team, including other design team members that would improve the inherent building thermal performance, which may lead to a reduction in both capital and energy costs. This may initially take the form of simple advice, and subsequently backed up by thermal modelling or similar methods. The process may take several iterative steps. The consultant or designer is expected to advise, contribute and if necessary lead such processes. Passive solutions and natural ventilation/ mixed mode ventilation must be considered where appropriate.
- b. Planning and architecture – Provide advice on the appropriate location of plant rooms and reticulation strategy to assist in both the planning of the building and the facilitation of better maintenance in the future. Such advice must be provided in the early stage of the design and planning process so that this can be taken into consideration by the architect.

5.3.3. ENGINEERING FUNCTIONS REQUIRED FROM DESIGN CONSULTANTS

The university expects consultants and designers (including D & C designers) to be fully qualified, experienced and capable of carrying out all engineering design, calculations, equipment selection, construction quality checks, overview and verification of commissioning. Designs will be submitted for approval before construction.

5.3.4. CALCULATIONS

Use of computer based load modelling/simulation/estimation programs, that account for building elements, thermal storage and diversification of peak loads for each zone and air-handling system must be performed. This must be part of the design advice for all services to verify the building performance.

5.3.5. DESIGN CONDITIONS

- a. Load estimation is to be performed using established weather design data for the specific project location (such data as AIRAH or ASHRAE), and an industry recognised load calculation (and energy modelling where requested) software. A general square meter approach must not be used.
- b. The University external design comfort conditions for the North Ryde/Marsfield campus is Summer 35.0°C DB/ 23.9°C WB, Winter 5.1°C DB / 80% relative humidity for general office and teaching spaces only
- c. For special use spaces such as Laboratories, Animal Houses, Green Houses, and research facilities or the like areas outside air conditions is 43.0°C DB/ 25.9°C WB, Winter 3°C DB / 80% relative humidity and internal conditions are critical.
- d. For general office and teaching spaces, the indoor design conditions must be for a minimum condition of 21°C in peak Winter and a maximum condition of 24°C in peak Summer conditions, humidity is not controlled but the summer design condition must be 50 - 55% relative humidity.
- e. For special use spaces such as Laboratories, Animal Houses, Green Houses, and research facilities or the like, refer to the specific project brief for internal space design conditions.
- f. Air conditioning of general public spaces used as student and staff congregation and informal meeting areas are to be considered on a case by case basis. Where temperature control is deemed necessary the design conditions required are minimum of 20°C in Winter and a maximum condition of 26°C in Summer.
- g. Adequate ventilation of spaces to control CO₂ levels in occupied spaces to a design of 1000

Mechanical Services Design Standards

ppm and not greater than a peak of 1500 ppm and to control odours, volatile organic compounds and any emissions from plant or equipment to safe and amenable levels as dictated by CIBSE and ASHRAE.

- h. Consideration of condensation risk and building construction when using systems such as chilled beams, or when close control of room temperature, humidity, or room pressurisation is a specific requirement. Notify MUP of any concerns in writing before design completion.

5.3.6. EQUIPMENT SELECTION AND SIZING

In selecting equipment, the consultant and designer shall select products of proven and reliable quality, with reputable support and after sales service. A design basis shall be nominated in the design documentation, with any alternatives to be of an equivalent standard and requiring the approval of MUP and its consultant prior to tender acceptance. Complying tenders shall be for specified equipment. Any alternative must be offered with reasons why that equipment is selected and MUP may reject the use of the alternative without additional cost.

The following general points apply to equipment selection and sizing:

- a. Chillers and chilled water plant must be sized and configured to handle peak load, part load and minimum load conditions in a stable and energy efficient manner across the entire load profile. This requires consideration of appropriate chiller types, capacity, buffer tanks or dedicated low load chillers. Hot gas bypass is not considered an energy efficient mode of operation and shall be used only for fine tuning control and not as the sole means of capacity control;
- b. Pumps and fans must be selected in their stable range and high efficiency points of the pump and fan curves. For variable flow applications, ensure that the entire flow range is stable;
- c. Consider if the building is used in summer months or not. Ensure load calculations are carried out for the appropriate peak ambient conditions;
- d. For critical environments such as animal houses, special laboratories, clean rooms, museums or the like, stable operation of chillers and/or other refrigeration systems are crucial. Ensure issues such as redundancy requirements are addressed in the project brief and consider use of buffer tanks, and decoupling of chilled water and heating water systems (i.e. primary and secondary loops) to provide stable temperature control;
- e. Rooms requiring 24/7 space conditioning should be provided with dedicated air conditioning systems that can be run independently of the base building air conditioning system. EG. All small comms rooms shall be provided with separate DX split type AC units. Multi-head split systems are not acceptable in such applications. Separate packaged small chilled water systems are acceptable for multi-story buildings when designed in new upgrades of a whole building with backup from the main chilled water circuit.
- f. Products which are closed systems and proprietary in nature, thus locking the University into exclusive dependence of one manufacturer must be avoided and only used if there are no other options. This must be agreed to by MUP Technical Services Manager in writing.

5.3.7. MINIMUM ENERGY EFFICIENCY AND HEAT RECOVERY REQUIREMENTS

- a. In terms of efficiency, plant shall be selected to achieve at least the greater of the NCC/BCA Part J requirements and the criteria nominated below. Where the efficiencies nominated below cannot be achieved, it should be highlighted to MUP for approval along with the reasons why it cannot be achieved.

<i>Item</i>	<i>Efficiency</i>
Pumps	60%
Fans	60%
Motors	Motors greater than 1.5kW in size shall comply with the high efficiency requirements of AS1359.5 Table A3 or Table B3.
Gas Fired Hot Water Heaters	85% for hot water generation at nominal 80°C supply (60-65°C return) i.e. non-condensing.

Mechanical Services Design Standards

	96% for hot water generation at nominal 50°C supply (35°C return) for condensing boilers
Water Cooled Chillers	Refer BCA/NCC
Air Cooled Chillers	Refer BCA/NCC
DX Systems including: <ul style="list-style-type: none"> • Packaged Units • VRF/VRV • Split Systems 	<p>Air Cooled DX Packaged systems and split systems shall achieve a minimum COP of 3.0</p> <p>Air Cooled VRF/VRV systems shall achieve a minimum COP of 3.2</p>

- a. Ducted air conditioning systems with higher than 40% outside air must incorporate air to air heat exchangers for heat recovery.
- b. For ducted air conditioning systems of higher than 25kW cooling, Full outside air economy cycle must be incorporated (subject to process requirements). Economy cycles shall compare return air enthalpy to local building (i.e. not referenced to another location) outside air enthalpy using the design dry bulb and absolute water content to limit useful conditions. See design guide conditions in the appendix. Temperature 12° to 19°C with humidity ratio 6 to 11g/kg.
- c. Air handling units or Fan coil units used to condition single floors will be treated as a group if located in a small plant room and serving half or all of a floor when applying the 25kw rule. It is the whole building that is to be considered to require an economy cycle and each group will have an economy cycle.
- d. A fan coil unit that is used to condition a meeting room or conference room is not required to have an economy cycle unless greater than 25kw.
- e. All pump motors greater than or equal to 3kW shall be provided with variable speed drives whether part of a variable flow system or not. All pump motors serving a variable flow system shall be provided with a variable speed drive with active control of pump speed via the control system.
- f. All motors for fans serving variable flow systems shall be provided with variable speed drives. Measures such as inlet guide vanes on fans, or throttling of pumps or fans at full speed is not acceptable practice. Where fans are part of a constant speed system, either a VSD or speed controller shall be provided for commissioning only.
- g. All small motors shall be EC drive motors where available and shall be set for the correct speed such as FCU's or shall be modulated where variable flow is useful such as condenser fans.

5.3.8. SYSTEM TYPES

It is the consultant's and D & C contractor's obligation to select the optimal system type to satisfy the project requirements and to comply with the NCC, Australian Standards and other statutory requirements. MUP must approve and agree with selections before acceptance into the design.

The following are application guidance for various system types:

- a. Macquarie University employs a chilled water reticulation infrastructure to several buildings on campus, with use of Thermal Energy Storage tanks for peak load reduction. Where available this facility shall be used, and coils designed for a differential temperature of 6°C entering and 14°C leaving chilled water. This is to allow the thermocline to be preserved and return temperatures should not fall below 11°C. Systems not on a storage tank shall be designed for standard conditions of 6° C to 12° C or 7° C to 13° C.
- b. Mixed mode Air Conditioning/Ventilation should be considered for offices, meeting and teaching areas where operable windows are considered suitable. A reed switch or similar window/door monitoring device should be provided to automatically switch off air conditioning when the operable windows are open to avoid energy wastage.
- c. Where practical and not deemed cost-prohibitive, heat recovery systems should be considered for applications where relief or exhaust air can be used to pre-treat outdoor air.
- d. Variable Air Volume (VAV) systems utilising pressure independent VAV boxes and variable speed air

Mechanical Services Design Standards

- handling units have proved to be reliable and appropriate for a wide range of applications in the University and provide flexibility.
- e. Low temperature VAV systems are not generally acceptable to MUP. Low air supply rates, low supply air temperatures in ductwork (and resulting condensation risk), and humidity control issues have proven to be problematic. Any design must show fresh air rates can be maintained at low flow and must be approved and agreed to by MUP.
 - f. Passive Chilled Beam (PCB) systems are not generally acceptable to MUP. They may be considered on a project by project basis upon approval by MUP only. PCB systems have proved to be problematic due to their lack of flexibility, slow response time, and the open nature of buildings (Leakage) which will create moisture formation on the beam.
 - g. Active chilled beam (ACB) systems are considered to be acceptable in certain applications. MUP to approve this application with agreement that the building is air tight.
 - h. The University does not accept ceiling cassette units (DX or Chilled Water/Hot Water) as an appropriate system type for installation in Office spaces due to noise levels and poor air flow distribution. Seek approval if the designer suggests these are to be considered.
 - i. Underfloor displacement systems have proven to be acceptable where sufficient height is available and subject to capacity requirements. Where underfloor plenums are to be used, detailing of construction methods and services reticulation constraints are required to be clearly indicated in the design documents to ensure that air leakage does not occur. Specific commissioning measures of such systems shall also be documented. These systems have typically poor flexibility for future space changes.
 - j. The use of split systems is permitted for very small additions to existing buildings, and in cases requiring 24/7 air conditioning where the main central plant load is not available due to operating hours or low load capacity constraints.
 - k. The use of RAC window units is not acceptable due to noise constraints.

5.3.9. FUTURE ALLOWANCE

The provision of spare capacity for future additions must be considered for all projects and confirmed at the design briefing stage. In making such allowances careful analysis of the options of increased plant size versus provisions for expansion, efficiency and performance at part load conditions, infrastructure sizing, reticulation system sizing, etc must all be considered.

5.3.10. OTHER DESIGN REQUIREMENTS

- a. Variable speed water cooled chillers and multi stage air cooled chillers must be used.
- b. Fume cupboard makeup air is to be tempered and is only to be achieved when the fume cupboard system is operational. Wherever possible fume cupboards will be grouped together in separate rooms, with make-up provided by natural ventilation, to minimise loss of conditioned air within the laboratory space & reduce energy consumption. Chilled and heating water systems shall be used for treatment of the make-up air for energy efficiency. Reverse cycle small chillers can be used where building chilled water is unavailable. DX systems will not be used due to their operating limitations.
- c. The water control loop volume must be sized for at least the minimum chiller/boiler requirements for stable operation, as advised by the manufacturer. Buffer tanks of an appropriate volume shall be used where required to achieve the water control loop volume and stability.
- d. Plant rooms must be ventilated, preferably with natural ventilation, and where not possible with mechanical ventilation, in accordance with AS1668.2 and specific plant requirements.
- e. Provision in the controls shall be made for either automatic shutdown of air conditioning plant when spaces are unoccupied, or reset of room temperature to a higher (summer) or lower (winter) set point, where appropriate. (e.g. Drifts between 20 to 26 degrees when un-occupied, resets to 23 degrees when occupancy is detected)
- f. In Conditioned spaces outside air must be supplied into a mixing plenum and not directly supplied into a space without conditioning, regardless of whether the air is delivered at room temperature or not.
- g. All constant speed fans (such as toilet exhaust, general exhaust etc.) shall be specified with electronic speed controller to aid in commissioning and avoid excessive use of air restriction devices (such as Volume Control Dampers) for balancing

Mechanical Services Design Standards

- h. All Electric Duct Heaters shall be specified with SCR control (or similar) to enable efficient operation at partial capacity. Controllers will reduce energy consumption and not cycle the voltage on and off. Energy use reduction is the main requirement not just modulation.
- i. Redundancy to an agreed standard (e.g. N+1, etc.) must be incorporated into the design for critical environments such as animal houses, special laboratories, clean rooms, constant temperature environments, museums or the like.
- j. Refrigeration pipework. All refrigeration pipework shall be hard drawn copper tube, except of small split systems up to 10kW cooling with less than 10m of pipe run.
- k. Condensate pipework shall be in copper and insulated its full length.
- l. Ductwork and pipework insulation shall meet the minimum MUP standards and BCA/NCC deemed to satisfy requirements whichever is greater. Alternative solutions incorporating reduced insulation performance (R value) are not be considered.
- m. Designers and installers shall demonstrate that provisions for safe and adequate access for maintenance and commissioning of plant and equipment has been made to an appropriate level of detail in accordance with the stage of the design. This shall include compliance with the current statutory requirements and any specific requirements of the project. Access to plant in need of regular maintenance should be readily available without the need for specialised plant such as scissor lifts, cherry pickers or the like and the minimum clear walkway shall be 700mm.
- n. The design of mechanical services systems shall include provisions to ensure the system can be fully commissioned. The standard of compliance shall be in accordance with the CIBSE commissioning codes, and respective reference documents, such as BSRIA Flushing AG1-2001-1 and ITP's and Functional Test Sheets shall be used to verify compliance with the specification.
- o. Staging of Cooling or Heating water systems will be designed using field energy metering. Flow energy meters will be installed on all water based systems.
- p. Water Treatment shall be to the Water Treatment Design Guide requirements. A dosing pot mounted on a plinth with SS Tray under the feet and drained to waste will be provided for each closed system. A set of corrosion coupons are to be provided for each closed system and tested each six months.

5.4. TECHNICAL COMPONENTS

The following sections contain technical requirements on equipment, materials and installations. Consultants and designers are required to adhere to these. In the preparation of consultants' specifications, they are required to ensure that those project specifications do not contain any conflicting requirements or information with this document, unless approved by MUP, and must state in the document the agreed variation from the design guide requirements.

5.5. AIR COOLED CHILLERS

5.5.1. APPLICATIONS

Air cooled chillers should be considered for cooling capacities up to 500 kW, except if it is a low load chiller and condenser water is available. For applications where each chiller is rated at higher capacities, water cooled arrangements should be considered as a preference. For capacity above 650kW water cooled systems must be used.

5.5.2. PREFERRED SUPPLIERS

The following manufacturers are the preferred suppliers of air cooled chillers:

Air Cooled Chillers (up to 500 kW):

- Carrier
- Hitachi
- Trane

Other alternative equivalent manufacturers can be considered subject to approval by MUP providing it can be shown that the chiller has an ongoing and mature support network.

Mechanical Services Design Standards

5.5.3. GENERAL REQUIREMENTS

Air Cooled Chillers must be rated for continuous operation up to 45 °C dry bulb ambient temperature without “tripping” on internal safety limits. The selected capacity must be rated at 35°C ambient dry bulb (for the North Ryde campus). Capacity loss is permitted at ambient temperatures above this condition.

Chillers must be equipped with soft starters and electronic expansion valves.

Chillers must be fitted with refrigerant isolation valves for easy recovery of refrigerant. Isolation valves must be fitted to refrigerant dryer and oil filters.

An Electronic expansion device must be used permitting operation at a lower condensing pressure and improved utilisation of evaporator heat exchange surface.

Subject to noise control requirements specific to the project and based on the advice of the project acoustic consultant, additional acoustic treatment may be required such as low noise condenser fans and/or fitting of silencers, and acoustic insulation of compressors. The designer shall ensure that vibration is not transmitted to the building structure.

It is preferred that low noise options are selected including low noise condenser fans and compressor acoustic treatment where applicable.

Chillers must be able to operate at a minimum of 20% of rated capacity in a stable and continuous manner.

An appropriate system of flow rate verification through the chiller shall be provided on all installations and this may be an orifice plate, or a flow/energy meter of an approved manufacturer.

5.5.4. REFRIGERANTS

Refrigerants shall comply with statutory requirements and should be selected to maximise efficiency, minimise global warming potential, reduce the potential for leaks, and be cost effective to maintain and replace over the life cycle of the chiller. Where blends are proposed, they should exhibit azeotropic properties.

Preferred refrigerants are R134A, R410A for small scroll compressor chillers up to approximately 300 kW. R407C is a non-azeotropic refrigerant and should be avoided.

If the chiller is installed inside a plant room or building, pipe refrigerant pressure relief devices to a safe location outside the plant room or building in hard drawn copper tubing grade B.

5.5.5. COMPRESSORS

Shall be either Scroll or screw type compressors.

Scroll – hermetic scroll compressors.

Screw – semi-hermetic screw compressors.

Use of air cooled centrifugal compressors are to be avoided due to poor performance at high ambient temperatures.

Loading/unloading of chillers - chillers should start at minimum capacity and gradually load to achieve design conditions.

Use of hot gas bypass shall not be used as the sole means of capacity control. It is permitted as a means of fine tuning control only and low load performance.

Capacity control may be achieved by:

- Use of multiple compressors and a low load chiller where required;
- Digital scroll compressors, or variable speed drive scroll compressors;
- Variable speed or slide valve control for screw compressors.

Variable speed compressor control is the preferred means of capacity control where it is available in the capacity range, and it can be economically justified, due to superior energy efficiency.

Variable frequency unloading of a fixed speed compressor is not acceptable.

Mechanical Services Design Standards

5.5.6. LIQUID COOLERS

Shell and tube liquid coolers are preferred on chillers greater than 200kW. Plate heat exchangers are permitted on smaller capacities.

Insulation of vessel and pipework shall have a minimum R value of 1.8m².K/W, or NCC section J5.4 requirements, whichever is the greater. Insulation shall cover the full extent of vessel and pipework.

Insulation shall be metal sheathed where exposed to weather unless approved by MUP.

5.5.7. CONDENSER COILS

Condenser coils must be an aluminium ripple fin heat exchanger on copper tube, and capable of cleaning with a high-pressure washer. MUP will not accept fins which have slits or the like, as these create opportunities for corrosion and crack formation. The entire coil shall have factory applied epoxy coated corrosion protection as described below in "Corrosion Protection". If this option is not available, then the coils will be treated before use using a product such as Blygold epoxy coating and shall have appropriate 10-year warranty.

5.5.8. CONDENSER FANS

Condenser fans must be multi stage systems installed to run under low ambient and low load conditions, condensers must have variable speed fans to maintain stable refrigeration system operation. (Head pressure control).

EC motors are preferred with high efficiency blade design.

5.5.9. CORROSION PROTECTION

All surfaces of a chiller are to come pre-treated and factory painted.

The Chiller and pipe work are to be isolated via a rubber flexible coupling.

The Condenser coil corrosion protection shall be suitable for a marine environment, and shall be applied in the factory, and be fully warranted. The coatings shall satisfy the following:

ASTM B117:	4000+ hours (neutral-salt spray test)
ASTM B287:	4000+ hours (acid-salt spray test)

The coating is to be applied to the assembled coil providing sealing to all joints on the coil. Pre-coated fin materials will not be used. Approved manufacturers are Blygold Polual. Other manufacturers will be considered subject to satisfactory test results and approval by MUP.

5.5.10. CONTROLS

The chiller shall be provided with a back lit LCD/LED touch screen control panel allowing viewing of all monitored points including temperatures, pressures, electrical data, changing of set points, and diagnostics. The control panel shall be a menu driven, stand alone, microprocessor based module.

BMS interface: Provide a BACnet/Modbus High Level Interface to enable the MUP building management system to interrogate the control panel, or reset the chiller set points.

The chiller controls must be configurable for manual or automatic start up and shutdown. In automatic operation mode, the controls must be capable of automatically starting and stopping the chiller. Controls must be capable of resetting and resuming normal operation after power outage.

Chiller unit must incorporate devices to limit the number of starts per hour to maximum of six (6) per hour. The design of the system and the sizing of capacity to match building load characteristic is a principal factor and consultants and designers must ensure that this has been considered in their design.

Mechanical Services Design Standards

Chiller controls should be suitable for chilled water flow temperature reset control via BMCS output to the chiller.

The preferred means of control of flow through the evaporator is to maintain the required differential pressure across the vessel, as sensed by differential pressure sensors across the flow/return connections to the vessel. These shall have sensing points as close as possible to the chiller vessel entry and leaving points. A strait section of tubing will be used to ensure the sensor points can be inserted. Chiller HLI values will not be used for control.

Where integral hydraulic modules are provided (i.e. pumps, expansion vessels, buffer tanks), the chillers integral controls shall control this equipment and have the points available for status, temperature, pressure and any alarms available to the BMCS via the HLI.

Hard wired control input/output points to be available:

- I. Contact for remote alarm for each refrigerant circuit
- II. Automatic chilled water reset hard wired signal to chiller from external source and HLI through BMS
- III. Outputs for driving chilled water pumps
- IV. Cooling call
- V. External safety device loop (such as pressure and flow switches)

The following points are to be available from the local controller and via HLI:

- I. Entering/Leaving chilled water temperature
- II. Ambient temperature
- III. Condenser fan operation
- IV. Refrigerant pressures and temperatures
- V. Oil temperature and Pressure
- VI. Automatic chilled liquid reset timer programmed locally at chiller controller
- VII. Soft loading control by temperature or load ramping
- VIII. Power (demand) limiter
- IX. Manual speed control (Variable speed Chiller)
- X. Chiller operating status message
- XI. Cooling call mode i.e.; local or remote
- XII. Power on/off
- XIII. Pre-start diagnostic check
- XIV. Compressor motor amps
- XV. Alert (pre-alarm)
- XVI. Alarm and description of fault
- XVII. I/O test function
- XVIII. Safety shutdown message
- XIX. Elapsed time (hours of operation)
- XX. Monitor/number compressor starts and run hours
- XXI. Chiller power input kW
- XXII. Cooling Demand kW

5.6. WATER COOLED CHILLERS

5.6.1. PREFERRED SUPPLIERS

The preferred chiller is the Smart/ PowerPax Chiller and it shall be specified unless agreed to and approved by MUP.

The following other manufacturers are considered preferred alternative suppliers of water cooled chillers should the PowerPax not be deemed suitable for the application. These shall only be used by agreement due to the better low load operating performance of the oil less Power Pax unit. Lower Cost is not an acceptable reason for use of these alternatives:

Mechanical Services Design Standards

- Trane
- Carrier
- Hitachi
- York

Other alternative equivalent manufacturers may be considered subject to approval by MUP.

5.6.2. GENERAL REQUIREMENTS

The chiller controls must be configurable for manual or automatic start up and shutdown. In automatic operation mode, the controls must be capable of automatically starting and stopping the chiller. Controls must be capable of resetting and resuming normal operation after power outage.

Chillers must be equipped with soft starters and electronic expansion valves.

Chillers must be fitted with refrigerant isolation valves for easy recovery of refrigerant. Isolation valves must be fitted to refrigerant dryer and oil filters.

An Electronic expansion device must be used permitting operation at a lower condensing pressure and improved utilisation of evaporator heat exchange surface.

Subject to noise control requirements specific to the project and based on the advice of the project acoustic consultant, additional acoustic treatment may be required. The designer shall ensure that vibration is not transmitted to the building structure.

Chillers must be able to operate at a minimum of 20% of rated capacity in a stable and continuous manner.

Chillers to be pre-factory tested with certification of test.

A Lifting beam must be installed above each chiller for maintenance and removal of compressors and endplates. Alternative hinged end plates are preferred.

Multi-chiller installations shall be selected to maximise efficiency over the entire operating range, with consideration of the part load performance of the chillers in isolation and as a system. The consultant should provide a staging diagram demonstrating the overall system performance across the entire operating range with capacity on the X axis, system energy and COP/EER on the vertical axes.

The chiller plant area must provide adequate service space for all servicing requirements including the removal of the condenser tubes. Manufacturers published requirements are to be allowed for in the plant room layout of the chillers.

The condenser water pipework connections to the chiller should include a flanged disconnection joint to allow removal of the end shell without cutting of pipework.

An appropriate system of flow rate verification through the chiller shall be provided on all installations and this may be an orifice plate, or a flow/energy meter of an approved manufacturer.

5.6.3. COMPRESSORS

Preference for use of multiple Danfoss magnetic bearing, oil-free compressors in the range of 300 kW_r to 1500 kW_r. On larger chiller selections, such as large base load chillers, large variable speed centrifugal and screw chillers shall be used.

Scroll compressors: typically, in the range of 50-300 kW_r.

Screw compressors- typically in the range of 150-750 kW_r.

Centrifugal – Greater than 300 kW_r.

Use of hot gas bypass shall not be used as the sole means of capacity control. It is permitted as a means of fine tuning control only where required and to handle low loads.

Capacity control:

Mechanical Services Design Standards

- Slide valve control or variable speed drive screw compressors
- Variable speed centrifugal compressors.

Variable speed compressor control is the preferred means of capacity control where it is available in the capacity range, and it can be economically justified, due to superior energy efficiency.

Step control is not allowed.

5.6.4. LIQUID COOLERS

Shell and tube construction typically.

Plate heat exchangers on smaller units less than 100 kW_r.

5.6.5. CONDENSERS

Shell and tube type construction is preferred.

Stainless steel end plates and water boxes or epoxy coated water boxes for corrosion protection is preferred if no stainless-steel option is available. Painted epoxy suitable for marine immersion is preferred over ceramic coatings due to their less brittle nature.

5.6.6. WATER BOXES

Water boxes must have vents, drains and be of marine grade A materials. Allow for tube cleaning space in plant rooms as per manufacturer's recommendation. Service space must be shown on the drawing.

A thermistor type temperature sensor with quick connects must be factory installed in each water box.

Water boxes must have lifting apparatus installed in the plant room or be hinged.

Marine water boxes are not to be used unless approved by MUP Mechanical Engineer.

5.6.7. CORROSION PROTECTION

All surfaces of the chiller are to come pre-treated and painted, water boxes and tube sheets are to be epoxy coated before commissioning of chiller with a five-year guarantee on the epoxy coating performance.

Chiller and pipe work are to be isolated via rubber flexible couplings.

Where the chiller is to be located outdoors, the chiller shall come in a weatherproof enclosure allowing access to all equipment, valves, electrical and controls. Lighting shall be installed in the housing suitable for maintenance requirements.

5.6.8. CONTROLS

The chiller shall be provided with a back lit LCD/LED touch screen control panel allowing viewing of all monitored points including temperatures, pressures, electrical data, changing of set points, and diagnostics. The control panel shall be a menu driven, stand alone, microprocessor based module.

BMS interface: Provide a BACnet/Modbus High Level Interface to enable the MUP building management system to interrogate the control panel, or reset the chiller set points.

The chiller controls must be configurable for manual or automatic start up and shutdown. In automatic operation mode, the controls must be capable of automatically starting and stopping the chiller. Controls must be capable of resetting and resuming normal operation after power outage.

The Chiller unit must incorporate devices to limit the number of starts per hour to maximum of six (6) per hour. The design of the system and the sizing of capacity to match building load characteristic is a principal factor and consultants and designers must ensure that this has been considered in their design.

Chiller controls should be suitable for chilled water flow temperature reset control via BMCS output to the chiller.

Mechanical Services Design Standards

The preferred means of control of flow through the evaporator and condenser is to maintain the required differential pressure across the respective vessel, as sensed by differential pressure sensors across the flow/return connections to the vessel. Chiller HLI shall not be used for his function.

Hard wired control input/output points to be available

- I. Contact for remote alarm for each refrigerant circuit
- II. Automatic chilled water reset hard wired signal to chiller from external source and HLI through BMS
- III. Outputs for driving condenser pumps
- IV. Outputs for driving chilled water pumps
- V. Cooling call
- VI. External safety device loop (such as pressure and flow switches)

The following points are to be available from the local controller

- I. Entering/Leaving chilled water temperature
- II. Ambient temperature
- III. Refrigerant pressures and temperatures
- IV. Oil temperature and Pressure
- V. Automatic chilled liquid reset timer programmed locally at chiller controller
- VI. Soft loading control by temperature or load ramping
- VII. Power (demand) limiter
- VIII. Manual speed control (Variable speed Chiller)
- IX. Chiller operating status message
- X. Cooling call mode i.e.; local or remote
- XI. Power on/off
- XII. Pre-start diagnostic check
- XIII. Compressor motor amps
- XIV. Alert (pre-alarm)
- XV. Alarm and description of fault
- XVI. I/O test function
- XVII. Safety shutdown message
- XVIII. Elapsed time (hours of operation)
- XIX. Monitor/number compressor starts and run hours
- XX. Chiller input kW
- XXI. Demand kW

5.7. HEATING HOT WATER GENERATORS

5.7.1. TYPE

Generators shall be condensing or non-condensing type depending on design requirements.

Atmospheric burner units shall not be used unless specifically approved by MUP.

5.7.2. PREFERRED SUPPLIERS

Heating hot water (HHW) generators shall be:

Gas-fired, cast aluminium or cast-iron sectional type equal to:

- Modulex or
- Baxi Luna; or

Forced draft, fire-tube type equal to:

- Autoheet Arizona,
- Eurogen or

Mechanical Services Design Standards

- Hunt model TN-AR

Other alternative equivalent manufacturers may be considered subject to approval by MUP.

5.7.3. GENERAL REQUIREMENTS

Generator output efficiency shall be not less than:

<i>Rated Capacity (KWH)</i>	<i>Minimum Gross Thermal Efficiency (%)</i>
Less than 90	75
90 to 750	80
More than 750	83
Condensing (all)	90

Note that the gross thermal efficiency equals the output heating capacity divided by the gross heat input.

Generators shall be suitable for a minimum system pressure of 100 kPa and a maximum system pressure of 600 kPa.

Condensing boilers shall be specifically constructed for the purpose, with corrosion resistant materials and suitable drains. Provide an approved condensate waste treatment system to neutralise the condensate from condensing generators prior to discharge to waste.

The generator shall be complete with the following:

- i. Modulating gas fired burner and gas train complying with AS 5601 and AS3814
- ii. Integral control panel
- iii. High limit manual reset thermostat
- iv. Remote stop/start input relay
- v. Boiler run output signal
- vi. Common fault output signal
- vii. Flanged heating water flow and return and vent connections.
- viii. Heating water flow and return temperature gauge.
- ix. Heater water pressure gauge
- x. Pressure relief valve(s)
- xi. Access provision for all maintenance requirements
- xii. Insulated casing with colorbond or powder coat finish
- xiii. Valved drain.

Primary/secondary pumping systems are preferred, incorporating a low loss header.

An appropriate system of flow rate verification through the HHW generator shall be provided on all installations and this may be an orifice plate, or a flow/energy meter of an approved manufacturer.

5.7.4. HHW GENERATOR FLUES

Flue heights and discharge locations shall comply with AS5601 and shall be at least 1500 from any building opening and 1000 horizontally from any neighbouring structure.

Flues shall be constructed from minimum 1mm thick grade 304 stainless steel.

Forced draft HHW generators shall be terminated with a coned discharge.

Flues shall be thermally insulated with 50mm thick high-temperature Rockwool insulation and shall be externally sheathed with minimum 1 mm thick aluminium.

Mechanical Services Design Standards

Flues operating at a temperature less than 60°C may be uninsulated above 1800mm. If the unit can be set at a higher temperature the flue must be insulated as above for service operator safety.

Provide flue supports, strays and fixings and high temperature / weatherproof flashing collar at the roof penetration.

Provide a flue dilution system complying with AS5601 where the flue needs to discharge through a wall and the HHW generator is not a room sealed or balanced flue terminal unit.

5.8. COOLING TOWERS

5.8.1. PREFERRED SUPPLIERS

Preferred manufacturers are:

- Baltimore Aircoil (BAC)
- Evapco with external motors only

Other manufacturers will be considered if they can demonstrate compliance with the technical requirements, are able to provide the equivalent technical support, life cycle and reliability to MUP. MUP reserves the right to refuse an alternative without additional cost.

5.8.2. GENERAL

Cooling tower and installation must comply with all relevant codes, standards, acts and regulations. Towers must be designed and installed strictly in accordance with AS 3666 and AS1055 as a minimum requirement and care is to be taken in its location with respect to intakes of air conditioning and ventilation systems, kitchen exhaust systems and similar locations which may pose a risk, and provide breeding environments for legionella.

Side stream filtration must be provided. It must include automatic control of suspended solids, particle removal down to 10 microns, a self-cleaning/backwash cycle and a low rate of water usage. Nozzles are to be installed to wash the basin with the return water to keep solids suspended and flushed to the low point of the basin for pick up by the filter intake. Water turnover rate shall equal or be greater than 7% of maximum system flow. Design to be approved by MUP. All piping and nozzles to be plastic high-pressure pipe. Suitable system is a Masterflow CTFP-3-A2-13 skid mounted with controls and Eductor nozzles for basin sweeping complete with BMCS fault contacts.

A dual biocide automatic water treatment system must be provided with alarm outputs for connection to a BMCS. A bund must be provided to house the chemicals.

Maintenance logs shall be kept on site and also sent to MUP in pdf format in accordance with statutory requirements. The log shall be contained in a metal holder in the plant room and clearly visible to the service personnel and council inspectors.

Make-up water supplies shall be provided with an RPZD valve that shall also protect the tap near the cooling tower to be used for wash down.

An external basin level indication and adjustment mechanism using a mechanical solenoid valve system shall be provided. A water meter shall be installed to monitor water usage using a pulse to the BMCS.

A high and low limit sensor shall be installed and connected to the BMCS.

A pressure sensor shall be installed on the water line to the cooling tower for supply pressure monitoring.

The tower must be designed and selected so that splashing or wetting of surfaces surrounding the tower including the external parts of the tower does not occur.

All hardware must be stainless steel to prevent corrosion and brackets and steel supports shall be hot dip galvanised the thickness of the coating to be suitable for corrosive environments and must not show any signs of rust for 10 years. Washers shall be used on all bolts.

5.8.3. CONSTRUCTION

Cooling towers to be of fibreglass reinforced polyester (UV resistant) or stainless-steel construction.

Sumps to be one piece and coated with a smooth gel coat finish to increase bacteria resistance of the sump.

All parts must be accessible for cleaning and service.

All access panels must have seals to prevent water leakage

All steel support components must be heavy gauge hot dip galvanised steel and all welded components after fabrication to be hot dip galvanised

Mechanical Services Design Standards

All hardware shall be 316 stainless steel.

All bolts shall have washers applied.

5.8.4. FAN

General: Provide fans with non-overloading power characteristics.

Cooling tower fans shall be either centrifugal or axial type fans.

Axial fans shall be aerofoil section blades constructed from cast aluminium alloy or glass reinforced plastic with manually adjustable pitch angle.

Centrifugal fans shall be forward or backward curved,

Balancing: Static and dynamically balance rotating equipment.

Shaft: Stainless steel.

Guards:

Axial flow fans - Provide a stainless-steel mesh guard over the fan discharge, for safe operation. Allow for tachometer insertion.

Centrifugal fans - Provide a galvanized or stainless-steel mesh guard over the fan inlet, for safe operation.

Fan bearings: Grease-lubricated, self-aligning, ball or roller bearings. Make provision for grease relief and extend lubrication lines to outside of tower.

Motors:

All cooling tower fan motors:

- Degree of protection: IP56 minimum.
- Stainless steel shaft.
- Cable entry into conduit box from below.
- Epoxy paint finish.

Motor insulation: Thermal class 155 (F) to IEC 60085.

Maximum fan operation speed must not exceed 1450 RPM.

Fan motors should be located outside of the air stream using a belt drive arrangement.

All cooling tower fans must have VSD's fitted for capacity control.

5.8.5. WATER DISTRIBUTION

Header pipes must be configured to ensure even distribution over the entire fill area.

UPVC or ABS Nozzles must be used.

Nozzles must be easily serviced with minimal dismantling of equipment.

5.8.6. DEAD LEGS AND BALANCE LINES

General: Arrange the cooling towers and piping so that all parts can be drained and flushed. Provide additional full way drain valves and flushing facilities so that balance/equalising lines between towers can be drained and flushed. Sizing of balance lines shall follow AIRAH design guide sizes as a minimum. (ref. DA 17 Cooling Towers Manual)

5.8.7. CAPACITY

Cooling towers dedicated to chilled water plant must be a minimum of 15% oversized for the designed heat rejection capacity.

5.8.8. ACCESS

Mechanical Services Design Standards

The tower and its installation on site must be designed to facilitate easy fan removal and maintenance with the installation of a platform and ladder for accessing and removing the cooling tower fan. Provision of FIXED access platforms, walkways, stairs and ladders in accordance with AS1657 to allow service/maintenance access must be provided. Platform must have a Structural Engineering approval certificate.

5.9. PUMPS

5.9.1. PREFERRED SUPPLIERS

Preferred suppliers are:

- Baker;
- Smoothflow;
- Wilo;
- Grundfos.

Other alternative equivalent manufacturers can be considered subject to approval by MUP.

5.9.2. GENERAL

Select pumps that meet the following general requirements:

- Shall be provided with a variable speed drive, regardless of whether constant or variable speed control is required. This enables the lowest speed achievable during commissioning of the pump.
- Constant falling head versus flow rate curve.
- Stable operation.
- Duty point near the maximum efficiency point for the impeller diameter within a band of -10% to +5% of the maximum efficiency point.
- No instability when operating either single or in parallel at the same shaft speed.
- Shut-off head difference between pumps > 10% of that of the pump with the lowest shut-off head.
- Selected so that their respective documented maximum flow rate is $\leq 80\%$ of the maximum flow for the pump shown in the manufacturer's catalogue.
- Energy efficiency: Conform to BCA J5.4.
- Preference for pumps selected for 1450RPM unless the duty point favours a 2900 RPM pump due to efficiency and stability of operation.
- Casting must be gun metal or cast iron
- Impellers must be bronze
- Shaft must be stainless steel
- Motors for external applications must be IP56, totally enclosed.
- Shall be long coupled pumps mounted on a base. In line or short coupled pumps may be used only where the application requires their use. MUP to agree and approve their use.
- Provide inertia bases with suitably rated anti-vibration seismic restraint spring mounts.
- Guards on pump shaft and couplings
- Greaseable bearings
- Mechanical seals
- Shall have Stainless steel drip trays under the pump

Installation:

Provide spool pieces on all pipework connections to pumps a minimum of 100mm long.

Provide 5 diameters of straight pipework between pump discharge and check valve or any bends.

Provide 4 pipe diameters of straight pipework between pump suction and any bends.

Drip trays:

General: For uninsulated chilled water pumps, provide grade 316 stainless steel drip trays between the pump and the base, to catch condensate from the pump body.

Size: Extend beyond the pump suction by 100 mm minimum, and beyond uninsulated pump flanges.

Mechanical Services Design Standards

Drainage: Provide 25 mm diameter sockets for drainage. Drain to the nearest waste with DN 25 copper pipe. Install with a fall to the drain outlet.

Sealant: Seal between trays and pumps with silicone sealant. Seal pump feet between feet and tray.

Marking: Provide impeller dia. and pressure design data on a label affixed to the pump.

Direction of rotation: Provide permanent indication on the principal component of the casing, indicating the direction of rotation.

Name plates: Attach to the casing permanent labels indicating the following:

- Make.
- Model.
- Serial number.
- Casing material.
- Impeller material.
- Shaft material.
- Impeller diameter (if reduced).
- Seal type.

Pumps shall be provided with pressure gauges on suction and discharge.

5.10. VARIABLE SPEED DRIVES (VSD'S)

5.10.1. PREFERRED SUPPLIERS

The following equipment is deemed to comply with this standard: Danfoss VLT, ABB HVAC.

Other alternative equivalent equipment may be provided subject to approval by MUP.

In an effort to standardise equipment for maintenance and operational efficiency, existing equipment shall be matched (subject to being one of the preferred suppliers). In older plants use a new drive from one of the above brands. Preference is for Danfoss drives.

5.10.2. GENERAL

Servicing of the drive must not require access from the back of the VSD.

The VSD must be capable of adjusting the speed of any 415V, 50 Hz, 3 phase motor of suitable power rating over a full speed range and determine the optimum power supply to its connected motor to maintain the most efficient running characteristic of that motor. The drive must be capable of starting a motor that is freewheeling backwards.

The drive must be able to accept a fire signal to run at a designated speed under fire conditions where required.

The variable speed drive must be interfaced to the University BMCS and allow full monitoring and control functionality from the MUP site wide BMCS.

The drive must include the following features:

- a. Ventilating enclosure
- b. 4-20mA DC or 0-10VDC signal
- c. Separately adjustable ramps for soft start and soft stop
- d. Manual speed control
- e. Manual reset button for all trip functions
- f. Adjustment facility for maximum and minimum speed setting
- g. Electronic overload motor protection – Faulty alarm relay 0-10VDC speed indicating signal.
- h. Interface screen for setting the drive parameters on each drive.

Under no circumstances will a speed controller causing noise in the building electrical wiring be acceptable. If noise can occur, then each drive must be provided with a suitable means of suppression.

Mechanical Services Design Standards

5.10.3. VSD MOTOR PROTECTION FEATURES

The VSD Motor must incorporate the following protection function:

- a. Over voltage, under voltage and main phase loss
- b. Output earth fault, short circuit and loss of motor phase
- c. Switching on output
- d. Flying Start of motor in forward or reverse direction
- e. Electronic motor thermal protection and motor condensation protection.
- f. Over current/ current limit with automatic ramp control
- g. Inverter overload/ over temperature/ operation without motor.
- h. Automatic restart must be available on over/under voltage and current limit trip.

5.10.4. CONTROL PAD

The control panel must include:

- a. Manual/ Off/ Auto, Start, Stop and Reset Control functions
- b. Output current, voltage, frequency, kW, kWh, Hours run, heat sink temperature reference and feedback signal indication;
- c. Last even fault memory and program lock.

Where the control pad is removable from the VSD, one control pad per VSD shall be provided. It shall be provided with a dust proof cover.

5.10.5. PERFORMANCE

VSD operating efficiency must be 96% minimum at 100% load and 92% minimum at 20% load.

5.10.6. LOCATION

Drives are to be internally mounted. The University does not accept externally mounted drives.

Drives must not be located in cabinets or enclosed boards unless approved by MUP. Drives must be mounted on metal support frames with free access for servicing. Mounting positions must be shown on drawings and approved by MUP.

Drives will not be mounted above each other or in locations which cause an impediment to servicing of the drive or other equipment.

5.10.7. PROTECTION

The drive must have ingress protection against duct and splashing water in all direction to not less than IP 54.

A door mounted control panel must be incorporated with alpha numeric display and keypad for programming, status and fault diagnostic indications in plain English.

5.10.8. COOLING

The VSD electronics must be cooled by sealed heat exchanges, with no contaminated air entering the electronic area.

5.10.9. SOFTWARE, PROGRAMMING, PASSWORD AND O&M

Provided with installation of VSD;

- a. Software and required unique devices for programming VSD
- b. VSD program parameters once final commissioning is complete
- c. HLI Point list
- d. All product passwords for servicing and installation
- e. Installation diagrams
- f. Sizing information of drive
- g. Wiring requirements
- h. Application support information

Mechanical Services Design Standards

- i. Trouble shooting charts

5.10.10. HIGH LEVEL INTERFACE AND CONTROL

All VSD's must be provided with a BACnet Compatible high-level interface to the BMCS.

The control signal to the VSD shall be provided via an analogue signal (0-10VDC or 0-10mA) signal. The analogue control signal shall be adjustable via the BMCS for testing and maintenance purposes.

A fixed on/off signal such as dry contacts may be provided where the VSD is set to run at a fixed speed as determined during commissioning.

Hand operation must be indicated on the BMCS.

5.11. FANS

5.11.1. GENERAL

Preferred manufacturers are:

- Fantech
- Flakt Woods

Other alternative equivalent equipment may be provided subject to approval by MUP.

Fan and motors must be selected to at least 10% additional capacity above the design duty flow rate at the corresponding increase in static pressure.

Fans shall be selected at a point on the fan curve that will not lead to a surge condition.

Fans shall be selected for stable operation across the entire range of operation of the fan.

Fans must not be driven above 50Hz for any reason whether approved by the manufacturer or not to compensate for poor or inadequate selection.

Variable volume systems: Provide fans for variable volume systems selected for:

- Maximum fan efficiency at 70% to 80% of design air flow rate.
- Operation from 30% to 110% of design air flow without going into a surge condition.

Fans with variable speed drives: Conform to the following:

- All fans: Provide fans selected to operate at ≤ 50 Hz under all conditions.
- Fans with belt drives: Adjust fan speed during commissioning for motor to operate at ≤ 50 Hz under all conditions.

Fans with multi-speed motors: Conform to the following:

- Two speed fans: Provide fans selected to perform duties documented.
- Fans with ≥ 3 speeds and single-phase fans with adjustable speed control: Provide fans selected to achieve the duty documented at a speed $\leq 80\%$ of highest speed.

The fans shall be selected to ensure the noise levels within the area served are within acceptable limits as determined by MUP or AS2107 if not specified in brief. Where fan noise levels would otherwise exceed the noise criteria, appropriate acoustic treatment shall be provided to meet the required acoustic criteria.

Generally, fans shall be selected at 50dba or less to provide quiet operation. High flow noisy fans are not to be selected based on lower cost.

5.11.2. INSTALLATION

General: Arrange fans and accessories to allow service access for maintenance, removal or replacement of assemblies and component parts, without disturbance of other items of plant, fire rating material and/or the building structure.

Mechanical Services Design Standards

Duct connections: Flexible connections: Provide flexible connections to prevent transmission of vibration to ductwork. If under negative pressure, make sure that the flexible connection does not reduce fan inlet area. If necessary, provide spacer pieces between fans and flexible connections. A straight run of duct must be provided of sufficient length to allow accurate measurement of total flow at the fan.

Drains: Where moisture is likely to enter or condense inside a fan, provide a trapped drain in conformance with AS/NZS 3666.1.

Vibration isolation: Provide each assembly with at least four anti-vibration mountings, selected to give an isolation efficiency not less than 95%.

Type: As recommended by the fan manufacturer to achieve the required isolation efficiency for the specific fan under the documented operating conditions. Provide levelling screws and locknuts on metal spring mounts.

Location: Locate the mountings so that the mounts deflect uniformly when the fan is operating and subject to all loads, including those imposed by the duct.

Duct connections: Arrange flexible duct connections so that the fan vibration isolation efficiency is not adversely affected.

5.11.3. BELT DRIVEN FANS

Drive sizing: Size for $\geq 125\%$ motor power and capable of transmitting the full starting torque without slip.

Belts: Wedge belts to AS2784, consisting of matched sets of at least 2 belts. Mark belt size in a prominent location on the fan casing.

Belt tensioning: Provide adjustment of belt drive tension by either movement of motor on slide rails or by pivoting support. Do not use the weight of motors to provide belt tension. Restrain motors with locknuts on bolts, clamping motor in place.

Provide rigid, removable belt guards on all fans where drive is accessible while motor is running.

5.11.4. KITCHEN EXHAUST FANS

Kitchen exhaust fans shall be of a backward curved centrifugal type that ensures the blades are “self-cleaning”, with provision for collection of drainage of grease. Motors shall be outside of the air stream to prevent collection of grease on the motor.

Fans should be located as close to the discharge from the building as possible, and shall discharge in a manner complying with AS1668.2. Use of exhaust air treatment devices to reduce the requirements for exhaust air discharge location will not be accepted without written approval from MUP.

In addition to the requirements above providing the following:

Access for cleaning – Provide a large gasketed access panel.

Drain – Provide trapped drain from lowest point in casing. Provide unions at connection and arrange drain to be easily cleaned, pipe drain to waste

Finish: Internally zinc sprayed

Fire rating: If installed in a fire rated duct system and not installed in a separate fire rated room or enclosure, fire rate fan to the same standard as duct. Make sure that fire rating provision permit easy access for inspection, cleaning and maintenance.

5.11.5. ROOF MOUNTED FANS

Types: Centrifugal, mixed flow, or aerofoil axial.

Centrifugal fans:

- Casing: Scroll ≥ 1.2 mm and side plates ≥ 2 mm thick zinc-coated steel, riveted or spot welded with joints sealed.

Mechanical Services Design Standards

- Bases: Metallic-coated steel sheets bolted to casings with at least 4 mounting brackets.
- Impellers: Constructed with extruded aluminium or zinc-coated steel blades secured between reinforced galvanized steel plates.
- Bearings: Self-aligning sealed for life ball or roller type.
- Finish: Brush and prime spot welds with zinc-rich organic primer to AS/NZS 3750.9.
- Motor minimum degree of protection: IP44.

Mixed flow fans:

- Impeller: Mixed flow with rotating parts vibration isolated from the unit casings by suitable resilient mountings.
- Arrangement: Position the motor above the impeller to allow servicing from above the roof.

Housing: House fans in compact bases fitted with weathering skirts and a hinged or removable weatherproof cowl with bird screen.

Material: UV stabilised ABS, polypropylene, polyethylene, glass-fibre reinforced polyester or steel, hot-dip galvanised (HDG) after manufacture, material as documented.

Vertical discharge: Provide weatherproof galvanized steel, plastic or aluminium backdraft dampers where the weather may enter when units are stopped.

Backdraft damper closure: Counter weighted or electrically driven.

Backdraft dampers on smoke spill fans: Conform to AS/NZS 1668.1 Unless all compartments served by the smoke spill fan are protected by a sprinkler system, arrange dampers to latch open or fail in the open position in the event of a fire. Provide temperature independent latch open device.

Vermin mesh: Where backdraft dampers are not fitted, provide vermin mesh guards. Comply with AS/NZS 3666.1 clause 2.2.1.

Motors:

Bearings: Provide bearings sealed for life or grease packed fitted with lubrication lines extending through roof cowls. Provide bearings with a minimum rating fatigue life of 40 000 hours. Provide access to grease relief ports.

Minimum degree of protection: IP56.

Drive: Belt or direct as appropriate.

Electrical connection: Provide terminal boxes external to fan casings and wired to fan motors.

Kitchen exhaust fans: Housing, base and casing: Hot-dip galvanized steel or stainless steel only.

Materials generally: Except for minor items such as grommets, junction boxes, etc., construct from materials with a temperature of fusion > 1000°C.

5.12. AIR HANDLING UNITS AND FAN COIL UNITS

5.12.1. PREFERRED SUPPLIERS

Preferred suppliers include:

- Air Design (AHU/FCU)
- GJ Walker (AHU/FCU)
- Temperzone (FCU only)
- Fan Coil Industries
- Flakt Woods

Mechanical Services Design Standards

5.12.2. INTERPRETATION

Definitions

General: For the purposes of this section the following definitions apply:

Air handling plant: Proprietary and non-proprietary pre-assembled plant and prefabricated and site erected plant and plenums. Includes fan coil units and air handling units.

Fan coil unit (FCU): A unit having a supply air flow less than 400 L/s and consisting of casing housing coils and a direct drive fan designed for mounting concealed or exposed within a room. The casing may also house filters and other items. Includes manufacturer's variations within a range of this type of unit mounted concealed or exposed with or without connected ducts.

Air handling unit (AHU): A unit having a supply air flow greater than 400 L/s and consisting of a casing housing a fan and coils. The casing may also house filters, dampers and other items.

5.12.3. GENERAL

Variable speed drives must be employed on all air handling units greater than 1000 l/s air flow. For VAV systems, these must be used for control of air flow; for CAV systems, these must be used for balancing and provide future flexibility.

Fans must comply with the fans section of this standard. Variable speed operation shall be achieved either by the use of 3 phase inverter drives, or EC motors, as appropriate to the application.

All fan coil units shall be provided with a minimum of a variable speed motor such as an EC motor.

Any AHU/FCU with a VSD provided for control purposes must come with a high-level interface (BACNET/MODBUS) which is connected to the BMCS.

5.12.4. CONSTRUCTION

AHU and FCU construction should generally be of double skinned sandwich panel construction, preferably modular type with easy and safe maintenance access. Minimum wall thickness to be 50mm. The design is to provide thermal breaks of the housing at corners.

Metal skin (sandwich panel): ≥ 0.55 mm base metal thickness factory pre-painted metallic-coated steel sheet.

Where a single skin casing or plenum is used, the internal insulation shall be faced with 0.55 mm thick perforated metallic-coated steel sheet with perforations of 2.5 mm diameter providing 10% open area applied to floor, ceiling and walls. Thickness of insulation shall be a minimum of 50mm fibre glass.

Metal skin (single skin): ≥ 1.2 mm base metal thickness factory pre-painted metallic-coated steel sheet or galvanized steel casing (if concealed). Unit to be painted if exposed in any location.

Casing stiffness:

Maximum deflection of casing: Under maximum internal-external pressure difference, provide casings having the lesser of the following:

- Maximum deflection permissible in AS 4254.2 Section 4.
- Maximum deflection consistent with correct operation and airtightness of the air handling / Fan Coil unit.

Coil access

General: Arrange coils so that both faces of each coil are easily accessible for inspection and cleaning in AHU's. FCU's (small sizes) can be close to each other with inspection from each side. Provide suitably located access panels and doors.

Mechanical Services Design Standards

5.12.5. FAN COIL UNITS

Casings

General: Provide the unit with an enclosure consisting of panels fabricated from sandwich panel or machine-folded sheet metal, reinforced where necessary with stiffening channels or angles, capable of supporting and retaining the components of the assembly without excessive noise and vibration. Provide adequate drainage.

Exposed units: Provide removable prefinished 1.2 mm metallic-coated steel cabinet.

Concealed units: Provide 1.2 mm galvanized steel casing for units located above ceilings or otherwise concealed.

Access panels: Provide access panels with quick release, captive fasteners. Do not use self-tapping screws.

Baffle plates: Close the space between the coil frames, fans and filters and the surrounding structure or equipment, with baffle plates. Seal gaps between coils and surrounding structure or equipment.

Coil supports: Support coils using the internal support frame of the unit.

Dissimilar metals: Provide neoprene gaskets to separate the mating surfaces of dissimilar metals. Provide non-metallic top hat washers in enlarged holes under nuts and bolts connecting dissimilar metals.

Condensate trays

General: Provide condensate tray or trays to collect all condensation occurring inside the unit. A trapped drain to waste shall be provided to maintain a sufficient column of water to provide an air tight seal under the greatest suction through pressure created by the unit. The drain shall terminate above a tundish or floor waste that is readily accessible and sighted for maintenance. Traps to be Easy Trap cleanable traps.

Material: Aluminium to AS/NZS 1734, or stainless-steel sheet grade 304L.

Provide a safety tray under the fan coil unit including the valves (isolation, balancing and motorised valves) to the unit, with condensate drain to waste.

Supply fans

Type: Provide direct driven tangential, forward curved centrifugal, or plug fan selected to make sure that the operation point is within the stable region of the fan's characteristic performance curve. Provide fans selected to deliver the scheduled air flow at $\leq 80\%$ of highest speed.

Construction: Galvanized steel wheels and casings. Balance and provide self-aligning sealed for life ball bearings.

Insulation

Insulation: Insulate and vapour seal to prevent condensation on the outside of unit under all operating conditions. K-value $\geq 0.4 \text{ m}^2\text{K/W}$ or higher if required to satisfy BCA or MEPS.

Connections

General: Provide isolating valves and unions at each unit so the fan coil assembly can be easily removed and replaced. Conceal piping to units exposed within rooms. Do not use flexible hose connections to fan coil units.

Electrical connection: Make all electrical connections to the unit through a terminal strip or multi-pin plug arranged to facilitate easy removal of the fan coil unit.

Duct connections: Provide flexible duct connections at unit.

Access panels – concealed fan coil units

General: Provide access panels for the following:

- Inspection and cleaning upstream and downstream sides of coils.
- Filter removal and replacement.

Mechanical Services Design Standards

Construction: Match the associated unit casing construction and insulation. Provide silicone rubber or soft neoprene gaskets. Provide minimum 2 wedge type sash latches and a handle on each panel.

Controls Provisions

All fan coil units shall be provided with a supply air temperature sensor for monitoring and/or control, in addition to the room and return air temperature sensor.

5.12.6. RETURN AIR

Return air must be ducted unless written approval from MUP is given.

5.12.7. FRESH AIR

Fresh air must be ducted from outside of plantrooms and spaces unless written approval from MUP is given.

5.12.8. COILS

Cooling coils:

- Air pressure drop when wet ≤ 150 Pa.
- Water pressure drop ≤ 30 kPa.
- Face velocity ≤ 2.5 m/s.
- Fin pitch ≤ 480 fins/metre.

Heating coils:

- Air pressure drop ≤ 70 Pa.
- Water pressure drop ≤ 20 kPa.
- Face velocity ≤ 3.5 m/s.
- Fin pitch ≤ 550 fins/metre.

Fins:

Provide plate fins to copper tubes.

Spacing: Space equally, perpendicular to the tubes.

Fin collars: Provide adequate control of fin spacing and provide a permanent mechanical bond between the tubes and the plate fins, by expanding tubes into fin collars, so that fin collars completely cover the tubes.

Material: Aluminium alloy to AS 2848.1, designation 3003 or 8011. Provide anti-corrosion treatment where ambient conditions may be corrosive. NOTE: Use copper fins on copper tube, electro-tinned after manufacture, for large AHU's greater than 10,000 l/s.

Thickness:

Aluminium alloy: ≥ 0.12 mm. Suitable for pressure cleaning.

5.12.9. DRIP TRAYS

Drip trays must be provided at each coil section, and connected to a main AHU / FCU drain. Drip tray must be manufactured from stainless steel. Drain pipework to be min 25mm.

A trapped drain to waste shall be provided to maintain a sufficient column of water to maintain an air tight seal under the greatest suction pressure created by the unit. The drain shall terminate above a tundish or floor waste that is readily accessible and sighted for maintenance. A transparent plastic tube section is to be provided at the coil end to provide an inspection point for blocked drains.

5.12.10. ACCESS DOORS AND PANELS

General: Provide an access door or panel in each section of the air handling units to which access is required for maintenance, inspection or removal of components. Provide access panels with quarter turn cam lock type fasteners. Do not use self-tapping screws.

Mechanical Services Design Standards

Door handles shall have a spring-loaded mechanism that will maintain pressure on the door seal over time.

For large AHU's (greater than 3000 l/s) access doors are to be provided.

Emergency fan shut off switch

Requirement: If the combination of internal pressure, door swing and door size is such that the door cannot reasonably be opened from the inside while the fan is running, provide an emergency fan shut off switch adjacent to the door inside each AHU section affected.

5.12.11. SERVICE LIGHTS

General: Provide waterproof fluorescent luminaires in each compartment with an access door or removable panel:

- Air handling units < 500 L/s: Not required.
- Air handling units ≥ 500 L/s < 10,000 L/s: One 18-watt compact fluorescent luminaire.
- Air handling units $\geq 10,000$ L/s: One 36-watt fluorescent luminaire or two 18-watt compact fluorescent luminaires.

Switching: Connect to a common switch located outside the chamber. If exposed to weather provide a weatherproof switch. Label the switch and provide pilot light to indicate when the lights are on.

Ensure adequate lighting for inspection and servicing.

5.12.12. FILTERS

Each air handling unit must be provided with pre-filters and high efficiency bag filters. Pre-filters must be minimum G4, and bag filters minimum F6. Higher grades of filtration may be required, depending on factors such as location and the application. The consultant/design contractor shall carefully consider the application and ensure the appropriate level of filtration is selected, in consultation with MUP.

Small fan coil units shall generally be provided with a single panel filter (minimum G4) unless the application requires a higher level of filtration.

5.12.13. MIXING PLENUMS

Mixing plenums for return and outside air must be of the same construction as the main body of the air handling unit. Opposed blade dampers must be provided at duct connections for balancing. Sufficient strait duct must be provided to allow accurate measurement of the air flow from each source RA/FA.

Mixing plenums for fan coil units must have a minimum of 50mm thick (or greater if required by BCA) acoustically insulated galvanised sheet metal casing, of the same gauge of sheet metal as required for the FCU.

A room cannot be defined as a plenum if equipment is located within the space. The area will be defined as a plant room as per MQP space designations. The designer or builder will not be allowed to define the space.

5.12.14. FACE BYPASS DAMPERS

Where an AHU supply air volume is above 8000L/s, coil face bypass dampers must be utilised to reduce fan static while operating on economy cycle.

5.12.15. LOCATION

All air handling units and multiple FCU's must be located in plant rooms with appropriate access for maintenance. Small FCU's will be mounted on a 1.2-metre-high frame on a plinth to allow easy maintenance of the equipment. Single room FCU's will be located as appropriate in the ceiling void.

Maintenance access must be provided to all components of the air handling unit or FCU. Minimum free space around service points will be a square area 600mm x 600mm unless approved by MUP. Larger AHU's will have adequate clearance for access e.g. 700mm to 900mm in front of access doors. Safety in design is of paramount importance.

Mechanical Services Design Standards

A plant room is defined as a room housing a single AHU or multiple FCU's servicing a floor as the main air conditioning unit. Plant rooms will have a single MCC which will have electrical supply to all equipment in the plant room including all controls associated with the floor and plant areas. They will be supplied from the main plant room electrical panel.

5.13. HEAT RECOVERY

5.13.1. PREFERRED SUPPLIERS

Preferred suppliers of dedicated heat recovery units include:

- Armcor
- Airchange
- Air Design
- Flaky Woods

Other suppliers will be considered subject to detailed review by MUP.

Heat recovery may also become an integral part of most modular air handling units and several packaged air conditioning units. Where this is possible or compatible with the system design this is preferred as it leads to rationalisation of plant and equipment.

5.13.2. GENERAL

The installation of an air to air heat exchanger setup must be assessed on each system design where there is exhaust or relief air from a space. The designer is to perform an assessment of the annual energy savings from the installation of the heat recovery system with consideration of additional fan energy required for the heat exchanger offsetting the reduction in cooling/heating energy requirements. Where the life cycle cost meets the University's investment criteria it should be included in the design.

Heat exchangers shall utilise bypass dampers when conditions for heat recovery are not favourable.

Counter flow plate type heat exchangers should be used due to their higher efficiency when compared to a cross flow heat exchanger.

The exhaust air stream used for the heat recovery shall not compromise the air quality supplied to the occupied space. Consider whether sensible only or sensible plus latent heat recovery is required based on the source of exhaust/relief, as well as the appropriate heat exchange media in terms of durability, efficiency and air quality.

Options to be considered include, but are not limited to:

- a. Energy Recovery wheel – total or sensible only
- b. counter flow plate exchanger – total or sensible only
- c. Run around coils – consider where air streams are remote from each other or where complete separation of air streams is required.

5.14. CHILLED WATER/ HEATING HOT WATER/CONDENSER WATER PIPEWORK

5.14.1. DESIGN

Future expansion allowances must be made when designing and sizing chilled/hot water pipe work reticulation systems with practical considerations of the steps in each pipe size.

Pipework systems must be designed and configured such that they assist in balancing inherently and reduces the reliance of high throttling of valves due to high system pressure difference between various legs. Reverse return systems shall be used in applications such as chilled beams, radiators, or in other instances where a self-balancing arrangement may be required or otherwise desirable.

Insulation provided on pipe work must be compliant with Section J: Energy Efficiency of the National Construction Code (NCC) and must have zero ozone Depletion Potential (ODP). Minimum thickness shall be 32mm Polystyrene / fibre glass or equivalent R value in other materials. Material to suit the application.

Mechanical Services Design Standards

5.14.2. PIPE SIZING

Pipework systems must be sized with considerations to flow rates, velocities and friction rates, to minimise noise, erosion and energy consumption.

The following are guidelines for velocities and friction rates:

Diameter in mm	Velocity in m/s
15,20,25	0.5,0.7,1
50	1.5
100	1.5
150	1.8
200	1.8
250	2.2
300	2.5

The friction rate of 100 - 300 Pa/m is considered a target range for most sizes; for smaller sizes (25mm or less) and in exceptional circumstances this may be exceeded, but to no more than 400 Pa/m.

Pipe sizing and design arrangement shall facilitate accurate balancing with a minimum of pressure loss.

Above velocities will not be exceeded unless approved in writing by MUP as this allows for increased flows for future expansion in branches.

5.14.3. PIPE MATERIAL

Pipework material must be as per the table below:

Chilled water and heating water	Copper to AS 1432 Type B, hard drawn.
Condenser water	Copper to AS 1432 Type B hard drawn, Stainless Steel Pipe to ASTM A312/A312M, or spiral butt welded from stainless steel sheet. Grade 316L.
Condensate drain	Copper to AS 1432 type B UPVC pressure pipe may be used on short runs only.

5.14.4. PIPE JOINTS

Fully silver solder all joints in copper piping in accordance with all relevant Codes. All bends must be pre-form bends with no flattening or corrugation of the pipework. Press set fittings such as Viega are generally not allowed unless specifically approved by MQP. Where approved these fittings will only be acceptable up to a maximum diameter of 32mm only, above 32mm fully silver soldered joints are required.

5.14.5. PIPE SUPPORTS

Mechanical Services Design Standards

All pipes must be adequately and substantially supported and restrained both horizontally and vertically using a proprietary support system. Pipework adjacent to equipment mounted on vibration isolation mounts must be arranged to provide adequate flexibility to ensure vibration is not transmitted to the building structure. Sprung pipe supports are required to prevent damage to the pipes.

All supports must be constructed from zinc plated galvanised steel with contact between dissimilar metals prevented by non-conducting isolating materials. A specially moulded PVC insulation strip will be used as supplied by the clamp supplier. Tape will not be used in any circumstances.

Support type: Proprietary metallic-coated steel channel section with clamps and hangers sized match external diameter of pipe being supported. Fit moulded plastic end caps to all channel.

Vertical pipes: Provide anchors and guides to maintain long pipes in position, and supports to balance the mass of the pipe and its contents.

Change in Direction: Provide a support at each change of direction.

Saddles: Do not provide saddle type supports for pipes \geq DN 25.

Uninsulated pipes: Clamp piping supports with non-conducting isolating material between support and pipe. Special material supplied by the support company shall be used as a separator. Tape will not be used.

Insulated pipe support:

- Spacers: Provide spacers at least as thick as the insulation between piping supports and pipes. Extend either side of the support by at least 20mm.
- Spacer material: Rigid insulation material of sufficient strength to support the piping and suitable for the temperature application.
- Vapour barriers: For cold pipes apply aluminium foil tape over the circumference of the spacer to form a vapour barrier.
- Metal sheathing: Provide a 0.55 mm thick metallic-coated steel band between the aluminium foil tape and the support, for twice the full width of the spacer.

Pipe support spacing table

<i>Nominal pipe size, DN</i>	<i>Maximum spacing (m)</i>	
	<i>Horizontal</i>	<i>Vertical</i>
≥ 10	1	2
$\geq 15, \geq 20$	1.5	2.5
25	2	3
32	2.5	3
40	2.5	4
50	3	4
65	3	4
80, 100, 125, 150	3	4

5.14.6. CLADDING AND INSULATION

Mechanical Services Design Standards

All CHW/HHW pipe work that is exposed to view or weather or inside a plant room must be insulated and encased in Metallic-coated sheet steel, 0.55mm minimum thickness coating class Z275 (painted) or Colourbond cladding. NOTE – ALUMINIUM SHEATHING WILL NOT BE ACCEPTED.

All pipework must be identified and labelled along its entire length in accordance with AS1345. Paint colours shall be in accordance with the MUP Approved Paint Colours for services identification.

All exposed pipework in plant rooms and risers must be fully painted and clearly labelled to indicate the purpose of the pipework. Direction of flow and, if relevant, hazards.

Insulation must be provided to chilled water and heating hot water piping to comply with NCC (BCA) requirements. Minimum thickness to be 32mm and R value is to be a strait calculation of radial thickness multiplied by the thermal conductivity @ 20C. No other calculation method will be used.

Moulded polystyrene section must be used for cold piping with an appropriate vapour barrier.

Mineral wool or glass fibre must be used for hot piping only.

Pipework metal sheathing:

General	Provide metal sheathing in plant rooms, in any room or space where insulation is exposed to mechanical damage, where exposed to weather, and on valves, pipeline components and pumps in sheathed pipework. Sheathing shall be continuous under brackets. All piping is to be sheathed in the plant room and where exposed to view. Sheathing to limited heights or runs are not approved and sheathing will be installed on all exposed pipe.
---------	---

Service	Location	Material
Chilled and heated Water	Plant Room/exposed to view/outside	0.55mm (min) colorbond. NOTE – ALUMINIUM SHEATHING WILL NOT BE ACCEPTED.
Chilled and heated Water	Sterile environment	0.55mm Stainless Steel 316

Joining			
Run	Lap	Location of lap	Riveting or banding
Horizontal	40mm min	Facing down	Stainless Steel pop rivets and be riveted with 100mm uniform spacing or banding using 12 x 0.55 mm straps in stainless steel or colorbond to match.
Vertical	As above	Sheltered	As above

Supports:

General	Inlet & outlet pipe work will not suffice as supporting of any equipment. Equipment must be supported separately to the inlet and outlet pipework.
---------	--

Mechanical Services Design Standards

	Also comply with the following AS 3500.1 2003. Table 5.2 Spacing of Brackets and Clips AS 3500.2 2003. Table 9.1 Maximum Spacing of Brackets, Clips and Hangers AS 3500.4 Heated Water Services
Channels	Use purpose made galvanised mild steel channel equal to “Nova Strut” series N1000 or N3300, complete with purpose made fittings. Provide plastic end caps on exposed brackets.
Insulation Barrier Locations	To be placed between the steel clamps and copper/steel/uPVC pipes
Insulation Barrier Material	Use purpose made PVC insulation barrier or block. Specially manufactured two-part blocks for each pipe size used in the following materials: - Hardwood in internal locations only - Polyurethane or polyethylene foam where exposed to weather or high moisture levels. Width of blocks must be minimum of 60mm. If the pipework is insulated, the diameter of this insulation material after it has been applied to pipe work must be the same as the diameter of the insulated pipe.
Fasteners	Galvanised bolts, nut and washers of adequate size. Do not use bright zinc coated.
General spacing and supports	Use minimum of two (2) fixing for each support Every 2 meters for pipework $\geq 100\text{mm}$ in diameter Separately support valves within pipework of 200mm or greater

Pipe Hanger Rod Diameters

<i>Pipe size (mm)</i>	<i>Rod diameter (mm)</i>	<i>Pipe size (mm)</i>	<i>Rod Diameter (mm)</i>
15-25	8	150-200	20
32-50	10	225-450	25
65-100	15		

5.14.7. PRESSURE TESTING

Each system must be pressure tested to 2 times the design operating pressure. The test pressure must be held for 24 hours as a minimum. The consultant/designer must be responsible for advising the designed system pressure and check the contractor’s proposed testing pressure.

5.14.8. FLUSHING OF PIPEWORK

Mechanical Services Design Standards

Each system must be precleaned and flushed to drain at flushing velocities as dictated by BSRIA AG.1/2001 to eliminate dirt in the system. The flushing shall occur prior to connection of any terminal equipment such as fan coil units, air handling units, chilled beams, any coils or heat exchangers or the like. Records must be provided showing the flushing velocity achieved in each section of pipework, typically as recorded by zone and branch balancing valves. The designer shall incorporate adequate provisions in the system to allow this to occur, such as flushing bypass loops, and adequate provisions for flow measurement.

A hold point for inspection prior to connection of terminal equipment or heat exchange equipment must be specified.

5.14.9. USE OF AIR AND DIRT SEPARATORS

Designers must incorporate an air and dirt separator into all chilled water, heating hot water, and closed loop condenser water systems. The air and dirt separator shall be located in the warmest part of the circuit. It shall be provided with isolation valves either side, and a bypass line with an isolation valve that is normally closed. The bypass line is used for maintenance only to allow cleaning/removal of the air and dirt separator.

The air and dirt separator must be piped to a suitable drain, and include a section of clear drain pipe (transparent plastic/Perspex tube) for visual checking of the drain water clarity. The purge valve on top of the separator will also be drained to a tundish as per standard drawing.

5.14.10. DEAD LEGS AND FLUSHING LOOPS

Dead legs will be installed with small bore piping containing isolation valves, test points etc. together with a flow regulation valve set to pass a nominal amount of water through the branch. This is to maintain water movement through the dead leg section. Drains and air bleeds will be installed to allow the system to have all air removed and to allow drain down when further extension of the pipework is undertaken.

These will also serve as flushing loops when cleaning the system. Please refer to the standard coil drawings for flushing loop requirements. Loops must be flushed at commissioning.

5.15. VALVES

5.15.1. GENERAL

Valves should be sized equal to the nominal pipe size, unless a smaller size is required for throttling, balancing and measurement, or for control valve authority.

Insulated valves: Provide extended shafts or bodies to butterfly and ball valves to allow full thickness of insulation without restricting movement of hand-wheel or lever.

Connections:

- Valves \leq DN 50: Screwed to AS ISO 7.1.
- Valves $>$ DN 50 and valves in headers: Flanged to AS 2129

Installation

Valves: If practicable, install with the stem horizontal.

Non-return valves: Provide at least 6 pipe diameters of straight pipe on the upstream side.

Flow measuring valves: Install with pressure tappings accessible and to manufacturer's recommendations.

Valve Identification

General: Tag all valves and flow measuring devices for identification purposes. Provide a circular brass disc attached to the valve by a stainless-steel wire drawn through the holes in the disc on each valve provided with operating hand heel or lever stamp the valve identification mark on the disc in characters 10 mm high. Refer to drawing No M01 – Valve Tag Details.

Mechanical Services Design Standards

Valves without operating hand wheels: Mark by aluminium or brass strap 20 mm wide by 90 mm long stamped in the same manner as the valve identification discs. Attach by wire to the body of the valves.

Balancing Valves

Balancing valves must be sized so that they do not need to be throttled below 25% of their adjustable range. Non-calibrated valves will not be used as balancing valves.

Calibrated balancing valves

Description: Continuously adjustable graduated with a limit stop for precise setting of the maximum valve opening, a numeric indication of valve opening position and pressure tappings across the variable orifice.

Preferred Suppliers:

- TA Hydronics
- Oventrop

Accuracy and repeatability errors: $\pm 5\%$ or better over the normal measuring range of the valve.

Handwheel scale resolution: $< 2.5\%$ of full scale.

Construction:

- Body:
- \leq DN 50: Dezincification resistant copper alloy of Brinell hardness > 130 .
- $>$ DN 50: Cast iron.
- Seat: PTFE.

Balancing valves shall have hand wheel setting and flow rate stamped on the disc. This must not be easily removed. The hand wheel shall be locked at the required setting following completion of balancing.

Automatic/dynamic system balancing valve

Description: Pre-calibrated special purpose valve which automatically controls flow rate within $\pm 5\%$ tolerance, with an internal spring-loaded cartridge control mechanism and external tappings for pressure and temperature.

Preferred Suppliers:

- TA Hydronics
- Oventrop
- Frese
- Belimo

Construction:

- Body: To suit the piping and fluid as documented.
- Cartridge: Passivated stainless steel, spring loaded type, incorporating a variable ported piston stamped with the manufacturer's identification number

Pressure Independent Automatic Control Valves

Preferred supplier:

- Belimo Pressure Independent characterised control valves (PICCV) type.
- Danfoss
- Frese

Where it is proposed to utilise PICCV's, they shall be used in lieu of calibrated balancing valves at terminals (heating/cooling coils).

However, the following means of flow verification shall be provided:

Mechanical Services Design Standards

- Calibrated balancing valves or orifice plates at each main branch sized and set for full flow.
- Binder points on either side of the PICCV and across the terminal device.
- Binder points on flow/return of each branch line
- An end of line three-way valve CCV with a flow regulation valve is to be fitted.
- An end of line DP transducer will be fitted to verify the correct system pressure to suit the PICCV's has been maintained. In simple systems, a single sensor is required. In systems with branches that may change to become the index run at different loads, then more sensors will be required. The designer must determine how many sensors are required and obtain approval from MUP.
A field DP sensor is always required combined with a bypass valve.

Care shall be taken in the design and installation of the pipework system to ensure that the minimum required pressure differential can be achieved across the PICCV at all times to ensure it operates in accordance with its design intent.

Control Valves

Control valves will be characterised ball valves and will have a characteristic to match the duty required. Coils will have an equal percentage characteristic to suit the coil characteristic such that a linear response of flow to valve % open is achieved.

These will have a flow regulation valve in series with the valve on the leaving side of the coil to allow for balancing.

A bypass valve will have a linear characteristic so that the percentage of flow is a linear response to valve % open.

Ball valves will be used in all cases as their pressure loss is less than other types of valve.

Globe valves are not encouraged for control function using motorised valves.

- Belimo characterised control valves (CCV) type.
- Danfoss characterised control valves.
- Frese characterised control valves

5.15.2. WATER VALVE TYPES

Water valve table

<i>Valve function</i>	<i>Valve type</i>
Isolating valves ≤ DN 50	Copper alloy gate, ball or diaphragm
Isolating valves ≥ DN 65	Butterfly, cast iron gate or diaphragm
Non-return valves ≤ DN 50	Copper alloy lift or swing check
Non-return valves ≥ DN 65	Cast iron lift or swing check
Throttling or balancing valves ≤ DN 50	Copper alloy globe, needle or diaphragm
Throttling or balancing valves ≥ DN 65	Cast iron globe or diaphragm
Throttling or balancing valves (No size limitation)	Calibrated balancing

Mechanical Services Design Standards

<i>Valve function</i>	<i>Valve type</i>
Level control valves ≤ DN 50	Copper alloy ball float
Level control valves ≥ DN 65	Cast iron ball float
Pressure relief valves ≤ DN 50	Copper alloy
Pressure relief valves ≤ DN 50	Cast iron
Strainer ≤ DN 50	Copper alloy
Strainer ≥ DN 65	Cast iron
Pressure reducing valves ≤ DN 50	Copper alloy
Pressure reducing valves ≥ DN 65	Cast iron
Automatic air vents ≤ DN 50	Copper alloy
Bleed valves ≤ DN 50	Ball
Gauge valves ≤ DN 50	Ball
Drain valves ≤ DN 50	Ball
Control Valves	Ball PICCV or CCV to suit application

All other valve types will be subject to MUP approval for their use. Globe valves will generally not be used for control functions, due to high pressure loss.

Mechanical Services Design Standards

5.15.3. SENSING POINTS

Test plugs: Provide in each pipe connection to every heat exchanging device, thermal plant (chiller, boiler, heat rejection plant), pump, automatic control valve; adjacent each sensor well, across each branch pipework to enable pressure drops across, and flow/return temperatures of each major branch in a system; and at other locations where temperature and/or pressure may be required for commissioning, maintenance, calibration of sensors, or the like.

Thermometer wells: Provide for each pipe mounted temperature sensor.

Test plugs

Selection: Suitable for the service fluid and up to the maximum system pressures and temperatures.

Material: Machined brass hexagon body with Nordel synthetic rubber cores and gasketed brass hexagon screw cap.

Installation: Screwed into sockets welded to pipes and extended above insulation.

All pressure, temperature sensors must have a test point within 150mm to calibrate the sensor.

Thermometer pockets

General: Arrange for use with glass stem thermometers. Use the same material as the pipe. Weld or braze to pipes. Fill pockets with conductive medium.

Length: Extend to within 5 mm of opposite pipe wall and extended above insulation.

Pipe enlargement: If thermometer pocket would otherwise decrease the pipe cross sectional area by more than 25%, provide a length of larger diameter pipe at the location to mount the pocket.

Thermometer wells

General: Provide stainless steel thermometer wells of the separable type to enable the sensing element to be withdrawn without draining the system. Screw wells into a boss welded to the pipe, to suit the installed sensing element and extended above insulation. Fill wells with conductive medium.

5.15.4. VALVES IN THE CEILING SPACE

All chilled water and heating water and any other valves in the ceiling space and which are subject to sweating must be insulated.

Access panels must be provided at each valve located within ceiling spaces to allow service access.

5.15.5. VALVE UNIONS

All screwed valves and fitting must have unions to allow removal of the valve or the equipment it serves without dismantling an extensive amount of pipework.

5.15.6. CONNECTIONS TO EQUIPMENT

Isolating valves must be used at connections to all items of plant and equipment.

Connections must allow the removal of the plant without removing a large section of pipework or draining the system.

5.15.7. BINDER COCKS

Must be fitted to all headers, all thermal plant (chiller, boilers, cooling towers flow and return connections), heat exchangers, each flow and return branch connection from a riser or main distribution pipework run, all flow and return lines to air handling units/ fan coil units, water cooled packaged unit, adjacent to all BMCS sensors, and across all motorised valves. Refer to standard design drawings.

5.15.8. VENTS, AIR AND DIRT SEPARATORS

Manual or Automatic Air vents must be provided at the highest points of the system and all other points where air may collect. This includes all connections to fan coil units, heating coils, and other terminal devices.

5.16. CONDENSATE DRAINS/SAFETY TRAYS

5.16.1. GENERAL

All drainage must comply with local planning and water authority requirements.

5.16.2. CONDENSATE PUMPS

The use of condensate lift pumps should be avoided wherever possible. Where it is proposed to use condensate lift pumps, it must be demonstrated to MUP that all practical options available have been considered and there remains no practical means of achieving gravity drainage. If condensate lift pumps are required, they should be integral to the fan coil unit, such as in split systems or VRF/VRV systems, and interlocked with the unit to switch off the unit on failure of the pump, as sensed by level switch or equivalent.

5.16.3. SIZING AND MATERIAL

Condensate drain pipework must be minimum 25mm diameter.

Drain pipework must be run in hard drawn copper if greater than 1 meter to the drain point.

5.16.4. CONDENSATE WASTE DRAIN INSULATION

All condensate waste pipework must be insulated for its full length from the respective indoor fan coil unit. Where copper or ABS is installed for condensate waste drain pipework, insulation must be minimum 12mm thick.

5.16.5. CONDENSATE TRAP

Either Barrel unions to be fitted to all traps or a clear trap with the access ports for maintenance of the traps is to be used to allow the ability for easy maintenance access. Easy trap or equal. The trap must be suitable for the fan duty required.

5.16.6. CONDENSATE DISCHARGE

All Condensate water is to be discharged to waste line only. All condensate drain lines must be plumbed and installed independently to the discharge point of the drain. A tundish must be fitted to the drain point in accordance with water board requirements.

5.16.7. SAFETY TRAYS

Condensate and safety trays must be independent of FCU, construction to be stainless steel.

Tray to cover associated valves and be fitted under all mechanical FCU's, AHU's and package units.

The tray is to be suitably strengthened using angles or Unistrut sections to allow the tray to support water filled to 50% of its depth without collapse.

5.17. SPLIT SYSTEMS

5.17.1. PREFERRED SUPPLIERS

Preferred suppliers are:

- Mitsubishi Electric
- Daikin;
- Actron;
- Temperzone.
- Carrier

Other alternative equivalent manufacturers can be considered subject to approval by MUP.

5.17.2. GENERAL

Condenser Unit casing must be weatherproof constructed from powder coated anti corrosion treated galvanised steel.

Location of condenser must be such that it does not create any noise and/or aesthetic issues. Designers shall obtain approval from the architect (if applicable) and MUP for locations of condensers.

Compressors must be inverter driven.

Condenser fins to be coated with epoxy or other durable finish suitable for a marine environment.

All external interconnecting pipework and cables must run within metal trunking or sheathing of appropriate colour and appearance to match the context of the building. Exposed wiring or conduits and insulation is unacceptable.

Insulation of refrigerant pipework shall be in Armaflex or equal. White low-grade insulation on coil pairs are not acceptable.

BACNET HLI to be provided, to allow interface with the Macquarie University site wide BMCS, unless specifically approved by MUP as not being required.

Required wall controller points

- Wall mounted controller with in-built temperature sensor
- On/off switch
- Daily reoccurring programmable off/on delay timer
- Fan speed selector
- Temperature set point adjustment
- Self-diagnostic function
- Liquid Crystal display
- Current space temperature
- System temperatures

When interfaced with BMCS, the BMCS must be able to override the local controller.

Refrigerant – R410A.

5.18. VRV/VRF

5.18.1. PREFERRED SUPPLIERS

Preferred suppliers are:

- Mitsubishi Electric;
- Daikin;

Other alternative equivalent manufacturers can be considered subject to approval by MUP.

5.18.2. GENERAL

Location of condenser must be such that it does not create any noise and/or aesthetic issues. Designers shall obtain approval from the architect (if applicable) and MUP for locations of condensers.

Multistage inverter driven compressors shall be provided.

Condenser fins to be coated with epoxy or other durable finish suitable for a marine environment.

Condenser Unit casing must be weatherproof constructed from powder coated anti-corrosion treated steel.

All external interconnecting pipework and cables must run within metal trunking or sheathing of appropriate colour and appearance to match the context of the building. Exposed insulation is unacceptable.

Insulation of refrigerant pipework shall be in Armaflex or equal.

BACNET HLI to be provided, to allow interface with the Macquarie University site wide BMCS, unless specifically approved by MUP as not being required.

Required wall controller points

- Wall mounted controller with in-built temperature sensor
- On/off switch
- Daily reoccurring programmable off/on delay timer
- Fan speed selector
- Temperature set point adjustment
- Self-diagnostic function
- Liquid Crystal display
- Current space temperature
- System temperatures

When interfaced with BMCS, the BMCS must be able to override the local controller.

Refrigerant – R410A.

Mechanical Services Design Standards

5.19. **REFRIGERANTS & REFRIGERATION PIPEWORK**

5.19.1. REFRIGERANT TYPE

Refrigerants must be non-ozone depleting and have low global warming potential (GWP). The following refrigerants are the acceptable to MUP:

- R134A,
- R410A
- R404A
- R507

Other alternatives may be considered by MUP provided a detailed submission outlining the benefits to the University is submitted for consideration and approved.

Natural refrigerants may be considered based on project specific requirements, subject to a detailed review by MUP.

As natural refrigerants are flammable and explosive in nature the use of these refrigerants should be restricted to small systems or specifically designed equipment and only specialist repairers should be used in maintenance.

5.19.2. REFRIGERANT RECOVERY

Refrigerant must be reclaimed and disposed of in accordance with Australian refrigeration handling guidelines. Certification of recovery must be recorded and provided to MUP upon completion of works.

For systems with large refrigerant volume, consider use of refrigeration recovery systems and present to MUP.

5.19.3. REFRIGERANT PIPE WORK

5.19.4. PIPES

Piping: Provide copper tubes as follows:

- To AS/NZS 1571, H temper.

Pipe wall thickness:

- Pipes \leq DN 50: To AS 1432 Type B.
- Pipes $>$ DN 50: \geq 1.6 mm.

All refrigeration pipework shall be hard drawn copper tube to AS1571, except of small split systems up to 10kW cooling with less than a 10m pipework run.

Pressure rating of pipework shall be suitable for the refrigerant pressure used.

Provide necessary refrigerant circuit accessories, including the following:

- Discharge muffler (internal or external type).
- Liquid line filter drier.
- Liquid line sight glass moisture indicator, with cap to prevent exposure to sunlight.
- Suction, discharge and oil pressure indication, either gauges or digital readout from transducers via the microprocessor based control module, as appropriate.

Refrigerant charging: Provide for charging and withdrawal of refrigerant.

Pipework layout: Install pipework in straight lines and uniform grades without sags. Grade horizontal hot gas lines and suction lines at not less than 1 in 200 in the direction of gas flow.

Grade liquid lines to liquid receivers or traps to ensure oil return.

Make sure of positive oil return to the compressor. Prevent oil draining back into the head of the compressor during the off cycle. Do not form unnecessary traps in pipelines.

Mechanical Services Design Standards

5.19.5. EXTERNAL TRUNKING

All external pipework shall be mechanically protected. A maximum of 300mm vertical/horizontal run of pipework to final connection point may be run external to trunking. The trunking shall be water-shedding to avoid any ponding.

External trunking must be:

Material: Zinc coated steel, 0.55mm minimum thickness

Type: Rectangular with clip-on lid. (Screw fix for safety where on outside of building)

Finish: Colorbond to match external building/roof colour as applicable.

5.19.6. PIPE JOINTS

Fully silver solder all joints in copper piping in accordance with all relevant Codes. All bends must be pre-form bends with no flattening or corrugation of the pipework. Use dry Nitrogen during welding.

5.19.7. PIPE SUPPORTS

All pipes must be adequately and substantially supported and restrained both horizontally and vertically using a proprietary support system. Pipework adjacent to equipment mounted on vibration isolation mounts must be arranged to provide adequate flexibility to ensure vibration is not transmitted to the building structure.

All supports must be constructed from zinc plated galvanised steel with contact between dissimilar metals prevented by non-conducting isolating materials.

Support type: Proprietary metallic-coated steel channel section with clamps and hangers sized match external diameter of pipe being supported. Fit end caps to all channel.

Vertical pipes: Provide anchors and guides to maintain long pipes in position, and supports to balance the mass of the pipe and its contents.

Saddles: Do not provide saddle type supports for pipes \geq DN 25.

Uninsulated pipes: Clamp piping supports with non-conducting isolating material between support and pipe. Special material supplied by the support company shall be used as a separator. Tape will not be used.

Insulated pipe support:

- Spacers: Provide spacers at least as thick as the insulation between piping supports and pipes. Extend either side of the support by at least 20mm.
- Spacer material: Rigid insulation material of sufficient strength to support the piping and suitable for the temperature application.
- Vapour barriers: For cold pipes apply aluminium foil tape over the circumference of the spacer to form a vapour barrier.
- Metal sheathing: Provide a 0.55 mm thick metallic-coated steel band between the aluminium foil tape and the support, for twice the full width of the spacer.

Pipe support spacing table

<i>Nominal pipe size, DN</i>	<i>Maximum spacing (m)</i>	
	<i>Horizontal</i>	<i>Vertical</i>
≥ 10	1	2
$\geq 15, \geq 20$	1.5	2.5
25	2	3

Mechanical Services Design Standards

<i>Nominal pipe size, DN</i>	<i>Maximum spacing (m)</i>	
	<i>Horizontal</i>	<i>Vertical</i>
32	2.5	3
40	2.5	4
50	3	4
65	3	4
80, 100, 125, 150	3	4

5.19.8. THERMAL INSULATION

All pipe work to be insulated with flexible closed cell sponge type material such as “Armaflex” or approved equivalent with minimum wall thickness of 19mm.

End joints must be neatly glued and taped with 50mm wide PVC tape of colour similar to the insulation.

Insulation must not be split or zippered type.

5.19.9. TESTING AND EVACUATION

All pipe work to be tested to twice the operating pressure. Dry Nitrogen will be used during welding and testing.

Evacuation will be required to meet a vacuum test of 500 micron or less. This must be held for 1 hour minimum and witnessed by an MUP representative. On completion of the test the system will be filled with refrigerant to the manufacturers requirements.

Mechanical Services Design Standards

5.20. DUCTWORK

5.20.1. GENERAL

All ductwork design and installation must meet the requirements of current AS4254, allow adequate provisions for maintenance and commissioning, and be designed to achieve low energy consumption and satisfy the project acoustic requirements.

In the design of the ductwork system, ensure the following:

- a. The system configuration must assist in the balancing of the system so that it does not rely on over throttling of dampers.
- b. Ductwork velocities must follow good design practice and not exceed levels that will compromise the acoustic criteria of noise sensitive spaces. The following points provide maximum velocities that are used in general, non-critical areas such as classrooms and office space. These velocities are considered to be the upper limit of what is acceptable:

- i. Main or riser duct, maximum velocity of 7m/s.
- ii. Horizontal mains or main branches on floor, maximum velocity of 5m/s.
- iii. Final branch ducts, 3.5m/s
- iv. Flexible ducts, 2.5m/s

Spaces with more stringent acoustic criteria will possibly require lower velocities and additional acoustic treatment.

- c. Friction loss shall not exceed 0.8 Pa/m for supply, return or outside air ductwork, or 1.2 Pa/m for miscellaneous unconditioned ventilation systems.
- d. Balancing dampers must be provided on each floor and at each branch. Use opposed blade dampers on any size supply duct and for all return and exhaust ducts. Splitter type only for supply branches up to 300 mm maximum dimension and with velocity in main < 5 m/s.
- e. Spigot dampers must be provided at each flexible duct connection. Do not exceed 15m between first spigot damper and last spigot damper on a branch, to avoid excess pressure being taken out by a spigot damper.
- f. Avoid the need for balancing dampers at diffusers or behind the face of grilles as this leads to noise generation in the room. This should be engineered out with good duct design and diffuser selection.

5.20.2. DUCT LEAKAGE TESTING:

- a. The designer shall determine whether ductwork leakage testing is required by AS4254 or for other reasons (e.g. reuse of existing ductwork, efficiency benefits, process benefits etc) for the project and if so, include it in the contract documents. In doing so, the designer shall specify the duct leakage class and allowable leakage rates. NOTE: "Systems" air quantity as mentioned in AS4254 shall comprise of the sum of all of the systems in the building. That is supply, return, exhaust etc. Only very small systems will not require leakage testing.
- b. The leakage test, if required, must be in accordance with SMACNA Standard: HVAC air duct leakage test manual, 2nd edition. Washington: SMACNA, (2012).

5.20.3. FLEXIBLE DUCT

Standard: To AS 4254.1.

Materials

Uninsulated flexible duct: Select from the following:

- Aluminised fabric clamped on a formed metal helix. Do not use adhesives. Reinforce lap joints in the fabric.
- Coated steel wire laminated between two layers of aluminised polyester fabric using fire rated adhesive. Reinforce lap joints in the fabric.

Mechanical Services Design Standards

Insulated flexible duct: As for uninsulated flexible duct with flexible blanket insulation wrapped around duct and covered with an outer vapour barrier.

Material R-value: To BCA Spec J5.2. A minimum R value of 1.0 is to be used where the BCA calls for a value less than 1.

5.20.4. FLEXIBLE CONNECTIONS

General

General: Isolate fans and conditioner casings from ductwork, by means of airtight flexible connections.

Materials:

- - Generally: Heavy duty, waterproof.
- - In kitchen exhaust ductwork: To AS 4254.2 clause 2.1.3.

Length: Provide sufficient slack free movement and vibration isolation under operating and static conditions.

Alignment: Align openings of connected equipment.

Fixing: Fix to attachments with metallic-coated steel strip. Seal joints. Do not paint flexible material.

Fire protection: To achieve the FRL of the attached duct when tested to AS 1530.4.

Maintenance: Arrange to permit easy removal and replacement without disturbing ductwork or plant.

Restriction: Do not protrude connections or frames into the airstream where this would be detrimental to the air flow.

5.20.5. VARIABLE AIR VOLUME UNIT (VAV)

Selection:

Maximum design air flow rate of each unit: Provide boxes selected for $\leq 80\%$ of the maximum rating shown in the manufacturer's catalogue.

Inlet velocity at documented air flow: ensure the velocity is high enough to provide accurate velocity sensing at the minimum flow range of the VAV, as well as a linear or almost linear control action.

Sensors must be removable for cleaning and inspection without disconnecting the ducting.

Noise Ratings: Provide terminals selected to conform to the requirements as documented in the VAV terminal noise rating schedule when operating at documented maximum air flow and a pressure drop across the terminal of at least 200 Pa.

Approved Manufacturers: Celmec (Only)

Site adjustment: Provide for site adjustment of the maximum capacity by $\pm 25\%$ of the design value.

Pre-completion tests:

Variable air volume boxes: Test fan motor assembly (fan assisted). Test volume dampers, wiring and controls. Check sequence of operation and pre-set air volume rate before shipment. Test operation of the damper actuator on the installed VAV box on site through multiple cycles of full range operation and ensure the actuator is securely fixed to the damper shaft via a proprietary mechanical fixing.

Ensure calibration of VAV boxes on site, and that K factors are documented in the commissioning records. Calibration of VAV boxes should be based on duct pitot velocity measurements.

Pressure independent boxes:

Control: Provide pressure independent boxes with an electronic averaging velocity sensor and factory fitted modulating volume control damper motor fully compatible with the control system.

Air volume tolerance: $\pm 5\%$ of set point value with inlet duct pressure varying from 50 to 400 Pa.

Fan assisted boxes:

Mechanical Services Design Standards

General: Provide fan assisted boxes where documented conforming to the following:

- Type: Series or parallel as documented.
- Fans: Forward curved centrifugal, direct drive with permanent split capacitor motor.
- Motors: Provide thermal overload. Provide terminal box external to the unit, wired to the fan.
- Speed control type: As documented in the VAV box schedule.
- Vibration isolation: Isolate the fan and motor from the terminal casing.

Casings:

Material: Metallic-coated steel, minimum 1 mm thick.

Leakage: < 1% at maximum operating pressure.

Fan assisted boxes: Provide access panels conforming to Ductwork with quick release fastenings, to allow fan removal with the box connected to the ductwork.

Duct connections:

- Inlet: Round, oval or rectangular, to suit application.
- Outlet: Drive slip or flanged.

Dampers:

Material: 1.6 mm minimum thickness metallic-coated steel or aluminium, with no deflection at inlet pressures.

Shafts: Bolt or weld blades to a continuous shaft rotating on self-lubricating nylon bearings.

Seals: Provide closed cell gasket seal. Preload blades to create a tight seal.

Leakage: < 2% of maximum primary air flow at static pressure differential of 250 Pa.

Internal insulation:

General: Conform to minimum required ductwork insulation except as follows:

- Insulation type: Semi-rigid glass wool or rock wool, 50 mm minimum thickness.
- Surface facing type: Factory applied perforated aluminium foil laminate.

Access panels:

General: Provide access panels to give access to each component located inside the VAV box that requires regular inspection or maintenance.

Construction: Conform to Access panels in the Ductwork work section.

Additional controls provisions:

Where VAV boxes are provided with electric or hot water heating coils, a downstream temperature sensor must be provided for verification of the functionality of the heating coil. This should be displayed on the BMS graphic for the VAV box.

5.20.6. VOLUME CONTROL DAMPERS

General: Provide dampers which are free of rattles, fluttering or slack movement and capable of adjustment over the necessary range without excessive self-generated noise or the need for special tools.

Face dimensions: Duct size.

Connections: Mating angle flanged cross joints.

Frames: 1.6 mm minimum thickness metallic-coated steel or 2 mm minimum thickness aluminium folded to form channel sections at least 150 mm wide and welded at corners.

Dampers required to provide tight shut-off: Comply with the Motorised dampers clause.

Dampers in smoke-spill systems: Metallic-coated steel or stainless-steel blades and frames.

Mechanical Services Design Standards

Blades

Material: Metallic-coated steel, aluminium or stainless steel.

Form: No sharp edges. Sufficiently rigid to eliminate movement when locked.

Minimum thickness:

- Metallic-coated sheet steel and stainless steel:
 - Single thickness blades: 1.6 mm.
 - Double thickness blades: 1.2 mm.
- Aluminium:
 - Single thickness blades: 2.4 mm.
 - Double thickness blades: 1.8 mm.

Maximum length: 1200 mm. If necessary, provide intermediate mullions.

Single blade dampers:

- For single thickness blades: 600 mm maximum length, 600 mm maximum width or 600 mm maximum diameter.
- For single thickness blades with 6 mm minimum edge breaks: 1200 mm maximum length x 175 mm minimum width.
- For double thickness blades: 1200 mm maximum length x 300 mm minimum width.

Multi-blade dampers:

- For single thickness blades with 6 mm minimum edge breaks: 1200 mm maximum length 175 mm minimum width.

Bearings

Type: Oil impregnated sintered bronze bearings, sealed-for-life ball bearings or engineering plastic sleeve bearings that do not require lubrication for the life of the duct system. If the operating temperature is more than 50°C, provide sealed-for-life ball bearings only.

Housings: Rivet to damper frames.

Spindles

Material: Stainless steel in stainless steel dampers, zinc-plated steel or stainless steel otherwise.

Construction: Securely fix to damper blades.

Minimum diameter:

- Blade lengths \leq 600 mm: 10 mm.
- Blade lengths $>$ 600, \leq 1200 mm: 12 mm.

Linkages

Fixing: Fix securely to blades so that the blades rotate equally and close tightly without slip.

Damper adjustment

Requirement: Provide a way to adjust the damper and lock it in position. Locate in an accessible position. Label the open and closed positions clearly and permanently.

5.20.7. SPLITTER DAMPERS

Construction

Standard: Fabricate to AS 4254.2 Figure 2.3 (H) with a minimum length 1.5 times the width of the larger branch.

Push rods: 5 mm diameter on 600 mm centres with screw locking bushes to fix position.

Mechanical Services Design Standards

5.20.8. MOTORISED DAMPERS

Construction

Requirement: To Volume control dampers and the following:

- Side seals: Aluminium or stainless steel.
- Blade tip seals: Neoprene or silicone rubber.
- Leakage: ≤ 25 L/s.m² at 1.5 kPa pressure differential.
- Bearings: Sealed-for-life ball bearings only.
- Drive shafts: Keyed, square or hexagonal.

Control characteristics

Flow characteristics: Linear flow relative to damper motor drive shaft rotation.

Type:

- Outdoor air/return air mixing dampers: Parallel blade type with air streams directed towards each other.
- All outside air dampers shall be of stainless steel construction.
- Face and bypass dampers: Parallel blade type with air streams directed towards each other.
- Other modulating dampers: Opposed blade type.
- Two position shutoff dampers: Parallel or opposed blade type.

5.20.9. NON-RETURN DAMPERS

Construction

Requirement: Conform to Volume control dampers. Counterweight the assembly so that it:

- Offers minimum resistance to air flow.
- Closes by gravity.

5.20.10. FIRE DAMPERS

Fire dampers in masonry walls shall be rated for 4 hours to AS 1682.

Fire dampers installed in floor slabs or plaster walls shall be rated for 2 hours to AS 1682.

Fire dampers shall be curtain type or blade type and shall be equal to I & M Industries ABC, Celmec Firelock, Bullock or High Fire Ruskin.

Curtain and blade type fire dampers shall have a fusible link which is readily accessible for maintenance. Blade type fire dampers shall close in the direction of airflow.

Fire dampers which are required to close automatically shall have an electro thermal link (ETL).

Intumescent fire dampers may be used subject to review by MUP.

Fire dampers in fume exhaust systems shall be type 316 stainless steel.

5.20.11. ACCESS OPENINGS – LOCATION

Access doors

Location: Provide an access door in each section of air handling units where access is required for maintenance, inspection or removal of components. Removable panels may be used instead of doors where access is required only for removal of coils.

Access panels

Location: Provide access panels in the following locations:

- Next to each component located inside the duct requiring regular inspection and maintenance

Mechanical Services Design Standards

including, but not limited to:

- Fire and smoke dampers.
- Smoke detectors.
- Motorised dampers.
- Filters.
- On the air entering side of electric duct heaters.
- On the air entering side of duct mounted heating coils.
- In air handling units where unit size is insufficient to fit an access door.
- Where specified in Kitchen exhaust.
- In the vicinity of moisture producing equipment, to AS/NZS 3666.1 clause 2.11.3.
- In other locations documented.

5.20.12. ACCESS PANELS

Sizes

Access panels: Minimum clear opening:

- Personnel access: 450 x 600 mm.
- Hand access: 200 x 300 mm.

Construction

Type: Double panel, deep formed, zinc-coated steel construction, insulated to match the duct, or filled with at least 25 mm glass wool or rock wool insulation.

Cold bridging: Arrange to prevent condensation on cold surfaces.

Frames: Provide rigid matching galvanized steel frames securely attached to the duct. Do not protrude any part of the panel or frame into the airstream.

Seals: Mechanically fixed to either the panel or the frame for an airtight seal against the operating pressure when latched in the closed position. Use a fixing method that permits easy replacement – as follows:

- Fire rated seals: Woven ceramic fibre material.
- Other seals, Silicone rubber or soft neoprene.

Latches: Wedge type sash latches.

Number of latches:

- For personnel access: 4.
- For hand access: 2.

Handles: Provide a 'D' handle on access panels for personnel access.

5.20.13. ACCESS DOORS

Construction

General: Provide rigid, reinforced access doors.

Thickness: ≥ 50 mm.

Construction: Provide either:

- Sandwich panel: As documented for wall and ceiling panels. Form door edging with a heavy gauge aluminium extrusion with double web seal to both skins. Mitre corner and firmly secure to panel with countersunk head screws.
- Folded: Two-piece press formed, or machine folded from ≥ 1.6 mm zinc coated steel.

Size: 1350 mm high x 600 mm wide clear opening or larger dimensions if:

- Necessary to permit safe removal of equipment inside the section, or
- Chamber: To BCA G1.2 in which case the minimum clear opening is 1500 mm high X 600 mm wide.

Mechanical Services Design Standards

Door swing: Except where the pressure differential would require an excessive force to open the door, swing doors against air pressure as follows:

- Doors on the inlet side of the fan: To open outwards
- Doors on the discharge side of the fan: To open inwards.

Cold bridging: Arrange to prevent condensation on cold surfaces.

Jamb, stiles and head: Rigid matching ≥ 2.5 mm zinc coated steel, or ≥ 3.0 mm PVC or fibreglass securely mounted.

Door hardware:

- Catches: Provide ≥ 2 heavy duty proprietary clamping-type latches with permanently attached handles that can be operated from both the inside and the outside of the door. Provide satin chrome plated finish to exterior components.
- Hinges: Hang doors on edge-mounted, rising butt type self-closing hinges capable of holding the door fully open. Construct from chrome plated brass or heavy-duty aluminium alloy. Provide stainless steel hinge shaft and nylon bearing surfaces.
- Installation: Securely bolt hardware to the door and frame by a method which minimises cold bridging and prevents the forming of condensation on the outside of the conditioner.

Seals: Mechanically fixed to the door to create an airtight seal when latched closed. Use a fixing method that permits easy replacement.

- Fire rated seals: Woven ceramic fibre material.
- Other seals, Silicone rubber or soft neoprene.

Insulation: 50 mm thick. Construction and insulation properties to match the insulation of the duct, plenum or casing in which the door is located.

5.20.14. INSULATION

All supply and return ductwork must be thermally insulated to meet NCC (BCA) “deemed to satisfy” (DTS) requirements. All exhaust ductwork which may be subject to surface condensation must also be insulated. Special attention is drawn to high temperature exhaust ducts such as kitchen exhaust and/or exhaust from dishwashers/sterilisers when they travel through a space with a lower environmental temperature.

Internal insulation shall be used where the duct is exposed to view or susceptible to damage, in plant rooms, exposed to weather, or where required for acoustic treatment.

NOTE: Duct insulation shall not be reduced below the DTS requirements using a BCA/NCC JV3 solution, or similar. Minimum approved thickness of insulation will be 50mm in all situations even where DTS allows a reduction.

5.20.15. DUCTWORK INSTALLATION

All ductwork must be cleaned prior to commissioning and switching on any fans and/or air handling units. Provide rough filters for unit protection at initial cleaning.

Arrangement

Ductwork: Arrange ductwork neatly. Provide access to ductwork components which require inspection, entry, maintenance and repairs. Where possible, arrange duct runs adjacent and parallel to each other and to building elements.

Spacing

Provide minimum clear spacing, additional to duct insulation, as follows:

- 25 mm between adjacent ducts.
- 25 mm between duct flanges or upper surfaces of ducts and undersides of beams and slabs.
- 50 mm between ducts and electric cables.
- 150 mm between ducts and ground, below suspended floors.

Mechanical Services Design Standards

Flexible duct

General: Install flexible duct as straight as possible with minimum number of bends. Maximise bend radius but not less than required by AS 4254.1 clause 2.5.3(i).

Length: Cut flexible duct to lengths that achieve this and to minimise the number of bands. Flexible connections must not be put under tension; they must be installed with play left to allow for any movement in ductwork or other equipment.

Flexible duct work to be a maximum length of 6 meters per run to terminal.

Joints: Securely fix flexible duct to rigid spigots and sleeves using sealant and draw band encased in duct sealing tape as detailed in AS 4254.1. Place mastic between the flexible and rigid duct, not as a fillet.

Joints between flexible ducts: Join lengths of flexible duct only for the purpose of providing an air tight or acoustic sleeve at a partition.

Support: To AS 4254.1. Limit sag to < 40 mm/m. Suitable wide supports (min. 75mm) to be used to prevent crushing of the duct over time. Thin strapping is not approved.

Maximum length of flexible duct sections: 6 metres including any rigid duct or sleeves used to join lengths of flexible duct.

Substitution: If rigid duct is shown on the drawings do not substitute flexible duct.

Flexible ducts used for air containing free moisture: Locate supporting helix outside airstream.

Motorised dampers

Maintenance access: Locate dampers and damper motors in accessible positions, for blade and motor maintenance and blade seal replacement.

Mounting: Sufficiently rigid to prevent flexing or distortion of the frame or ductwork during operation.

Operation: If 2 sets of dampers are connected to a single motor, provide linkages which allow either damper to be adjusted without affecting the other.

Cleaning

During installation progressively remove construction debris and foreign material from inside ducts.

Drainage

Provide drainage to AS/NZS 3666.1 at locations in ductwork where moisture may accumulate including at outside air intakes.

Labelling

Flexible duct covering is to be labelled as per AS4254 every 1.5m.

5.20.16. LEAKAGE TESTING PROCEDURES

Standard

Leakage testing methods:

- SMACNA HVAC Air Duct Leakage Manual.

Maximum leakage rate under test: To AS 4254.2.

Test method

Amount of system to be tested: ≥ 10% of the total surface area of the system including a pro-rata proportion of the following:

- Floor distribution, riser and plant room ducts.
- Each seam, joint and sealing construction type.
- Longitudinal seams.

Mechanical Services Design Standards

- Circumferential joints.
- Rigid ductwork.
- Flexible ducts.
- Flexible connections.
- Diffusers grilles and other terminal devices.
- Air handling plant and plenums.
- VAV boxes and other duct mounted equipment.
- Supply, return, outside air and exhaust ducts.
- Builders' work risers used in lieu of sheet metal ducts.

Duration of the test: Maintain the test pressure within $\pm 5\%$ for ≥ 5 minutes.

Instruments: Conform to Mechanical commissioning.

Leakage flow rate measurement: Use instruments that have been certified by a Registered testing authority in the past 12 months and have:

- Accuracy: Better than $\pm 5\%$ of measured value.
- Resolution: Better than 1% of measured value.

Failure under test

Requirement: If the leakage in the duct system exceeds the documented maximum leakage rate under test:

- Locate leaks and mark their position on the outside of the duct.
- Rectify leaks.
- Record the generic location of leaks and corrective action.
- Retest the system as above but with $\geq 20\%$ of the total surface area of the system.

Repeat test: If the leakage in the duct system under retest exceeds the documented maximum leakage rate under test, retest with 100% of the total surface area of the system.

5.21. AIR GRILLES AND DIFFUSERS

5.21.1. GENERAL

Outlets, grilles and registers must be selected to provide adequate air movement without creating draft. The throw of air diffusers must be selected such that there is no splash on wall above occupied level. Average air velocity in the room must be between 0.1 and 0.15m/s. Horizontal and vertical flow patterns and sound power levels must all be checked to ensure compliance with the intent of this standard.

All slot diffusers, linear grilles, air boots and light air troffers must have provision for air pattern adjustments such that air can be deflected in a vertical and horizontal direction.

Small offices and some labs will have swirl diffusers fitted to prevent draughts.

5.21.2. EXHAUST GRILLES

Exhaust grilles must be egg-crate type with a 12mm x 12mm core. Limit face velocity to 3.5m/s

All exhaust grilles must be complete with integral opposed blade volume control dampers operable through the respective grille face.

5.21.3. PLENUM BOXES

Plenum boxes must be galvanised steel plenum constructed as for low pressure steel ductwork, insulated internally with minimum 50mm thick (or to NCA, whichever is the higher requirement) internal duct insulation. All joints must be sealed air tight.

5.21.4. DOOR GRILLES

Mechanical Services Design Standards

Door grilles must be of the flanged frame type with inverted chevron, sight proof blades with minimum 60% free area. Grilles must comprise fixed horizontal blades, concealed vertical bracing bars where necessary and must be of aluminium construction anodised to the colour to be nominated. Limit face velocity to 2.5m/s

5.21.5. UNDERCUTTING OF DOORS

Undercutting of doors for return air path is not acceptable unless approved by the Architect and MUP.

5.22. VIBRATION/ NOISE

5.22.1. MACHINERY

Statically and dynamically balance machinery and isolate from the building structure.

Select vibration isolators with due regard to the weight and speed of the equipment to be isolated and with isolating efficiencies as specified by consultant/ designer for the particular equipment or in any case, not less than 95%. Select springs with a length when loaded approximately equal to their diameter.

Provide inertia blocks as required to suit the pump weight.

5.22.2. PIPING

Piping must be designed to have sufficient flexibility where connected to vibrating machinery and must be effectively isolated from the building structure where necessary to prevent the transmission of vibration.

With respect to the pipework installation to pump sets, for a minimum of 15 meters run there must be anti-vibration insulation whenever possible to aid the positive vibration isolation steps taken.

5.22.3. DUCTWORK

Ductwork and fitting must be designed and constructed to prevent any excessive generation of air noise and vibration of fittings.

5.22.4. FLEXIBLE CONNECTIONS FOR PIPEWORK

Flexible connections must be installed parallel with and horizontal to the shaft of operating equipment whenever possible and of full bore.

5.22.5. FLEXIBLE CONNECTIONS FOR DUCTWORK

Flexible connection must be fitted to isolate fans and/or conditioner casings from ductwork.

Materials and application of flexible connections must be in accordance with AS 1668.1. Flexible connections must be airtight and arranged to permit the renewal of the fabric without disturbing the ductwork or paint. All fabric at the seam must be folded back to conceal raw edges.

Use flexible connections for ductwork where there are building movement joints. Flexible connections within ceiling spaces must be wrapped with 1 (one) layer of "Wavebar" or equal.

5.22.6. PUMP INERTIA BASES

All pumps must be mounted on inertia bases specifically sized for total vibration isolation.

The pump inertia bases must be fitted with spring isolators specifically selected and manufactured to suit the final pump selection. The mounts will be seismic restraints.

Care must be taken to ensure the removal of any construction debris under pump bases to avoid vibration transmission.

Each pump set must be completed with flexible connections on the pipework and electrical supplies. These flexible connections must be selected such that they isolate the vibration at source and do not transfer it into the pipework or other connections.

Mechanical Services Design Standards

5.23. MECHANICAL SWITCHBOARDS AND CONTROL PANELS

5.23.1. GENERAL

All switchboards shall be provided with a main switch accessible without opening the switchboard, via an extended handle through the face of the board. On any switchboard, greater than 1500mm high/wide a separate compartment and door shall be provided for the main switch. A handle release button will be provided.

Physical protection against contact with any live electrical parts shall be provided at all parts within the switch board. This should be provided by means of an escutcheon plate with cut-outs for the miniature circuit breakers or accessible components.

Plant rooms will have an MSB and/or a MCC in each plant room containing equipment. The Panel shall include auto/off/manual switches for each piece of equipment for testing purposes together with run and fault lights and Fire indicator light. Testing switches must not be in other rooms or on other floors.

Generally, panels in plant rooms should contain electrical supplies and controls for that plant room. The panel can be supplied from a main MSSB in a main plant room for the building and the sub-panel will be labelled to indicate the source of supply. Metering of energy in each plant room is required.

5.23.2. FORM OF SEPARATION

The form of separation shall be determined for the project by the consultant based on the project requirements. The following principles are provided as guidance:

- On any switchboard, greater than 1500mm high/wide, the main switch should reside within its own compartment with form 2b separation. The handle of which should be accessible from the front face of the board.
- On any switchboard, less than 1500mm, a minimum separation between controls wiring and power distribution of Form 2b is required.

5.23.3. METALWORK

A high standard of metalwork is required for all MSB, MCC and control panels. The following points concerning the metalwork should be noted:

- a. The thickness of metal used will depend on the size of the board. For large free-standing switchboards, the minimum metal size for major components is 2mm thick furniture quality bright steel sheet. Smaller components may be of reduced gauge.
- b. All hinged panels are to be suitably stiffened and fitted with lift-off hinges and a locking handle with standard MUP 92286 key.
- c. Large lift-off panels are not favoured, but if unavoidable they must be equipped with a means of handling them such as fitted D handles. Such panels must have a means of support, such as studs or a supporting ledge, for use while the fixing screws are being installed.
- d. Escutcheon plates and hinged panels shall be fixed in place with a fixing which can be undone without the use of tools. Dzus Adjustable Panel latches are favoured.
- e. The metal cabinet is to be mounted on a welded channel (if floor mounted) steel frame predrilled, to take holding-down bolts.

5.23.4. KWH METERS

Energy consumed in a University building must be accounted for. To achieve this each mechanical switchboard will have an electricity meter fitted. The electricity meter and communications will be supplied installed and commissioned by the mechanical contractor (who also supplies and installs the MUP approved C/T's). The electricity meter will have a BMCS interface to automatically transmit all power usage data to the BMCS for logging. Metering will be connected to a metering Jace in the building. If none is present a metering Jace must be included in the project.

Main switch:

Mechanical Services Design Standards

The general rule for the selection of main switches is:

- up to 150-amp supply – manually-operated 150-amp slow break switch 150-600-amp supply - moulded case circuit-breaker (electronic)
- over 600-amp supply - air break withdraw able switch with electronic protection

The minimum interrupting rating for the main switch in major buildings shall be 50 kA.

The approved main switch shall be NHP Socomec with metal extension rod and quick release handle.

Switchboard and Control Panel Wiring:

Switchboard and control panel wiring shall be neatly and securely carried out. Channels, ducts or other supports shall be provided in clearly-defined access-ways for sub-main cabling. The minimum size of switchboard metering instrumentation wiring shall be 4mm² (7/0.85) cable, phase coloured and numbered. All other control wiring 1mm² (7/0.85).

5.23.5. FINISH

All metal work for switchboards and control panels is to be thoroughly cleaned, descaled, de-rusted with a phosphoric rust remover and given one coat of self-etching rust-inhibiting primer. It should then be filled, rubbed down and painted with a suitable undercoat. Final external finish is to be provided by two coats of gloss enamel paint in a colour similar to Australian Standard 2700 Colour No X15 Orange. Internal finish colour shall be the same as the external colour. If a distribution cabinet is fitted the doors are to be labelled with the following legend in 50mm high letters, in red "DANGER" followed by the words "415 VOLT ELECTRICITY SUPPLY". Alternatively, an approved danger notice bearing a similar legend may be accepted.

5.23.6. LABELS

All components on the switchboard shall be clearly labelled with the labels fixed to the face of the switchboard. In addition, the rear of all outgoing units shall have an identical label to the front, affixed close to the outgoing cable connections. The main labels shall have 25 mm high letters.

In addition, all outgoing combination switch fuse units shall be clearly labelled with similar labels in 5mm high letters. Labels shall be fixed to the switchboard or escutcheon plates with zinc-plated metal thread screws.

5.23.7. FUSES

Any switchboard, main, sub-distribution or control board, to which HRC fuses are fitted, must also contain or have installed adjacent to it, a fixture in which spare fuse cartridges can be stored. Three cartridges for each size of cartridge used on the switchboard should be accommodated in the fixture and supplied with the switchboard.

Size of Control Panel

Each control panel must be generously sized. The number of power circuits continually grow as departments purchase additional equipment. New control panels therefore should have at least 20% additional spare capacity when installed, unless greater is required for the specific project. The designer shall confirm as part of the briefing process the spare capacity required.

Note 20% spare capacity means each type of equipment in the board must have spare capacity rounded out to a whole number. E.g. Terminals, transformers (if one then two spaces required), circuit breakers, relays etc.

5.23.8. APPROVED COMPONENT SUPPLIERS

Basic equipment specification as follows.

- Circuit Breakers to be Terasaki DTCB series or equivalent.
- AOM Rotary Switches to be Kraus & Naimer 50mm CG4 Series
- Indicator Lights to be Sprecher and Schuh 25mm D7P Series with LED Lights
- Contactors to be Sprecher and Schuh CA7-9 Series
- Relays to be IDEC RY2S or similar Plug in base with indicator light
- Main Isolator to be Stromberg or equivalent.

Mechanical Services Design Standards

- Terminals shall be Weidmuller WDU - 4 or equivalent.
- Timers to be Sprecher and Schuh DBA or equivalent.
- Wire numbers to be Graphoplast Trasp Slide on Type not clip on.

5.24. MECHANICAL SERVICES WIRING

5.24.1. WIRING GENERAL

All wiring in the mechanical services plant room and building areas will conform to the requirements of the Electrical Design Guide and AS3000.

Wiring shall be run in conduit, cable trunking and on trays or cable ladder to suit the application and all trays, trunking, cable ladder and troughing will be painted orange as per painting requirements for electrical items.

All external equipment will be connected using anaconda flexible steel sheathed conduit with appropriate fittings to produce a water tight connection. Flexible PVC conduit will not be used externally unless rated for that duty and will have a smooth external coating for protection such as Clipsal sheathed flexible conduit type CMS. No flexible conduit will be longer than 0.5 Metres long. This applies to controls connections as well.

Tray, ladder and cable supports must be suitable for the load applied and will conform to Australian Standard AS3000. Also project specific requirements for seismic restraints requirements and compliance

All wiring penetrating a fire wall shall be installed using a special fire rated intumescent fitting.

Mechanical Services Design Standards

5.25. PAINTING

Refer to the MUP Colour Guide.

All exposed mechanical services (including mechanical electrical cable tray) shall be painted in accordance with the Macquarie University approved paint colours.

<i>Type of Pipe</i>	<i>Std Colour AS 2700</i>	<i>British Std BS381C</i>	<i>Dulux</i>
Chilled Water, Heating Water, Make up water	Jade – G21 Emerald Green – G13 Shamrock – G23	Green – NO. 228	Emerald Green P26G8
Gases- Town gas, Flue gas	Biscuit – X42 Sand - Y44 Straw – Y 24	Light Beige – No. 366	Cream G2
Drains	Black – N61	-	Black
Oils, Petrol, Diesel	Golden Tan – X 53 Brown – X54 Tan – X51	Brown – No. 414	Golden Brown P11E9
Fire Services	Signal Red – R13	Red – No. 537	
Air – Compressed or Vacuum	Aqua – B25 Bluebell – b41	Light Blue – No. 112	
Electric Power including all Cable Tray	Orange – X15	Orange – no. 557	
Dangerous Materials	Golden Yellow – Y14	Golden Yellow – No. 356 with black markings	
Communications – Telephone, controls	White - N14	-	

Table 1 Pipework – Gloss Enamel Solvent based

<i>Ductwork</i>	<i>Std Colour AS 2700</i>	<i>British Std BS381C</i>	<i>Dulux</i>
General ducting			Shoji White

Table 2 Ductwork – Gloss Enamel Solvent Based

<i>Plant Rooms</i>	<i>Std Colour AS 2700</i>	<i>White Knight</i>	<i>Dulux</i>
Floor		Tubman’s Stone age (Grey)	
Plinths	Black N61		Black
Plinth Edges	Golden Yellow – Y14	British Std BS381C Golden Yellow – No. 356 with black strip	

Mechanical Services Design Standards

		markings	
--	--	----------	--

Table 3 Plant Rooms – Gloss Enamel Solvent Based

<i>Electrical Boards</i>	<i>Std Colour AS2700</i>	<i>British Std BS381C</i>	<i>Dulux</i>
Electric Switchboards Distribution Boards Mechanical Boards Electrical Trays, ladder & troughing	Orange – X15	Orange – no. 557	
Internal surfaces of all boards	White - N14		

Table 4 Electrical Boards – Gloss Enamel Solvent Based or Powder Coated

<i>Electrical Boards</i>	<i>Std Colour AS 2700</i>	<i>British Std BS381C</i>	<i>Dulux</i>
BMCS Controls Boards	Orange – X15	Orange – no. 557	
Internal walls and backing plates	White - N14		

Table 5 BMCS Controls Boards – Gloss Enamel Solvent Based or Powder Coated

<i>Lab Gas Piping</i>	<i>Std Colour AS 2700</i>	<i>White Knight</i>	<i>Dulux</i>
Argon	Peacock Blue – T53		
CO2	Green Grey - N32		
Helium	Brown – X54		
Nitrogen	Pewter – N63		
Oxygen	Black – N61		
Hydrogen	Signal Red – R13		

Table 6 Lab Gas Piping – Gloss Enamel Solvent Based

AS 2700 Standard Colours and AS1345 Identity of Contents in Pipes.

Mechanical Services Design Standards

5.26. LABELLING

5.26.1. GENERAL

General: Mark services and equipment to provide a ready means of identification and as follows:

- Locations exposed to weather: Provide durable materials.
- Pipes, conduits and ducts: Identify and label to AS 1345 throughout its length, including in concealed spaces. Note piping must be painted for its full length to identify contents coloured labels alone are not acceptable due to fading over time.
- Cables: Label to indicate the origin and destination of the cable.

Consistency: Label and mark equipment using a consistent scheme across all services elements of the project.

Electrical accessories

General: Label isolating switches and outlets to identify circuit origin.

Equipment concealed in ceilings

Location: Provide a label on the ceiling indicating the location of each concealed item requiring access for routine inspection, maintenance and/or operation. In tiled ceilings locate the label on the ceiling grid closest to the item access point. In flush ceilings locate adjacent to closest access panel. Items to be labelled include but are not limited to:

- Fan coil units and terminal equipment (e.g. VAV boxes).
- Fire and smoke dampers.
- Isolating valves not directly connected to items otherwise labelled.
- Motorised dampers.
- Wall mounted equipment in occupied areas: Provide labels on wall mounted items in occupied areas including the following:
 - Services control switches.
 - Temperature and humidity sensors.

Points lists

Automatic control points: Provide plasticised, fade-free points lists for each automatic control panel. Store in a pocket on the door of the panel. Lists to include terminal numbers, point addresses, short and long descriptors.

Pressure vessels

General: Mount manufacturer's certificates in glazed frames on a wall next to the vessel.

Valves and pumps

General: Label to associate pumps with their starters and valves. Screw fix labels to body or attach label to valve handwheels with a key ring.

All valves shall be numbered and provided with a valve tag with relevant information to the valve. All valves shall be scheduled in a valve table with the relevant details of the valve.

EG. Balancing valve tags shall include flow rate and setting.

Motorised valve tags shall indicate respective unit/function.

Underground services

Survey: Accurately record the routes of underground cables and pipes before backfilling. Include on the record drawings.

Records: Provide digital photographic records of underground cable and pipe routes before backfilling. Include in operation and maintenance manual.

Mechanical Services Design Standards

Location marking: Accurately mark the location of underground cables and pipes with route markers consisting of a marker plate set flush in a concrete base, engraved to show the direction of the line and the name of the service.

Markers: Place markers at ground level at each joint, route junction, change of direction, termination and building entry point and in straight runs at intervals of not more than 100 m.

Marker bases: 200 mm diameter x 200 mm deep, minimum concrete.

Direction marking: Show the direction of the cable and pipe run by means of direction arrows on the marker plate. Indicate distance to the next marker.

Plates: Brass, aluminium or stainless steel with black filled engraved lettering, minimum size 75 x 75 x 1 mm thick.

Plate fixing: Waterproof adhesive and 4 brass or stainless steel countersunk screws.

Marker height: Set the marker plate flush with paved surfaces, and 25 mm above other surfaces.

Marker tape: Where electric bricks or covers are not provided over underground wiring, provide a 150 mm wide yellow or orange marker tape bearing the words WARNING – electric cable buried below, laid in the trench 150mm below ground level.

Labels and notices

Materials: Select from the following:

- Cast metal.
- For indoor applications only, engraved two-colour laminated plastic.
- Proprietary pre-printed self-adhesive flexible plastic labels with machine printed black lettering.
- Stainless steel or brass ≥ 1 mm thick with black filled engraved lettering.

Emergency functions: To AS 1319.

Colours: Generally, to AS 1345 as appropriate, otherwise black lettering on white background except as follows:

- Danger, warning labels: White lettering on red background.
- Main switch and caution labels: Red lettering on white background.

Edges: If labels exceed 1.5 mm thickness, radius or bevel the edges.

Fixing: Fix labels securely using screws, rivets, chain or wire looped through equipment, proprietary self-adhesive labels or double-sided adhesive tape and as follows:

- If labels are mounted in extruded aluminium sections, use rivets or countersunk screws to fix the extrusions.
- Use aluminium or monel rivets for aluminium labels.

Adhesive labels shall only be used on flat, smooth and clean surfaces and where screw or rivet fixings would compromise the integrity of the item being labelled.

Label locations: Locate labels so that they are easily seen and are either attached to, below or next to the item being marked.

Labelling text and marking: To correspond to terminology and identifying number of the respective item as shown on the record drawings and documents and in operating and maintenance manuals.

Lettering heights:

- Danger, warning and caution notices: ≥ 10 mm for main heading, ≥ 5 mm for remainder.
- Equipment labels within cabinets: ≥ 3.5 mm.
- Equipment nameplates: ≥ 40 mm.
- Identifying labels on outside of cabinets: ≥ 5 mm.
- Isolating switches: ≥ 5 mm.
- Switchboards, main assembly designation: ≥ 25 mm.

Mechanical Services Design Standards

- Switchboards, outgoing functional units: ≥ 8 mm.
- Switchboards, sub assembly designations: ≥ 15 mm.
- Valves: 3.5mm on a 25mm Brass Tag.
- Self-adhesive flexible plastic labels:
- Labels < 2000 mm above floor: 3 mm on 6 mm wide tape.
- Labels ≥ 2000 mm above floor: 8 mm on 12 mm wide tape.
- Other locations: ≥ 3 mm.

Operable devices: Mark to provide a ready means of identification. Include the following:

- Controls.
- Indicators, gauges, meters.
- Isolating switches.

Vapour barriers: Do not penetrate vapour barriers.

5.27. SERVICE ACCESS/ SAFETY REQUIREMENTS

5.27.1. GENERAL

The following are the University access & service requirements;

- a. Position all equipment and arrange access provisions at equipment, to optimise future maintenance and repairs.
- b. Equipment must not be located in ceiling spaces above labs, animal houses and critical environments. Plant will only be accepted in ceiling spaces within office buildings.
- c. The University will not accept plant within tight spaces. Plant that is located in ceiling space must have free and easy access. This includes the ability to service the system without reaching around or over columns, beams, cable trays, pipework, light and ductwork.
- d. All motors are to be provided with isolators within 1 meter distance from motor
- e. A plus 20% additional dimension access allowance is to be provided above the manufacturers access requirement for equipment.
- f. Plant located above 3m height will have permanent stair/ladder access provisions with permanent workable platform.
- g. Trip hazards to be identified and painted yellow with black strip.
- h. Electrical Hazards must be identified and labelled appropriately
- i. Yellow walkways to be painted around all plant areas in plant rooms
- j. Chemical Hazards to be labelled and yellow safe clearance lines to be painted on the floor. Also, appropriate paperwork i.e. MSDS to be presented onsite.
- k. Confined spaces to be noted and appropriate signage applied
- l. Fixed switchable lights are to be provided in AHU chambers
- m. Access to plant and equipment must comply with all WHS regulations and safety in design requirements.

5.28. REDUNDANT EQUIPMENT

All redundant mechanical services and associated services (power, controls, water, drainage, etc) must be removed as part of the project. Building surfaces and finishes must be made good.

5.29. PRODUCT SUPPORT/ EXPERIENCE REQUIREMENTS

All products must be supported locally and internationally by factory trained service networks.

Equipment and associated accessories shall be specified as products that have been established manufacturing reliability and proven installation history in Australia.

Proven installation history includes products installed and operated for over 8 years and operational costs and detailed life cycle reports can be provided.

Mechanical Services Design Standards

The main contractor is to provide a full MEP services asset register.

All spare parts must be available ex-stock factory for a period of 10 years from purchase date.

All spare parts must be readily available as spares with minimum ordering and delivery times.

Mechanical Services Design Standards

5.30. COMMISSIONING

Macquarie University requires a comprehensive plan demonstrating how mechanical services systems are to be inspected, tested and commissioned to achieve the project design objectives.

The Contractor shall provide Inspection & Test Plans (ITP's) for all major items of equipment and systems to be installed as part of their works, including but not limited to:

- Ductwork
- Ductwork pressure testing.
- Pipework, including pressure testing and flushing
- Electrical
- Controls including point to point testing and Function verification
- All equipment to be installed

In addition to the above, the contractor shall also submit a commissioning methodology statement outlining how the systems will be commissioned, requirements and preconditions for commissioning, and pre-typed commissioning sheets for systems such as:

- Air
- Water
- Controls – functional testing
- Essential Services Testing (E.g. Stair pressurisation, Smoke Exhaust, Fire Trip and interlocks, etc).

The above documents shall form a testing and commissioning plan that will be developed by the contractor in conjunction with the shop drawings and be submitted for approval to MUP prior to commencement of construction.

Sample ITP's and functional verification sheets for operation are available from MUP. These are a guide to the format required to be submitted as a minimum. The detail of the project will have to be added to these basic documents.

6. QUALITY CONTROL

6.1. DESIGN STANDARD COMPLIANCE

Compliance with requirements of this standard must be checked throughout the design, construction and commissioning phases of project by:

- a. The MUP Technical Services Representative
- b. The MUP Project Manager

Competent MUP representatives must check compliance with this standard during design reviews and formal site inspections.

Any non-compliances with requirements of this standard must be documented by the consultant and contractor (as applicable) and brought to the attention of the MUP Project manager and/or client's representative. Project Managers must maintain a register of non-conformances and manage close out of outstanding non-conformances.

Contractors and their consultants issued with non-conformances must take appropriate corrective or preventive actions. Proposed corrective or preventive actions and close out of non-conformances must first be formally approved by issuer of the standard or their delegate.

6.2. DESIGN STANDARD CERTIFICATION

Contractors and their consultants must certify compliance to the design standard by completing and submitting a letter of certification to the MUP Project Manager at each of the following project phases:

- a. Design and Documentation
- b. Tender
- c. Construction

Notwithstanding MUP internal quality control process, contractors and their consultants must implement their own robust quality assurances and control procedures to ensure compliance with the requirement of this standard.

7. REFERENCES

7.1. STANDARD DRAWINGS

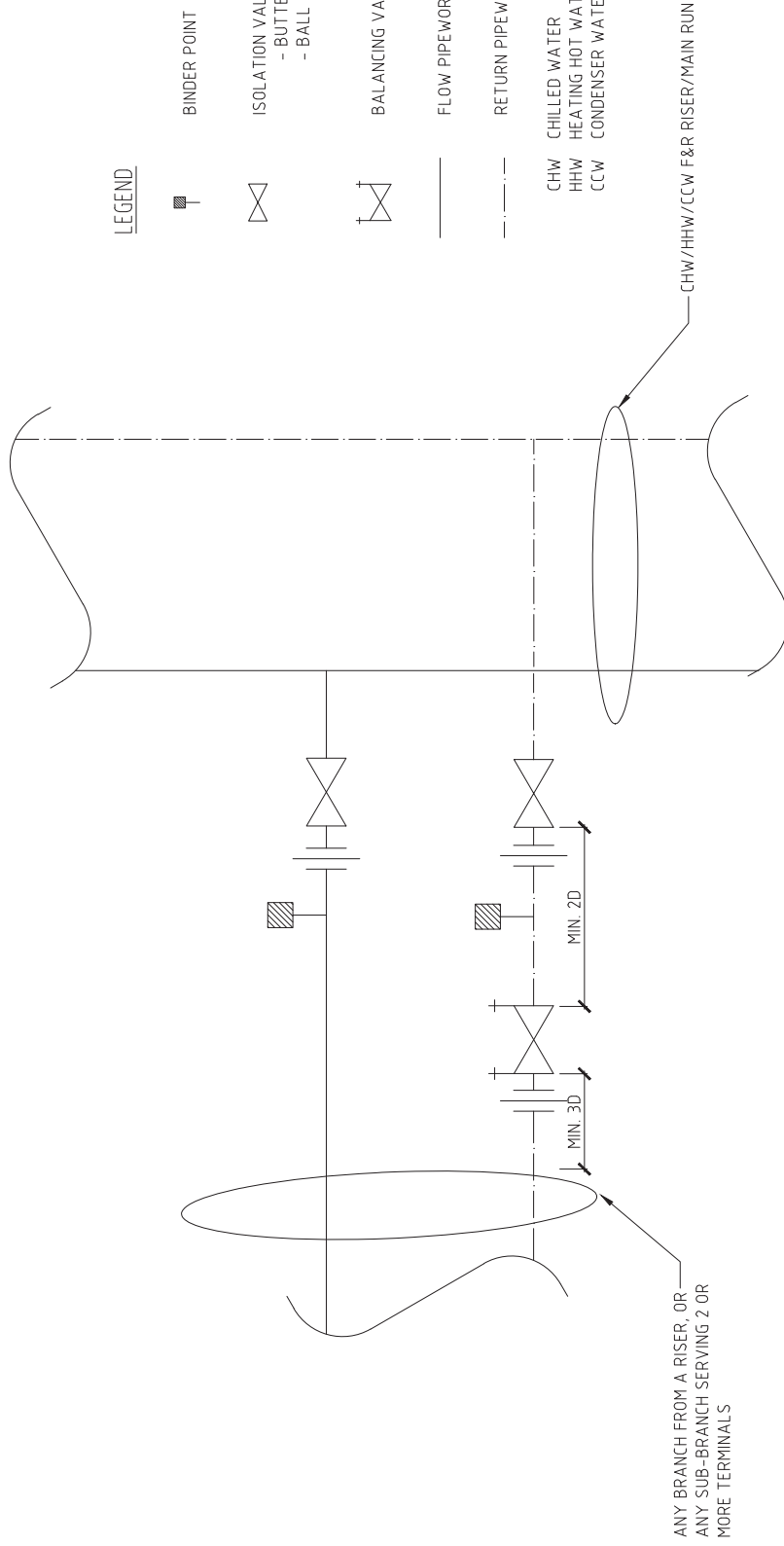
The following Macquarie University standard drawings shall be referenced in the design and installation of mechanical services. Any deviations require the approval of the MUP Technical Services Manager.

<i>Drawing Title</i>	<i>Drawing No</i>	<i>Revision</i>	<i>Date</i>
TYPICAL BRANCH VALVING DETAIL	MSD-01	1	DEC 2014
PICCV COIL CONNECTION DETAIL	MSD-02	1	DEC 2014
HEAT RECOVERY UNIT TYPICAL ARRANGEMENT	MSD-03	1	DEC 2014
AIR & DIRT SEPERATOR ARRANGEMENT	MSD-04	1	DEC 2014
FAN COIL UNIT DETAIL	MSD-05	1	DEC 2014
PUMP INSTALLATION DETAIL	MSD-06	1	DEC 2014
COIL CONNECTION DETAIL	MSD-07	1	DEC 2014
VALVE TAG DETAILS	MSD-08	1	JAN 2015
PIPING SUPPORT	MSD-09	1	DEC 2014
QA IMAGES	MUP QA	1	OCT 2017
MCL 01 – Mechanical Works Checklist	MCL-01	1	OCT 2017

7.2. MSD 01 – TYPICAL BRANCH CONNECTION DETAIL

LEGEND

- BINDER POINT
- ISOLATION VALVE
- BUTTERFLY > 50
- BALL VALVE < 50
- BALANCING VALVE
- FLOW PIPEWORK (CHW/HHW/CCW)
- RETURN PIPEWORK (CHW/HHW/CCW)
- CHW CHILLED WATER
- HHW HEATING HOT WATER
- CCW CONDENSER WATER



NOTE

1. MINIMUM 3 PIPE DIAMETER STRAIGHT LENGTH UPSTREAM OF BALANCING VALVE AND 2 PIPE DIAMETER STRAIGHT LENGTH DOWNSTREAM OF BALANCING VALVE
2. ALL VALVES MUST BE REMOVABLE WITHOUT CUTTING OR REMOVING LARGE SECTIONS OF PIPING.

DATE	REV	AMENDMENT	BY/CHKD	DATE	JAN 2015	DRAWN	TITLE
JAN 2015	1	STANDARD ISSUE	-	-	-	-	TYPICAL BRANCH VALVING DETAIL FOR CHW/HHW/CCW SYSTEMS
							SCALE N.T.S.
							CHECKED
							APPROVED
							SHEET SIZE A3
							CAD FILE
							DRAWING NO.
							IMSD-01
							REVISION
							1

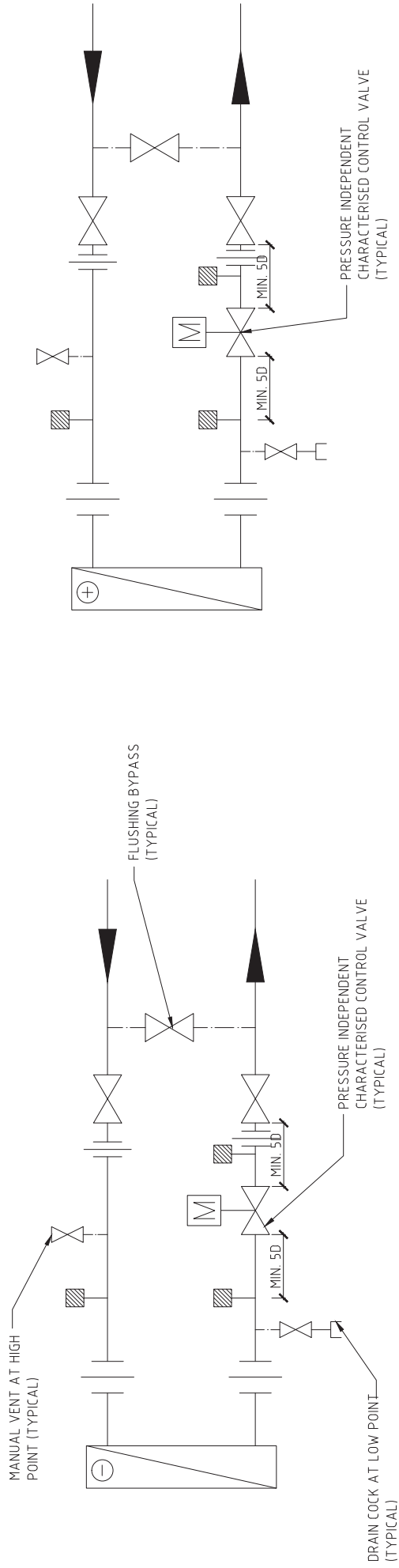


MECHANICAL

Level 2, 33 Castleside Street
Sydney NSW 2000
T +61 2 9599 9559
F +61 2 8786 4406
E info@cpj-engineering.com.au

MACQUARIE UNIVERSITY
STANDARD DRAWINGS








MSD 02 - PICCV Coil Connection Detail



TYPICAL 2 - WAY CHW COIL CONNECTION DETAIL

TYPICAL 2 - WAY HHW COIL CONNECTION DETAIL

LEGEND

-  BINDER POINT
-  ISOLATION VALVE
- BUTTERFLY > 50
- BALL VALVE < 50
-  2 WAY MOTORISED VALVE
-  DRAIN COCK
-  UNION
-  MANUAL AIR VENT
-  PICCV PRESSURE INDEPENDENT CHARACTERISED CONTROL VALVE

NOTE

1. MINIMUM 5 PIPE DIAMETER STRAIGHT LENGTH UPSTREAM AND DOWNSTREAM OF PICCV
2. ALL VALVES MUST BE REMOVABLE WITHOUT CUTTING OR REMOVING LARGE SECTIONS OF PIPING.

DATE	REV	AMENDMENT	BY/CHKD
JAN 2015	1	STANDARD ISSUE	-

CLIENT



MECHANICAL



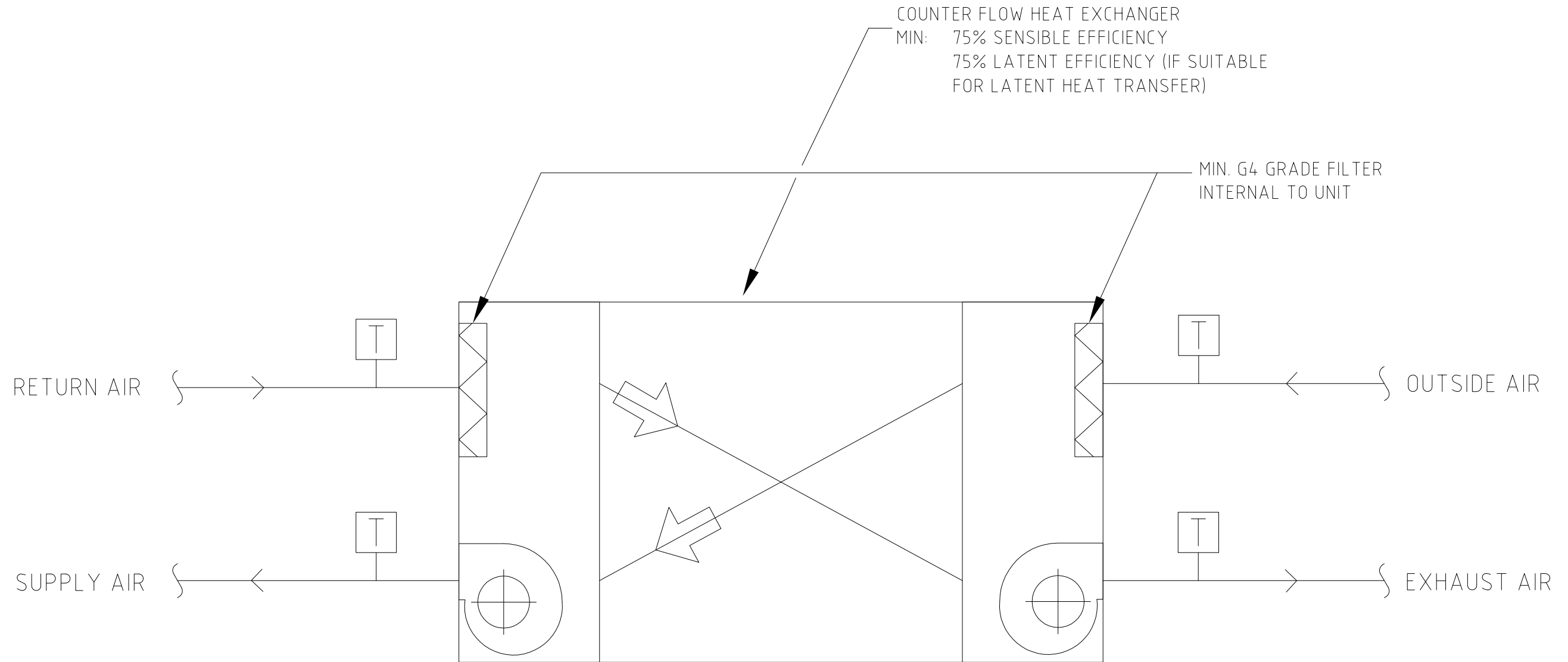
Level 2, 33 Castleside Street
Sydney NSW 2000
T +61 2 9594 9559
F +61 2 9594 4406
E info@jpmengineering.com.au

**MACQUARIE UNIVERSITY
STANDARD DRAWINGS**

DATE	JAN 2015	DRAWN	TITLE
			PICCV COIL CONNECTION
			DETAIL
			DRAWING NO.
			REVISION

1



MSD 03 – Heat Recovery Unit Typical Arrangement



NOTE

1. LATENT HEAT TRANSFER SHALL ONLY BE USED WHERE QUALITY OF SUPPLY AIR WILL NOT BE COMPROMISED
2. FANS SHALL BE INDEPENDENTLY SPEED ADJUSTABLE
3. MONITORING OF AIR TEMPERATURES BY BMS SHALL BE PROVIDED
4. INSULATED TO BCA SECTION J

LEGEND

-  TEMPERATURE SENSOR, MOUNTED VIA BMS
-  FAN C/W SPEED ADJUSTABLE MOTOR FOR COMMISSIONING

DATE	REV	AMENDMENT	BY	CHKD
DEC 2014	1	STANDARD ISSUE		



MACQUARIE UNIVERSITY
STANDARD DRAWINGS

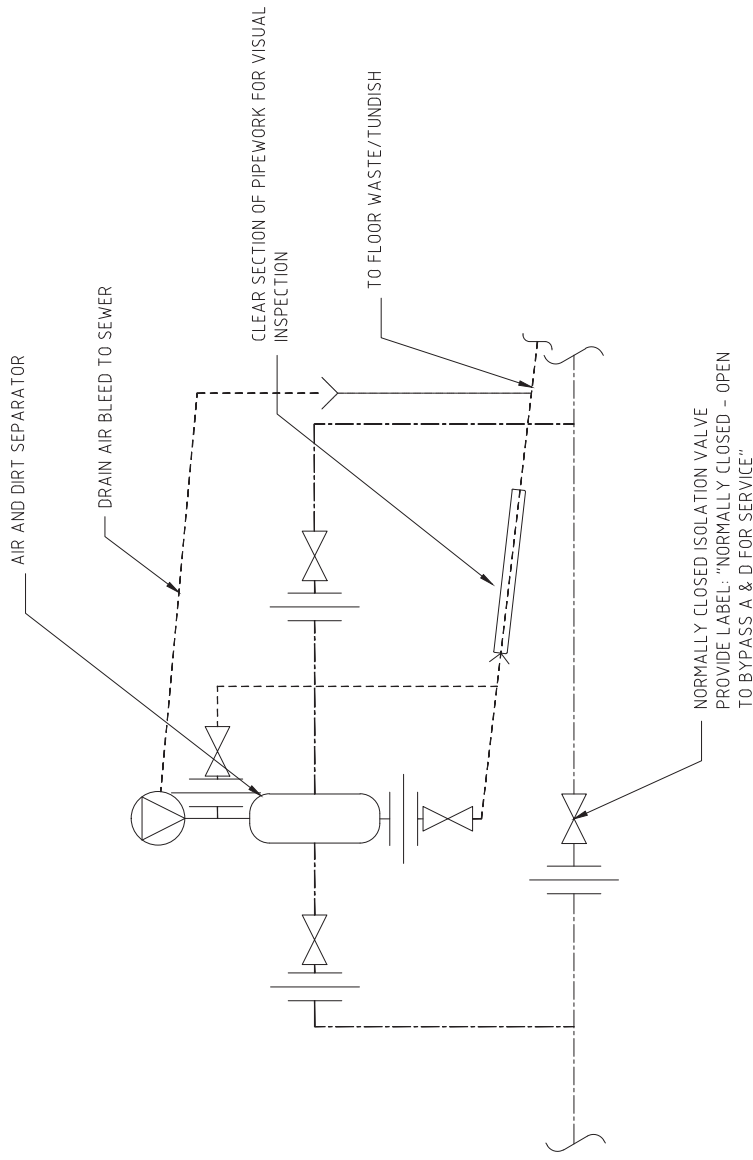
DATE	DEC 2014	DRAWN
SCALE	N.T.S.	CHECKED
SHEET SIZE	A3	APPROVED
CAD FILE		

TITLE	HEAT RECOVERY UNIT TYPICAL ARRANGEMENT
DRAWING NO.	MSD-03
REVISION	1

MSD 04 – Air / Dirt Separator Arrangement

LEGEND

- ISOLATION VALVE
- BUTTERFLY > 50
- BALL VALVE < 50
- AUTOMATIC AIR VENT
- AUTOMATIC AIR VENT



NOTE

1. AIR AND DIRT SEPARATOR TO BE LOCATED IN THE "WARMEST" PART OF THE CIRCUIT
I.E: - CHW RETURN
- HHW SUPPLY
2. ANY NEW CHW/HHW SYSTEMS TO BE PROVIDED WITH AN AIR AND DIRT SEPARATOR
3. ALL VALVES MUST BE REMOVABLE WITHOUT CUTTING OR REMOVING LARGE SECTIONS OF PIPING.

DATE	REV	AMENDMENT	BY/CHKD
JAN 2015	1	STANDARD ISSUE	-

CLIENT

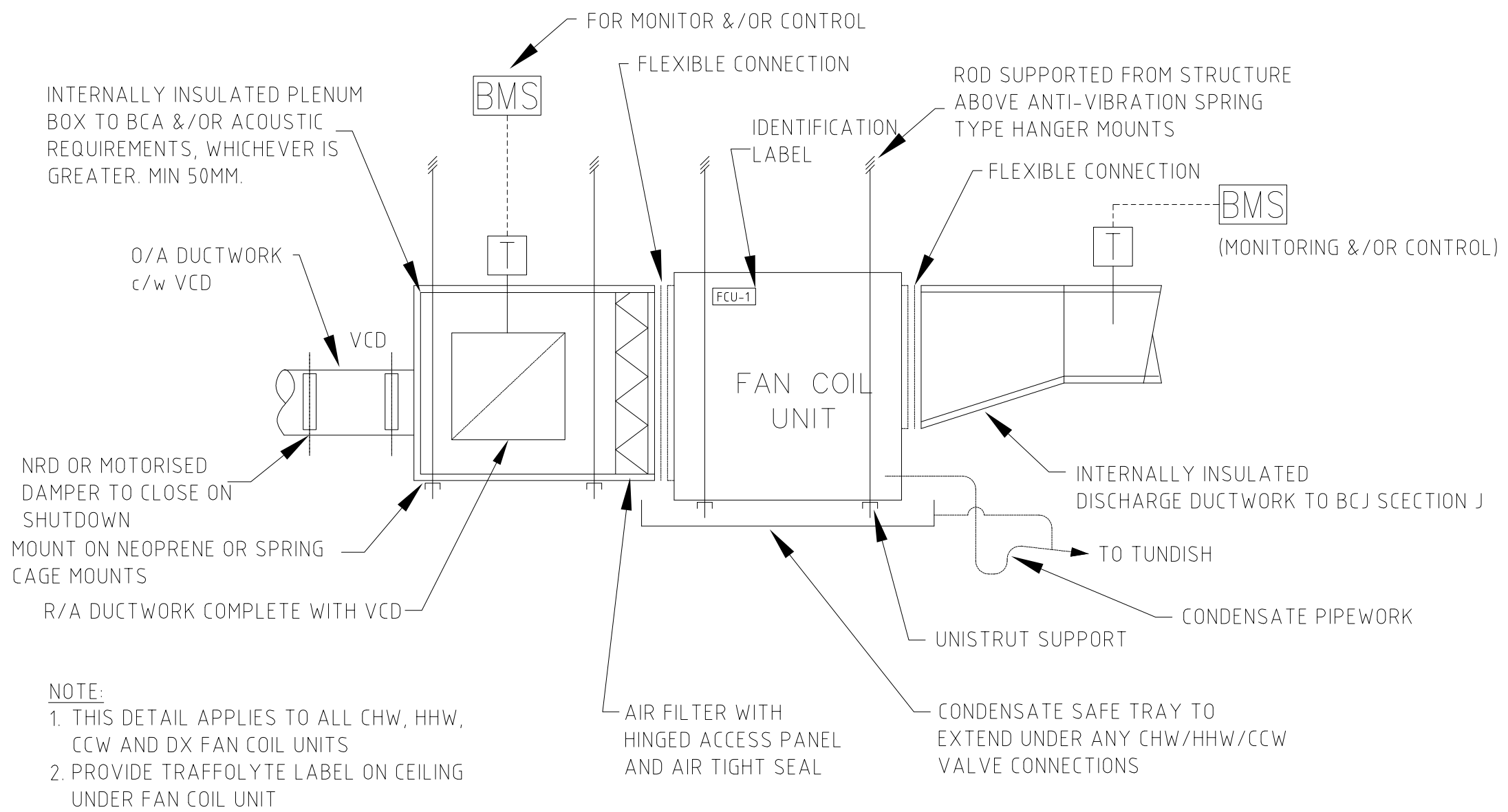


MECHANICAL



Level 2, 33 Castleside Street
Sydney NSW 2000
T +61 2 9599 9559
F +61 2 9599 4406
E info@macquarie.edu.au

MACQUARIE UNIVERSITY STANDARD DRAWINGS		DATE	SCALE	DATE	TITLE
		JAN 2015	N.T.S.		AIR AND DIRT SEPARATOR
					DETAIL
			SHEET SIZE A3		
			CAD FILE		
					DRAWING NO.
					MSD-04
					REVISION
					1

MSD 05 – Fan Coil Unit Detail



LEGEND

-  TEMPERATURE SENSOR, MOUNTED VIA BMS
-  DAMPER
- VCD VOLUME CONTROL DAMPER
- NRD NON RETURN DAMPER
- O/A OUTSIDE AIR
- R/A RETURN AIR
- CHW CHILLED WATER
- HHW HEATING HOT WATER
- CCW CONDENSER WATER

NOTE:
 1. THIS DETAIL APPLIES TO ALL CHW, HHW, CCW AND DX FAN COIL UNITS
 2. PROVIDE TRAFFOLYTE LABEL ON CEILING UNDER FAN COIL UNIT

DATE	REV	AMENDMENT	BY	CHKD
DEC 2014	1	STANDARD ISSUE		

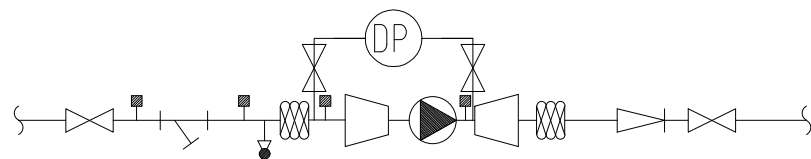


**MACQUARIE UNIVERSITY
STANDARD DRAWINGS**

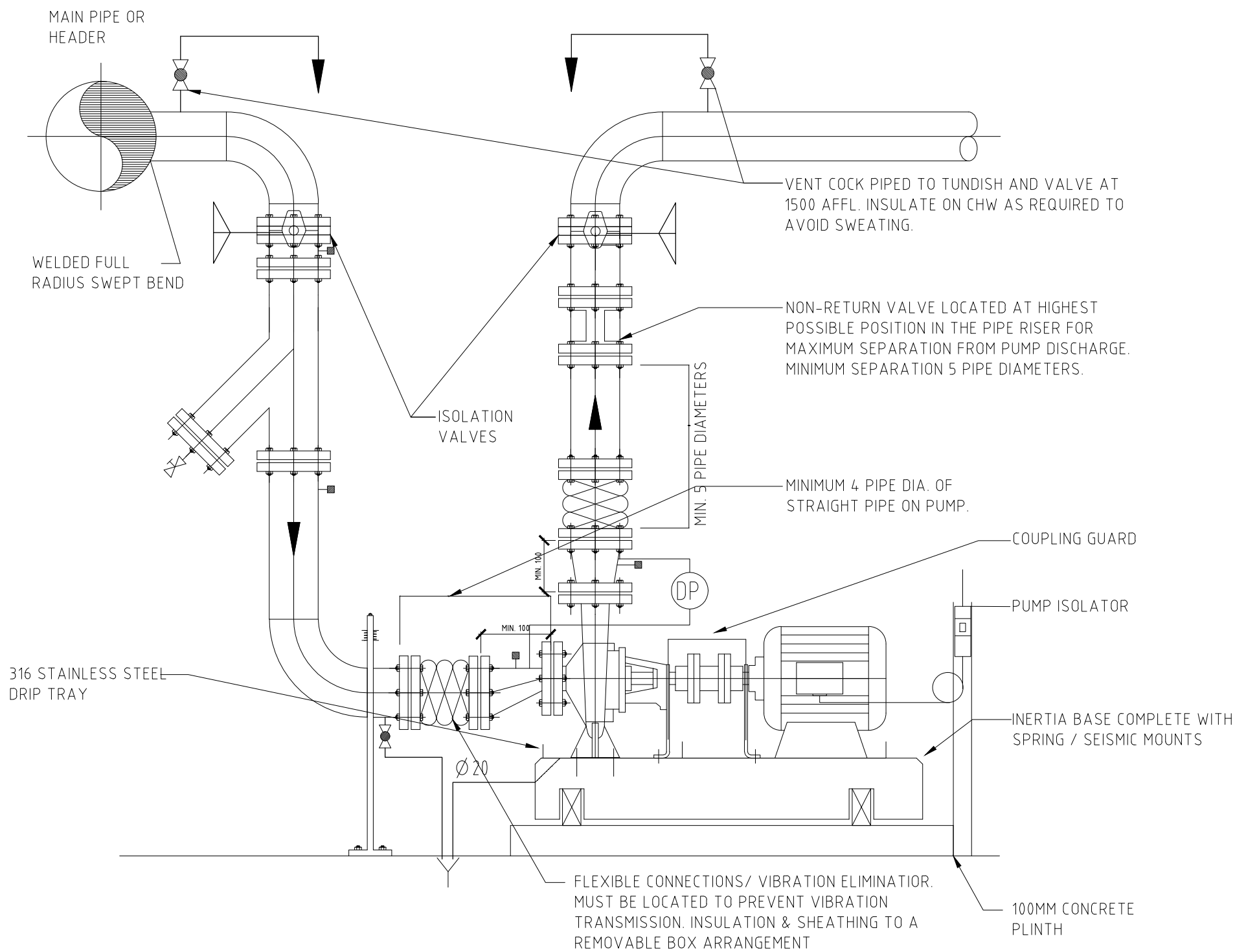
DATE	DEC 2014	DRAWN
SCALE	N.T.S.	CHECKED
SHEET SIZE	A3	APPROVED
CAD FILE		

TITLE	FAN COIL UNIT DETAIL
DRAWING NO.	MSD-05
REVISION	1

MSD 06 – Pump Installation Detail



SCHMATIC REPRESENTATION



NOTE

1. FOR PUMP ARRANGEMENT DETAILS REFER TO SPECIFICATION.
2. PIPEWORK INSULATION AND SHEATHING NOT SHOWN FOR CLARITY
3. VALVE OPERATOR AS PER SPECIFICATION, EXTEND VALVE SPINDLES AS REQUIRED TO PROVIDE ADEQUATE CLEARANCE FROM PIPEWORK INSULATION.
4. PROVIDE SUFFICIENT CABLE LENGTH TO ALLOW FOR MAINTENANCE WITHOUT DISCONNECTION OF MOTOR CABLING & A MINIMUM OF ONE LOOP FOR VIBRATION ISOLATION. ELECTRICAL INSTALLATION: IP66 MOTOR RATED ISOLATOR, IP66 FLEXIBLE CONDUITS & CONNECTORS.
5. FLEXIBLE CONDUIT CABLE TO MOTOR BE ARMORFLEX OR HEAVY DUTY PVC FOR EXTERNAL USE. LIGHT/ORDINARY DUTY NOT ACCEPTABLE

LEGEND

- BINDER POINT
- DIFFERENTIAL PRESSURE SWITCH
- SPOOL TRANSITION PIECE
- NON-RETURN VALVE
- STRAINER
- ISOLATION VALVE
- BUTTERFLY > 50
- BALL VALVE < 50
- BALL VALVE
- PUMP
- FLEXIBLE PIPE COUPLING

DATE	REV	AMENDMENT	BY	CHKD
JAN 2015	1	STANDARD ISSUE	-	-

CLIENT



MECHANICAL

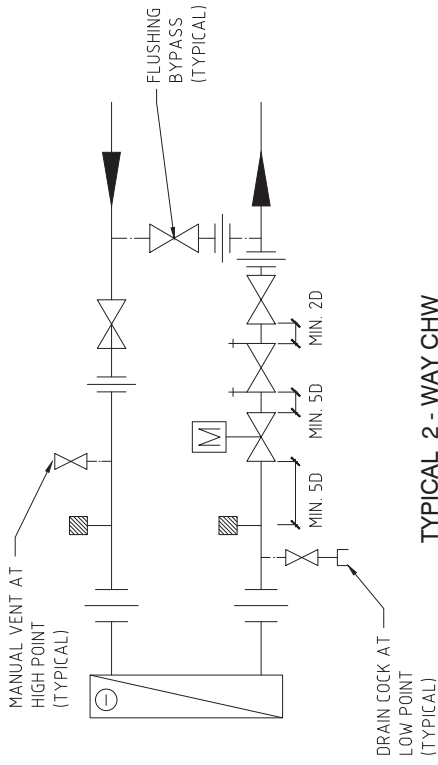


Level 2, 32 Carrington Street
Sydney NSW 2000
T: +612 9259 9059
T: +612 8078 4406
E: Info@cjpconsulting.com.au

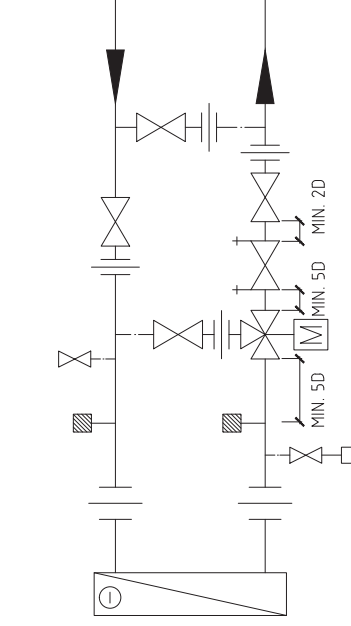
**MACQUARIE UNIVERSITY
STANDARD DRAWINGS**

DATE	JAN 2015	DRAWN	-	TITLE
SCALE	N.T.S.	CHECKED	-	PUMP INSTALLATION DETAIL
SHEET SIZE	A3	APPROVED	-	DRAWING NO. MSD-06
CAD FILE				REVISION 1

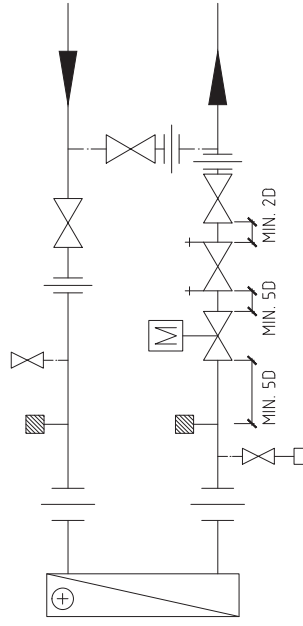
MSD 07 – Coil Connection Detail



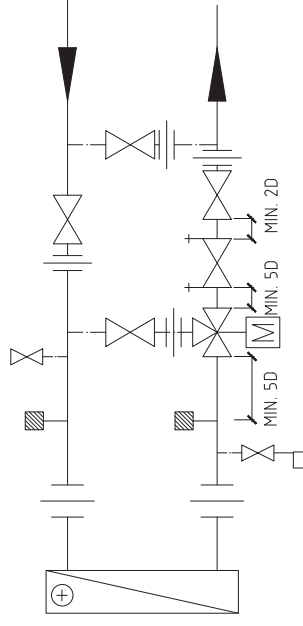
**TYPICAL 2 - WAY CHW
COIL CONNECTION DETAIL**



**TYPICAL 3 - WAY CHW
COIL CONNECTION DETAIL**



**TYPICAL 2 - WAY HHW
COIL CONNECTION DETAIL**



**TYPICAL 3 - WAY HHW COIL
CONNECTION DETAIL**

LEGEND

- BINDER POINT
- ISOLATION VALVE
- BUTTERFLY ≥ 50
- BALL VALVE ≤ 50
- 3 WAY MOTORISED VALVE
- 2 WAY MOTORISED VALVE
- BALANCING VALVE
- DRAIN COCK
- FLEXIBLE CONNECTION
- MANUAL AIR VENT

NOTE

1. MINIMUM 5 PIPE DIAMETER STRAIGHT LENGTH BETWEEN MOTORISED VALVE
2. MINIMUM 3 PIPE DIAMETER STRAIGHT LENGTH UPSTREAM OF BALANCING VALVE AND 2 PIPE DIAMETER STRAIGHT LENGTH DOWNSTREAM OF BALANCING VALVE
3. ALL VALVES MUST BE REMOVABLE WITHOUT CUTTING OR REMOVING LARGE SECTIONS OF PIPING.

DATE	REV	AMENDMENT	BY/CHKD
JAN 2016	1	STANDARD ISSUE	-

CLIENT



MECHANICAL

Level 2, 33 Castleside Street
Sydney NSW 2000
T +61 2 959 9599
F +61 2 959 4406
E info@pm-engineering.com.au



**MACQUARIE UNIVERSITY
STANDARD DRAWINGS**

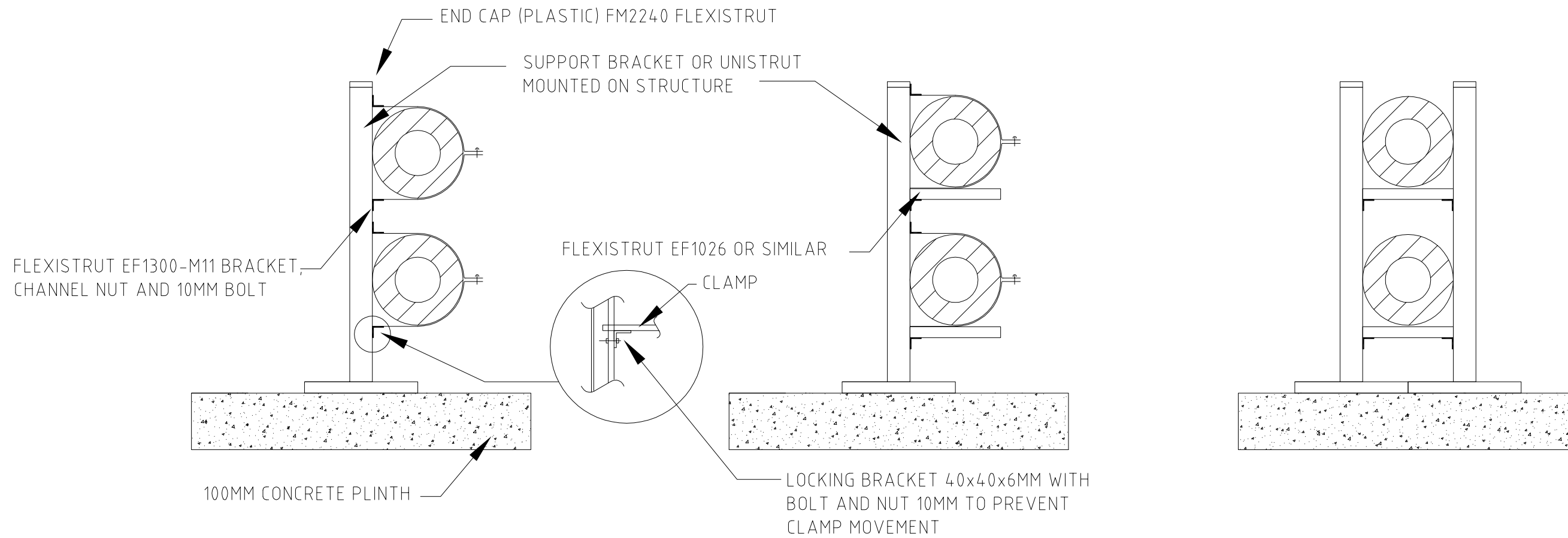
DATE	JAN 2016	DRAWN	TITLE
SCALE	N.T.S.	CHECKED	COIL CONNECTION DETAIL
SHEET SIZE	A3	APPROVED	
CAD FILE			DRAWING NO. MSD-07
			REVISION 1

MSD 09 – Piping Support

ALTERNATIVE PIPING SUPPORT

PREFERRED PIPING SUPPORT

PREFERRED PIPING SUPPORT
(GREATER THAN 200MM)



DATE	REV	AMENDMENT	BY	CHKD
DEC 2014	1	STANDARD ISSUE		

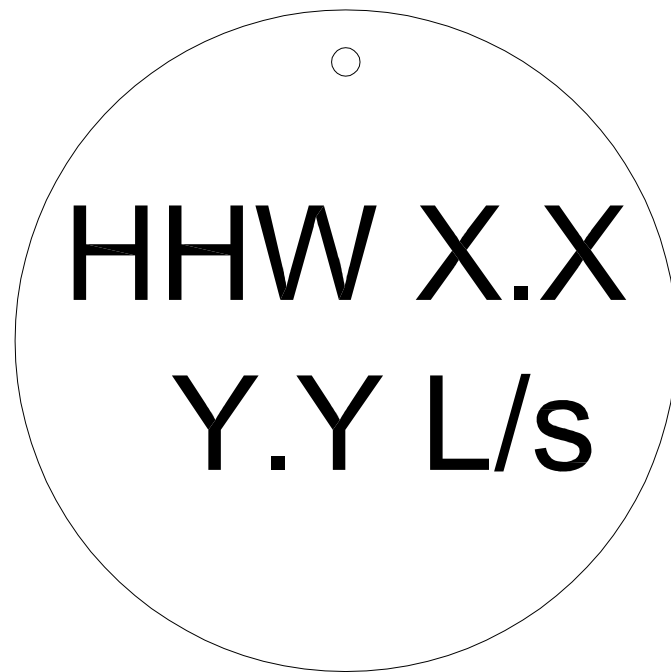


MACQUARIE UNIVERSITY
STANDARD DRAWINGS

DATE	DEC 2014	DRAWN
SCALE	N.T.S.	CHECKED
SHEET SIZE	A3	APPROVED
CAD FILE		

TITLE	PIPING SUPPORT
DRAWING NO.	MSD-09
REVISION	1

MSD 08 – Valve Tag Details



REVERSE SIDE V004/ V010 ONLY

3.5MM LETTERING ON 25MM BRASS TAG.
 HELVETICA BOLD ADJUSTED FOR CLARITY OF READING OF TEXT.

TABLE OF VALVES (EXAMPLE)

- V001 - CHW ISOLATION VALVE AT BRANCH
- V002 - CHW ISOLATION VALVE AT UNIT
- V003 - CHW CONTROL VALVE
- V004 - CHW FLOW REGULATION VALVE CHW=4.5 0.82L/s
- V005 - CHW ISOLATION VALVE AT REGULATION VALVE
- V006 - CHW ISOLATION VALVE AT BRANCH

- V007 - HHW ISOLATION VALVE AT BRANCH
- V008 - HHW ISOLATION VALVE AT UNIT
- V009 - HHV CONTROL VALVE
- V010 - HHW FLOW REGULATION VALVE HHW=3.2 0.41L/s
- V011 - HHW ISOLATION VALVE AT REGULATION VALVE
- V012 - HHW ISOLATION VALVE AT BRANCH

DATE	REV	AMENDMENT	BY	CHKD
DEC 2014	1	STANDARD ISSUE		



MACQUARIE UNIVERSITY
 STANDARD DRAWINGS

DATE	DEC 2014	DRAWN
SCALE	N.T.S.	CHECKED
SHEET SIZE	A3	APPROVED
CAD FILE		

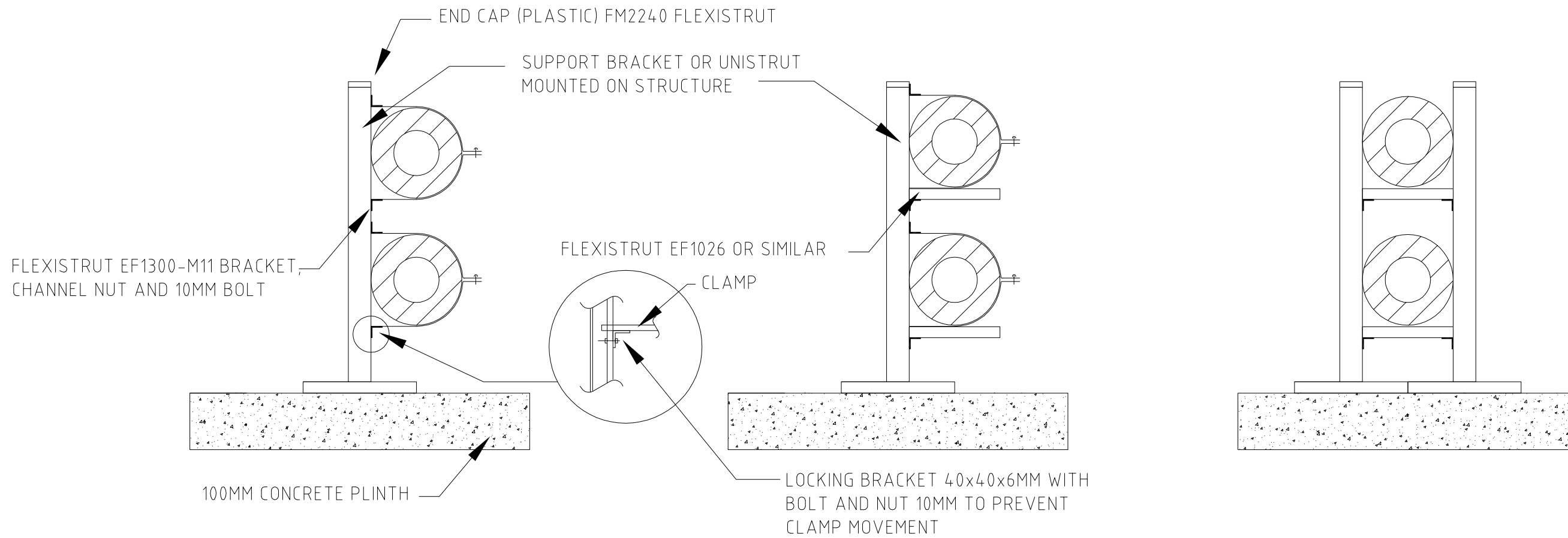
TITLE VALVE TAG DETAILS	
DRAWING NO. MSD-08	REVISION 1

MSD 09 – Piping Support

ALTERNATIVE PIPING SUPPORT

PREFERRED PIPING SUPPORT

PREFERRED PIPING SUPPORT
(GREATER THAN 200MM)



DATE	REV	AMENDMENT	BY	CHKD
DEC 2014	1	STANDARD ISSUE		



MACQUARIE UNIVERSITY
STANDARD DRAWINGS

DATE	DEC 2014	DRAWN
SCALE	N.T.S.	CHECKED
SHEET SIZE	A3	APPROVED
CAD FILE		

TITLE	PIPING SUPPORT
DRAWING NO.	MSD-09
REVISION	1

MUP QA – QA Images

HHW Boiler Installation



✓ - Acceptable



X - Not Acceptable



Pump Installation



✓ - Acceptable



X - Not Acceptable



Chiller Installation



✓ - Acceptable



X - Not Acceptable



Access to Plant



✓ - Acceptable



X - Not Acceptable



MSB Installation



✓ - Acceptable



X - Not Acceptable



Cooling Tower Installation



✓ - Acceptable



X - Not Acceptable



Electrical & Mechanical Boards

Board Colour & Lock Mechanism



✓ - Acceptable



X - Not Acceptable



Pipe Bracketing



✓ - Acceptable



X - Not Acceptable

Pipe & Cladding Specification



✓ - Acceptable



X - Not Acceptable

Cable Tray Standard



✓ - Acceptable



X - Not Acceptable



Valve Identification



✓ - Acceptable



X - Not Acceptable

Drain Details



✓ - Acceptable



X - Not Acceptable

MCL 01 – Mechanical Works Checklist

MECHANICAL WORKS CHECKLIST

A summary of key technical requirements

Version 1.2
February 2016

Source document: MQU Mechanical Services Design Standard V1.2

MECHANICAL WORKS CHECKLIST

Table of Contents

5.2	STANDARDS.....	3
5.3	DESIGN and DOCUMENTATION	3
5.4	TECHNICAL COMPONENTS.....	4
5.5	AIR COOLED CHILLERS	4
5.6	WATER COOLED CHILLERS	4
5.7	COOLING TOWERS	5
5.8	PUMPS	5
5.9	VARIABLE SPEED DRIVES (VSD's).....	5
5.10	FANS	6
5.11	AIR HANDLING (AHU) and FAN COIL UNITS (FCU).....	6
5.12	HEAT RECOVERY	7
5.13	VARIABLE AIR VOLUME UNIT (VAV)	7
5.14	CHW / HHW / CONDENSOR WATER PIPEWORK	7
5.15	VALVES.....	8
5.16	CONDENSATE DRAINS /SAFETY TRAYS.....	9
5.17	SPLIT SYSTEMS.....	9
5.18	VRV / VRF	10
5.19	REFRIGERANTS and REFRIGERATION PIPEWORK.....	10
5.20	DUCTWORK	11
5.21	AIR GRILLES and DIFFUSERS	12
5.22	VIBRATION / NOISE.....	12
5.23	MECHANICAL SWITCHBOARDS	13
5.24	PAINTING Table.....	13
5.25	LABELLING	13
5.26	SERVICE ACCESS / SAFETY REQUIREMENTS.....	14
5.27	REDUNDANT EQUIPMENT.....	14
5.28	PRODUCT SUPPORT / EXPERIENCE REQUIREMENTS.....	14
5.29	COMMISSIONING.....	14
6.	QUALITY CONTROL.....	14
7.1	APPENDIX 1 – Standard Drawings	15
7.2	APPENDIX 2 – MQU Guidelines	15
7.3	APPENDIX 3 – Compliant and Non-Compliant Works - Examples	16

MECHANICAL WORKS CHECKLIST

Sect. Ref	Technical Requirement	Complies	Comment
5.2	STANDARDS		
	Meets applicable Standards	<input type="checkbox"/>
5.3	DESIGN and DOCUMENTATION		
5.3.1	Meets priority design considerations	<input type="checkbox"/>
5.3.2	Proactive consultation	<input type="checkbox"/>
5.3.3	Fully qualified consultants	<input type="checkbox"/>
5.3.4	Computer based modelling performed	<input type="checkbox"/>
5.3.5	Design conditions met	<input type="checkbox"/>
5.3.6	Equipment selection and sizing	<input type="checkbox"/>
	Design basis nominated in documentation	<input type="checkbox"/>
5.3.7	Minimum Energy Efficiency and Heat Recovery requirements		
	a. Meets specified Efficiency requirements	<input type="checkbox"/>
	d.e. VSDs for pumps and fan motors	<input type="checkbox"/>
5.3.8	System Types		
	a. Uses MQU CHW reticulation infrastructure	<input type="checkbox"/>
	b. Mixed mode AC/Ventilation considered	<input type="checkbox"/>
	c. VAV systems with variable speed AHU	<input type="checkbox"/>
	d. Not acceptable-Low temp. VAV systems	<input type="checkbox"/>
	e. Not acceptable-Passive chilled beam systems	<input type="checkbox"/>
	f. Active chilled beam system	<input type="checkbox"/>
	g. Not acceptable-ceiling cassette units	<input type="checkbox"/>
	h. Underfloor systems, subject to capacity	<input type="checkbox"/>
	i. Split systems for very small additions	<input type="checkbox"/>
	j. Not acceptable-RAC window units	<input type="checkbox"/>
5.3.9	Future allowance-spare capacity	<input type="checkbox"/>
5.3.10	Other Design Requirements		
	a. Variable speed chillers must be used	<input type="checkbox"/>
	b. Fume cupboard requirements	<input type="checkbox"/>
	c. Water control loop sizing (buffer tank)	<input type="checkbox"/>
	d. Plant room ventilation	<input type="checkbox"/>
	e. BMCS controls	<input type="checkbox"/>
	f. Outside air supplied into mixing plenum	<input type="checkbox"/>
	g. Redundancy incorporated for critical environ.	<input type="checkbox"/>
	h. Hard drawn refrigeration pipework	<input type="checkbox"/>
	i. Condensate pipework copper and insulated	<input type="checkbox"/>
	j. Duct and Pipe insulation shall meet BCA	<input type="checkbox"/>
	k. Not acceptable-RAC window units	<input type="checkbox"/>
	l. Complies with CIBSE commissioning	<input type="checkbox"/>

MECHANICAL WORKS CHECKLIST

Sect. Ref	Technical Requirement	Complies	Comment
--------------	-----------------------	----------	---------

5.4 TECHNICAL COMPONENTS

Specifications to adhere to requirements and no conflicting requirements or information

.....

5.5 AIR COOLED CHILLERS

5.5.1 Meets Air or Water cooled selection

.....

5.5.2 Preferred supplier installed

.....

5.5.3 Meets general requirements

.....

5.5.4 Preferred Refrigerant used

.....

5.5.5 Scroll or screw compressor

.....

5.5.6 Liquid Coolers

.....

Insulation sheathing meets requirement

.....

5.5.7 Condenser coils meets specification

.....

5.5.8 Condenser fans, variable speed

.....

5.5.9 Coil has Blygold corrosion protection

.....

Chiller and pipework isolated

.....

5.5.10 Controls panel LCD/LED touch screen

.....

BACnet HLI interface

.....

5.6 WATER COOLED CHILLERS

5.6.1 Preferred supplier installed

.....

5.6.2 Meets general requirements

.....

5.6.3 Danfoss Compressor

.....

5.6.4 Liquid coolers meet specification

.....

5.6.5 Condensers meet requirements

.....

5.6.6 Water boxes meet requirements

.....

5.6.7 Corrosion protection, 5 year guarantee

.....

Chiller and pipework isolated

.....

5.6.8 Controls panel LCD/LED touch screen

.....

BACnet HLI interface

.....

MECHANICAL WORKS CHECKLIST

Sect. Ref	Technical Requirement	Complies	Comment
-----------	-----------------------	----------	---------

5.7 COOLING TOWERS

5.7.1	Preferred supplier installed	<input type="checkbox"/>
5.7.2	Meets general requirements	<input type="checkbox"/>
5.7.3	Meets Construction requirements	<input type="checkbox"/>
5.7.4	Fans meet requirements	<input type="checkbox"/>
5.7.5	Water distribution meet requirements	<input type="checkbox"/>
5.7.6	Dead legs – all parts can be drained and flushed	<input type="checkbox"/>
5.7.7	Capacity oversized >15%	<input type="checkbox"/>
5.7.8	Access - maintenance	<input type="checkbox"/>

5.8 PUMPS

5.8.1	Preferred supplier installed	<input type="checkbox"/>
5.8.2	Meets general requirements	<input type="checkbox"/>
	Drip trays	<input type="checkbox"/>
	Drainage	<input type="checkbox"/>
	Sealant	<input type="checkbox"/>
	Marking	<input type="checkbox"/>

5.9 VARIABLE SPEED DRIVES (VSD's)

5.9.1	Preferred supplier installed	<input type="checkbox"/>
5.9.2	Meets general requirements	<input type="checkbox"/>
5.9.3	Motor protection features	<input type="checkbox"/>
5.9.4	Control pad	<input type="checkbox"/>
5.9.5	Performance >96% at 100% load	<input type="checkbox"/>
5.9.6	Location – internally mounted	<input type="checkbox"/>
5.9.7	IP 54 Protection	<input type="checkbox"/>
5.9.8	Cooling	<input type="checkbox"/>
5.9.9	O&M documentation	<input type="checkbox"/>
5.9.10	BACnet HLI interface	<input type="checkbox"/>

MECHANICAL WORKS CHECKLIST

Sect. Ref	Technical Requirement	Complies	Comment
-----------	-----------------------	----------	---------

5.10 FANS

5.10.1	Meets General requirements	<input type="checkbox"/>
	Preferred manufacturer installed	<input type="checkbox"/>
	Meets efficiency and design air flow	<input type="checkbox"/>
	Acceptable noise level	<input type="checkbox"/>
5.10.2	Meets Installation requirements	<input type="checkbox"/>
	Installation-Maintenance	<input type="checkbox"/>
	Installation-Flexible duct connections	<input type="checkbox"/>
	Installation-Drain	<input type="checkbox"/>
	Installation-Ant-vibration isolation	<input type="checkbox"/>
5.10.3	Belt driven fan – rigid guard	<input type="checkbox"/>
5.10.4	Kitchen exhaust fans		
	Self cleaning	<input type="checkbox"/>
	Close to discharge	<input type="checkbox"/>
	Access, drain, finish, fire rating	<input type="checkbox"/>
5.10.5	Roof mounted fans	<input type="checkbox"/>
	Type	<input type="checkbox"/>
	Housing	<input type="checkbox"/>
	Backdraft dampers	<input type="checkbox"/>
	Motors IP65	<input type="checkbox"/>

5.11 AIR HANDLING (AHU) and FAN COIL UNITS (FCU)

5.11.1	Meets Preferred Suppliers requirements	<input type="checkbox"/>
5.11.2	Interpretation AHU, FCU - meets requirements	<input type="checkbox"/>
5.11.3	VSD's for >1000l/s, FCU 3-speeds	<input type="checkbox"/>
5.11.4	Construction and access panels	<input type="checkbox"/>
5.11.5	Room FCU requirements	<input type="checkbox"/>
5.11.6	Return Air must be ducted	<input type="checkbox"/>
5.11.7	Coils – meet requirements	<input type="checkbox"/>
5.11.8	Drip trays – S/S and drain	<input type="checkbox"/>
5.11.9	Access Doors and Panels	<input type="checkbox"/>
5.11.10	Service lights	<input type="checkbox"/>
5.11.11	Filters	<input type="checkbox"/>
5.11.12	Mixing plenums	<input type="checkbox"/>
5.11.13	Face Bypass dampers	<input type="checkbox"/>
5.11.14	Location – maintenance access	<input type="checkbox"/>

MECHANICAL WORKS CHECKLIST

Sect. Ref	Technical Requirement	Complies	Comment
-----------	-----------------------	----------	---------

5.12 HEAT RECOVERY

- 5.12.1 Preferred supplier installed
- 5.12.2 Meets general requirements

5.13 VARIABLE AIR VOLUME UNIT (VAV)

- Selection
- Pressure independent boxes
- Fan assisted boxes
- general, casings, dampers, insulation, access panels
- controls

5.14 CHW / HHW / CONDENSOR WATER PIPEWORK

- 5.14.1 Design
 - Future expansion allowance
 - Pipework assists in balancing inherently
 - Compliant Insulation
- 5.14.2 Pipe Sizing
 - According to guidelines
 - Shall facilitate balancing with minimum pressure loss
- 5.14.3 Pipe Material
 - As per table AS1432 Type B, hard drawn
- 5.14.4 Cladding and Insulation
 - Zinc coated steel or Colorbond
 - Painted, identified and labelled
 - Supports as per AS3500, refer table
 - Pipe hanger rod diameter, as per table
- 5.14.5 Pressure Testing
 - 2x design for >24 hours
- 5.14.6 Flushing of Pipework
 - Prior to connection of any terminal equipment
 - Records provided
 - Hold point for inspection specified
- 5.14.7 Use of Air and Dirt Separators
 - Location, isolation valves, drain
 - Bypass line, with isolation valve closed

MECHANICAL WORKS CHECKLIST

Sect. Ref	Technical Requirement	Complies	Comment
5.15 VALVES			
5.15.1	General	<input type="checkbox"/>
	Equal in size to nominal pipe size	<input type="checkbox"/>
	Connections: screwed or flanged	<input type="checkbox"/>
	Installation as per Requirements	<input type="checkbox"/>
	Tag all valves and flow measuring devices	<input type="checkbox"/>
	Balancing valves – hand wheel setting and flow rate stamped on the disk	<input type="checkbox"/>
	Automatic/dynamic system balancing valves as per Requirements	<input type="checkbox"/>
	Pressure Independent Automatic Control valves ensure minimum required pressure differential	<input type="checkbox"/>
5.15.2	Water Valve Types	<input type="checkbox"/>
5.15.3	Sensing Points	<input type="checkbox"/>
	Test plugs in each pipe connection to every device and other locations where required	<input type="checkbox"/>
	Installation as specified	<input type="checkbox"/>
5.15.4	Valves in the Ceiling Space	<input type="checkbox"/>
	Must be insulated	<input type="checkbox"/>
	Access panels provided	<input type="checkbox"/>
5.15.5	Valve Unions	<input type="checkbox"/>
	Unions to allow removal without dismantling pipework	<input type="checkbox"/>
5.15.6	Connections to Equipment	<input type="checkbox"/>
	Isolating valves must be used at connections to all items of plant and equipment	<input type="checkbox"/>
	Connections allow removal of plant without removing large section of pipework or draining the system	<input type="checkbox"/>
5.15.7	Binder Cocks	<input type="checkbox"/>
	Isolating valves must be used at connections to all items of plant and equipment	<input type="checkbox"/>
5.15.8	Vents, Air and Dirt Separators	<input type="checkbox"/>
	Vents must be at highest points of the system and all other points where air may collect.	<input type="checkbox"/>

MECHANICAL WORKS CHECKLIST

Sect. Ref	Technical Requirement	Complies	Comment
5.16 CONDENSATE DRAINS /SAFETY TRAYS			
5.16.1	General	<input type="checkbox"/>
	Complies with Authority requirements	<input type="checkbox"/>
5.16.2	Condensate Pumps	<input type="checkbox"/>
	Gravity drainage, not lift pumps	<input type="checkbox"/>
	If lift pump used, integral to the FCU	<input type="checkbox"/>
5.16.3	Sizing and Material	<input type="checkbox"/>
	Min.25mm diameter	<input type="checkbox"/>
	Hard drawn copper	<input type="checkbox"/>
5.16.4	Waster drain insulation	<input type="checkbox"/>
	Insulated full length, Min.12mm thick	<input type="checkbox"/>
5.16.5	Trap	<input type="checkbox"/>
	Barrel unions or clear trap eg Easy Trap	<input type="checkbox"/>
5.16.6	Discharge	<input type="checkbox"/>
	Discharge to waste line only	<input type="checkbox"/>
	Tundish fitted to drain point	<input type="checkbox"/>
5.16.7	Safety Trays	<input type="checkbox"/>
	Independent of FCU, stainless steel	<input type="checkbox"/>
	Under all FCUs, AHUs, and package units	<input type="checkbox"/>
5.17 SPLIT SYSTEMS			
5.17.1	Preferred Suppliers - used	<input type="checkbox"/>
5.17.2	General	<input type="checkbox"/>
	Weatherproof powder coated anti-corrosion	<input type="checkbox"/>
	Location – no noise and/or aesthetic issues	<input type="checkbox"/>
	Inverter driven	<input type="checkbox"/>
	Fins coated with epoxy or durable finish	<input type="checkbox"/>
	Metal trunking/sheathing; no exposed insulation	<input type="checkbox"/>
	Insulation of refrigerant pipework-Armaflex	<input type="checkbox"/>
	BACnet HLI for BMCS interfacing	<input type="checkbox"/>
	Refrigerant R410A	<input type="checkbox"/>

MECHANICAL WORKS CHECKLIST

Sect. Ref	Technical Requirement	Complies	Comment
5.18 VRV / VRF			
5.18.1	Preferred Suppliers - used	<input type="checkbox"/>
5.18.2	General	<input type="checkbox"/>
	Location – no noise and/or aesthetic issues	<input type="checkbox"/>
	Multi-stage Inverter driven	<input type="checkbox"/>
	Fins coated with epoxy or durable finish	<input type="checkbox"/>
	Weatherproof powder coated anti-corrosion	<input type="checkbox"/>
	Metal trunking/sheathing; no exposed insulation	<input type="checkbox"/>
	Insulation of refrigerant pipework-Armaflex	<input type="checkbox"/>
	BACnet HLI for BMCS interfacing	<input type="checkbox"/>
	Refrigerant R410A	<input type="checkbox"/>
5.19 REFRIGERANTS and REFRIGERATION PIPEWORK			
5.19.1	Acceptable refrigerant type to be used	<input type="checkbox"/>
5.19.2	Refrigerant Recovery	<input type="checkbox"/>
	Reclaimed and disposed of within guidelines	<input type="checkbox"/>
	Certification of recovery submitted to MUP	<input type="checkbox"/>
5.19.3	Refrigerant Pipe Work	<input type="checkbox"/>
5.19.4	Pipes	<input type="checkbox"/>
	Copper hard drawn, pipe wall thickness to AS	<input type="checkbox"/>
	Necessary circuit accessories	<input type="checkbox"/>
	Provide for charging and withdrawal of refrigerant	<input type="checkbox"/>
	Straight lines, positive oil return	<input type="checkbox"/>
5.19.5	External Trunking	<input type="checkbox"/>
	Mechanically protected, water-shedding	<input type="checkbox"/>
	Zinc coated, rectangular, colorbond matched	<input type="checkbox"/>
5.19.6	Pipe Joints	<input type="checkbox"/>
	Silver solder	<input type="checkbox"/>
	Pre-form bends, no flattening or corrugation	<input type="checkbox"/>
5.19.7	Pipe Supports	<input type="checkbox"/>
	Restrained vertically and horizontally	<input type="checkbox"/>
	Vibration is not transmitted to the building structure	<input type="checkbox"/>
	Supports – zinc plated galvanised steel	<input type="checkbox"/>
	Anchors and guides for long pipes	<input type="checkbox"/>
	No saddle supports for pipes > DN 25	<input type="checkbox"/>
	Anchors and guides for long pipes	<input type="checkbox"/>
	Insulated pipe support as per requirements	<input type="checkbox"/>
	Pipe support spacing as per Table	<input type="checkbox"/>
5.19.8	Thermal Insulation	<input type="checkbox"/>
	Armaflex or approved equivalent > 19mm thickness	<input type="checkbox"/>
	End joints neatly glued and taped	<input type="checkbox"/>
	Not split or zippered	<input type="checkbox"/>

MECHANICAL WORKS CHECKLIST

Sect. Ref	Technical Requirement	Complies	Comment
5.20 DUCTWORK			
5.20.1	General - Design and installation meets AS4254	<input type="checkbox"/>
	a. configuration assists in balancing	<input type="checkbox"/>
	b. Within specified velocities for acoustic levels	<input type="checkbox"/>
	c. Friction loss < 0.8 Pa/m	<input type="checkbox"/>
	d. Balancing dampers at each floor and branch	<input type="checkbox"/>
	e. Spigot dampers at each flexible duct connection	<input type="checkbox"/>
	d. Avoid balancing dampers at diffusers or behind grilles	<input type="checkbox"/>
5.20.2	Duct Leakage Testing	<input type="checkbox"/>
	a. Designer specifies duct leakage class and allowable leakage rates	<input type="checkbox"/>
	b. Leakage test in accordance with SMACNA Standard	<input type="checkbox"/>
5.20.3	Flexible Duct		
	As per AS4254.1 and requirements	<input type="checkbox"/>
5.20.4	Flexible Connections – refer AS4254.2	<input type="checkbox"/>
	Isolate from ductwork - airtight flexible connections	<input type="checkbox"/>
	Heavy duty, waterproof	<input type="checkbox"/>
	Meets other requirements	<input type="checkbox"/>
5.20.5	Volume Control Dampers	<input type="checkbox"/>
	Free of rattles, fluttering or slack movement	<input type="checkbox"/>
	Meets other requirements	<input type="checkbox"/>
5.20.6	Splitter Dampers	<input type="checkbox"/>
	Fabricated to meet requirements	<input type="checkbox"/>
5.20.7	Motorised Dampers	<input type="checkbox"/>
	As per Volume Control Dampers (5.19.5)	<input type="checkbox"/>
	Meets other requirements	<input type="checkbox"/>
5.20.8	Non-Return Dampers	<input type="checkbox"/>
	As per Volume Control Dampers (5.19.5)	<input type="checkbox"/>
	Meets other requirements	<input type="checkbox"/>
5.20.9	Access Openings – Location	<input type="checkbox"/>
	Door - in each section of AHU for maintenance	<input type="checkbox"/>
	Panel – next to each component inside the duct requiring regular inspection and maintenance	<input type="checkbox"/>
5.20.10	Access Panels	<input type="checkbox"/>
	Personnel access – minimum 450 x 600mm	<input type="checkbox"/>
	Hand access – minimum 200 x 300mm	<input type="checkbox"/>
	Construction to meet requirements	<input type="checkbox"/>

MECHANICAL WORKS CHECKLIST

Sect. Ref	Technical Requirement	Complies	Comment
5.20.11	Access Doors	<input type="checkbox"/>
	Construction to meet requirements	<input type="checkbox"/>
5.20.12	Insulation	<input type="checkbox"/>
	All supply and return ductwork must meet NCC/BCA "deemed to satisfy" (DTS) requirements	<input type="checkbox"/>
5.20.13	Ductwork Installation	<input type="checkbox"/>
	Cleaned prior to commissioning	<input type="checkbox"/>
	Meets requirements	<input type="checkbox"/>
5.20.14	Leakage Testing Procedures	<input type="checkbox"/>
	Test method SMACNA HVAC Air Duct Leakage	<input type="checkbox"/>
	Maximum leakage rate to AS 4254.2	<input type="checkbox"/>
	Test method as per requirements	<input type="checkbox"/>
5.21 AIR GRILLES and DIFFUSERS			
5.21.1	General	<input type="checkbox"/>
	Provides adequate air movement without draft	<input type="checkbox"/>
	Provision for air pattern adjustments	<input type="checkbox"/>
5.21.2	Exhaust Grilles	<input type="checkbox"/>
	Egg-crate type with 12mm x 12mm core	<input type="checkbox"/>
	Integral opposed blade volume control dampers	<input type="checkbox"/>
5.21.3	Plenum Boxes	<input type="checkbox"/>
	As per requirements	<input type="checkbox"/>
5.21.4	Door Grilles	<input type="checkbox"/>
	As per requirements	<input type="checkbox"/>
5.21.5	Undercutting of Doors - not acceptable	<input type="checkbox"/>
5.22 VIBRATION / NOISE			
5.22.1	Machinery	<input type="checkbox"/>
	As per requirements	<input type="checkbox"/>
5.22.2	Piping	<input type="checkbox"/>
	As per requirements	<input type="checkbox"/>
5.22.3	Ductwork	<input type="checkbox"/>
	As per requirements	<input type="checkbox"/>
5.22.4	Flexible Connections for Pipework	<input type="checkbox"/>
	As per requirements	<input type="checkbox"/>
5.22.5	Flexible Connections for Ductwork	<input type="checkbox"/>
	As per requirements	<input type="checkbox"/>
5.22.6	Pump Inertia Bases	<input type="checkbox"/>
	All pumps must be mounted on inertia bases	<input type="checkbox"/>
	Inertia bases fitted with spring isolators	<input type="checkbox"/>
	Flexible connections that isolate vibrations	<input type="checkbox"/>

MECHANICAL WORKS CHECKLIST

Sect. Ref	Technical Requirement	Complies	Comment
5.23 MECHANICAL SWITCHBOARDS			
5.23.1	General	<input type="checkbox"/>
	Main Switch without opening switchboard	<input type="checkbox"/>
	Escutcheon plate for physical protection	<input type="checkbox"/>
5.23.2	Form of Separation	<input type="checkbox"/>
	As per project requirements and guiding principles	<input type="checkbox"/>
5.23.3	Metalwork	<input type="checkbox"/>
	a. minimum 2mm thick bright steel sheet	<input type="checkbox"/>
	b. lift-off hinges, locking handle, MUP 92286 key	<input type="checkbox"/>
	c. large panels with fitted D handles	<input type="checkbox"/>
	d. escutcheon plates and hinged panels can be undone without the use of tools	<input type="checkbox"/>
	e. cabinet mounted on a welded channel steel frame	<input type="checkbox"/>
5.23.4	KWH Meters	<input type="checkbox"/>
	Meter, C/Ts and comms. interface supplied by Contractor	<input type="checkbox"/>
	Installation as per requirements	<input type="checkbox"/>
5.23.5	Finish	<input type="checkbox"/>
	Painted as per requirements and approved colours	<input type="checkbox"/>
	Distribution Board labelled correctly	<input type="checkbox"/>
5.23.6	Labels	<input type="checkbox"/>
	Labelling as per requirements	<input type="checkbox"/>
5.23.7	Fuses	<input type="checkbox"/>
	Fixture for spare fuse cartridges	<input type="checkbox"/>
5.23.8	Size of Control Panel	<input type="checkbox"/>
	> 20% additional spare capacity	<input type="checkbox"/>
5.23.9	Approved Component Suppliers	<input type="checkbox"/>
	Meets equipment specifications as listed	<input type="checkbox"/>
5.24 PAINTING Table			
	As per Standard Approved Colours eg:	<input type="checkbox"/>
	▪ Pipework - Green (Jade/Emerald)	<input type="checkbox"/>
	▪ Ductwork - Shoji White	<input type="checkbox"/>
	▪ Plant Rooms - Grey	<input type="checkbox"/>
	▪ Electrical Boards - Orange, White interior & plate	<input type="checkbox"/>
	▪ BMCS Boards - Orange, White interior & plate	<input type="checkbox"/>
	▪ Cable Trays - Orange	<input type="checkbox"/>
	▪ Plinths - Black top, yellow edges	<input type="checkbox"/>
5.25 LABELLING			
5.25.1	General	<input type="checkbox"/>
5.25.2	Equipment Labelling	<input type="checkbox"/>

MECHANICAL WORKS CHECKLIST

Sect. Ref	Technical Requirement	Complies	Comment
5.26 SERVICE ACCESS / SAFETY REQUIREMENTS			
5.26.1	General	<input type="checkbox"/>
	a. position to optimise maintenance and repairs	<input type="checkbox"/>
	b. plant in ceiling spaces only in offices	<input type="checkbox"/>
	c. unacceptable - plant within tight spaces	<input type="checkbox"/>
	d. all motors with isolators	<input type="checkbox"/>
	e. manufacturers access requirement + 20%	<input type="checkbox"/>
	f. plant above 3m – permanent stair and work platform	<input type="checkbox"/>
	g. trip hazards painted yellow with black strip	<input type="checkbox"/>
	h. electrical hazards identified and labelled	<input type="checkbox"/>
	i. yellow walkways around plant in plant rooms	<input type="checkbox"/>
	j. chemical hazards to be labelled and clearance lines to be painted; paperwork on-site	<input type="checkbox"/>
	k. confined spaces note and signage applied	<input type="checkbox"/>
	l. fixed switchable lights in AHU chambers	<input type="checkbox"/>
	m. access complies with WHS requirements	<input type="checkbox"/>
5.27 REDUNDANT EQUIPMENT			
	All redundant equipment removed	<input type="checkbox"/>
	Surfaces and finishes made good	<input type="checkbox"/>
5.28 PRODUCT SUPPORT / EXPERIENCE REQUIREMENTS			
	All products supported locally and internationally by factory trained service networks	<input type="checkbox"/>
	Parts available for 10 years ex-stock	<input type="checkbox"/>
	Products with established reliability	<input type="checkbox"/>
	Proven installation history in Australia, 8 years operation	<input type="checkbox"/>
	Spares readily available	<input type="checkbox"/>
5.29 COMMISSIONING			
	Comprehensive plan	<input type="checkbox"/>
	ITPs for all major items	<input type="checkbox"/>
	Commissioning methodology statement	<input type="checkbox"/>
	Shop drawings prior to commencement of construction	<input type="checkbox"/>
6. QUALITY CONTROL			
6.1	Design Standard Compliance	<input type="checkbox"/>
6.2	Design Standard Certification	<input type="checkbox"/>
	a. Letter of Certification - Design and documentation	<input type="checkbox"/>
	b. Letter of Certification - Tender	<input type="checkbox"/>
	c. Letter of Certification - Construction	<input type="checkbox"/>

MECHANICAL WORKS CHECKLIST

7.1 APPENDIX 1 – Standard Drawings

Contractor must use latest version at date of project.

No.	Description	Complies
1	MSD-01 Branch Valve Detail	
2	MSD-02 PICCV coil connection	
3	MSD-03 Heat Recovery unit	
4	MSD-04 Air and Dirt Separator	
5	MSD-05 Fan Coil Unit installation	
6	MSD-06 Pump installation	
7	MSD-07 Coil connections	
8	MSD-08 Valve tag details	
9	MSD-09 Piping support	

7.2 APPENDIX 2 – MQU Guidelines

Contractor must use latest version at date of project.








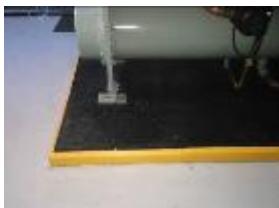
No.	Description	Complies
1	MUP Mechanical Services Design Standard V1.2	
2	MUP Electrical Services Standard V1.0	
3	MUP Hydraulics Standard V1.0	
4	MUP Guideline Design Standard for BMS V2.0	
5	BMS Alarm Subsystem Specification V2.0	
6	BMS Configuration Management Plan Part A V0.1	
7	BMS Example Graphic screens	

MECHANICAL WORKS CHECKLIST





7.3 APPENDIX 3 – Compliant and Non-Compliant Works - Examples

PIPEWORK INSULATION and SHEATHING			
			
✓ Correct R rating	✓ 50mm width, metal continuous under bracket	✓ Pipe supports	✓ Green colourbond sheathing
			
✓ Correct labelling	✓ Pipework supported	✓ All fittings as per design guidelines	✓
			
✗ Wrong colour and poor pipe joins	✗ Poorly supported pipe runs	✗ Non-galvanised sheathing	✗ Gaps in sheathing
			

MECHANICAL WORKS CHECKLIST

X Poor joint sealing	X Non-galvanised fittings	X Swarf and rust on metal work	X Touch-up paint scratches
BMS CONTROLS			
			
✓ Cable tray - Orange	✓ Actuators with metal covers with clips	✓	✓
			
X BMS panel interior - must be white	X BMS wiring - not fully labelled	X Non-waterproof enclosure for actuators	X A4 document holder inside door of panels
			
X BMS panel lables – holding screws required	X	X	
OTHER WORKS			
			
✓ Correct plinth painting	✓	✓	✓

MECHANICAL WORKS CHECKLIST

			
X No sharp protrusions	X No sharp edges	X Seal valve penetrations	X Cover trip hazards