Building Energy Management Systems (BEMS) - Engineering Specifications
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1.0 Introduction

This document indicates the University’s generic Building Energy Management Systems (BEMS) specification.

Users of this specification must also refer to any additional project specifications identified by a University Project team in furtherance of unique needs and regulatory compliance appertaining to the respective building.

Any new or retrofit design must have the capability to integrate with the University's existing BEMS systems (see 1.4).

Consultants and or designers must obtain approval in writing for any variation from these specifications.

Before incorporating these specifications in tender documentation etc, always check to ensure that the current approved Issue is used.

Please consult with ESS Sustainability Team to discuss any point for clarification or possible improvement - and to obtain further copies of this specification.

1.1 General

These Specifications must be used by Mechanical & Electrical Consultants / Supervising Engineers, and by University staff when specifying controls on either new build or retrofit installations.

Reference is made throughout to the nominated Field Equipment List attached at Appendix A. It is a requirement that checks are completed before incorporating these Specifications in tender documentation and that they have the current Issue of the Specifications and Field Equipment List.

Building Energy Management Systems (BEMS) control package must be installed by a Controls Specialist Contractor and in accordance with the Standard Form of Building Contract (all Editions).

1.2 Contract Programme

The University requires ample opportunity for the ESS BMS Operations Group to comment on proposals therefore a minimum of ten working days from
receipt of the detail documents must be made available to enable the University to comment.

At Pre Tender stage: A draft Narrative on Mechanical Installation and Control Design Philosophy: A draft Mechanical Layout drawings & Equipment List: A draft BEMS Points List and Control Equipment List

At Tender Stage: A narrative on Mechanical Installation and Control Design Philosophy: Mechanical Layout drawings & Equipment List: BEMS Points List and Control Equipment List

The Design Consultants shall copy relevant documents to the ESS Sustainability and Maintenance teams at the same time as submitting them to the University’s Project Lead.

Any exclusions or changes to the final tender documents, at any stage, must be reported to the University Project Lead.

Ten working days after receipt of an order, the Controls Specialist Contractor must submit a Components List of all equipment required for the project, and a project programme.

The Controls Specialist Contractor shall give the ESS Sustainability and Maintenance Teams a minimum of ten working days’ notice of the following key stages:

Familiarisation with installation, prior to formal commissioning (proposals for Graphics Pages, Software, Alarm Priorities, Alarm Routing and Logging for the Supervisory PC must be tabled at this stage)

Demonstration of the system shall be presented to the ESS Sustainability and Maintenance Teams after seven days of performance, which met the specification. This demonstration shall include all software, completed graphics, logging, alarms, control installation using a laptop computer and a trended performance demonstration of at least 7 days evidencing that the system works as specified. A Snagging List of items that have still to be completed shall be prepared with a timetable for completion.

Office handover of as fitted O&M digital Manuals and installation of completed software, log configuration, alarm routing and graphics.
1.3 Designers’ and Contractors’ Responsibilities

These Specifications have been drafted to indicate the University’s generic specifications however in the event of any control strategy not being covered in this specification then it is the responsibility of the Controls Specialist Contractor to refer the issue to the ESS Sustainability and/or Maintenance Teams. If in doubt please always ask for clarification.

It shall be the responsibility of the Controls Specialist Contractor to identify any conflict or discrepancy between the proposed mode of operation and what is achievable for a specific project in reality. The Controls Specialist Contractor shall report any such issues and provide proposed options to the ESS Sustainability and Maintenance Teams to enable robust and effective, energy efficient plant operation.

1.4 Approved Controls Specialist Contractors

Siemens Desigo and Schneider (Struxerware) BEMS are the preferred BEMS for buildings maintained by the Estate Support Service. No other BEMS shall be installed without express written approval from University BMS Operation Group.

The controls wiring installation shall be carried out under the direction of the Controls Specialist Contractor as an integral part of any controls package.

2.0 Controls Philosophy

2.1 General

The University BEMS controls philosophy in general is to provide safe, healthy, comfortable environmental conditions for its building users. High emphasis is placed on implementing Energy Conservation measures at all stages, from the initial design of a system through to final commissioning and thereafter during maintenance and operation of the plant.

The diversity of the University buildings and the differing specifications of the end users, make it impossible to generalise on the required approach for controlling specific items of plant and control systems. However, the following
typical plant types can be specified and should be strictly adhered to unless otherwise instructed by the University BMS Operation Group. If in doubt ask!

2.2 **Offices and Standard Teaching Areas with Natural Ventilation**

Standard occupancy time for these areas is 08:00 to 17:00 hours Monday to Friday.

Plant shall be initiated to give a desired room temperature of 19-21°C at building occupancy time. Start/stop functions of the plant shall be provided via Optimiser control with integral room low limit for fabric frost protection during “plant off” periods of 10°C On / 12°C Off.

During Optimiser run-up or boost periods, all mixing and local zone valves shall be driven to the full heat position to achieve the desired occupancy temperature in as short a period as possible, except when supplied from one of the university CHP systems, in which case valves will be kept under normal day control during Optimiser Boost periods.

Once occupancy time or temperature is achieved, whichever is first, compensated mixing valves or local zone valves shall take control of the building room temperatures to maintain a temperature of 19-21°C. “Optimum Off” temperature shall be the same as occupancy temperature.

Where multiple offices are serviced via a VT wet system then one temperature sensor per 4 offices should be fitted, where large offices are serviced with more than 20 people then 2 sensors should be fitted and an averaging reading must be used for the actual temperature

2.3 **Lecture Theatres and Seminar Rooms with Mechanical Vent & Radiators**

Occupancy times for these areas are normally 08:00 to 17:00 hours Monday to Friday.

Theatres and Seminar Rooms should be designed with enough radiator capacity to allow optimisation to desired room temperature of 19-21°C without the use of ventilation plant. However, where this is not achievable, then ventilation will be required for optimisation of the space.
Plant shall be started via Optimiser control for a boost period to achieve the desired room temperature of 19-21°C. During this boost period the extract fans shall be kept off (on full fresh air systems only), the supply fans and heating medium shall be initiated, and any mixing dampers shall be forced to full recirculation position to achieve the desired occupancy temperature in as short a period as possible.

On termination of the optimised boost period, microwave/PIR occupancy sensors shall take control of the start/stop function of the ventilation supply and extract fans. If occupancy is not sensed, the fans will switch off, dampers will stay in full recirc, or drive to fully close on full fresh air systems, and the space temperature will be allowed to drop to a setback temperature of 4°C below the normal day control setpoint. At this setback temperature, the plant shall be started again to raise the room temperature back up to 3°C below the normal day setpoint and then switch off again i.e. keep the space at a 1°C differential.

Where occupancy is sensed by a microwave/PIR sensor, program for a continuous period of more than thirty seconds, then a twenty-minute, delay-off, software timer shall be initiated. The supply and extract fans shall be started and the heating battery and control dampers initiated to control the room temperature at 21°C with a minimum fresh air supply. After the last occupancy is sensed the plant will continue to run for the twenty minutes. This will allow for any periods of relative inactivity within an occupied room e.g. during examinations when occupants make minimal movements. An override microwave/PIR toggle must be available on the graphics control panel.

Where two-speed fans are fitted, natural “cooling” shall be achieved by switching the fans to high speed if the room temperature rises above 24°C and reverting back to normal speed below 22°C. Where inverters are installed, natural cooling shall be achieved via the space temperature control loop acting on the supply and extract fan speeds.

Cooling will normally be by ventilation, but where mechanical cooling is installed then cooling shall normally only be enabled if the room temperature rises above 25°C and switched off again when temperature drops to 24°C.
BEMS interface cards shall always be provided for cooling cassettes, fan coil units etc. to enable remote start/stop, run and trip facilities. These cards will normally be supplied by the cassette manufacturer/installer.

Carbon dioxide (CO₂) sensors should be installed to control ventilation of spaces with over 60 seats. Approved sensors (see appendix A) in the extract ducts, shall override the normal damper and temperature controls and try to maintain CO₂ levels below 0.1% (1000ppm) by opening the fresh air dampers. If the ventilation system has two-speed or inverter controlled fans, then the CO₂ sensor shall be used to change the fans to either the high speed or ramp up the inverter speed to achieve this value.

Lighting in lecture theatres may be integrated into the H&V control strategy, being disabled when the occupancy sensor twenty-minute timer program has timed out. Lighting should be "local manual on/local manual off/BEMS auto off" via a relay output from the BEMS interfacing with the lighting control panel. See Electrical Specification for more information.

2.4 Research Facilities

Some of these areas are occupied 24 hours, they shall be programmed with a time schedule and holiday schedule set initially for 24 hour continuous running to allow flexibility should their occupancy specifications change.

Individual temperature and humidity specifications will vary depending on the type of establishment and should therefore be set only after consultation with the University Project Leader. Generally speaking, room temperatures are normally controlled at 21°C +/- 2°C. Humidity control (if required) is normally 55%RH +/- 10%RH.

All temperature and humidity sensors should be set-up with the facility for high and low alarm limits and allowance made within the control system for a common alarm signal to be generated to a remote monitoring facility. This shall be either a volt free pair of contacts at the control panel terminal rail or a dial out facility via SMS calls to mobile phones. The exact method of remote alarm monitoring used may differ for each project and so guidance should be sought.
from the ESS Sustainability and Maintenance Teams before engineering this facility.

Stock Holding Room temperature alarm conditions are normally set to - High Temp Alarm 25°C, Low Temp Alarm 16°C with a transient delay time into alarm condition of 20 minutes.

Stock Holding Room humidity alarms are set at two different levels. Level 1 has a High Humidity Alarm of 75%RH (but below85% RH), and a Low Humidity Alarm of 35%RH (but above 25%RH) with a transient delay time into alarm condition of 12 hours. Level 2 has a High Humidity Alarm of 85%RH and a Low Humidity Alarm of 25%RH with a transient delay time into alarm of 20 minutes.

All equipment in BMS control systems must be capable of being manually overridden.

A facility for the printing of continuous logs of daily environmental space conditions to meet Home Office specifications shall be provided. This will take the form of daily printouts of temperature and humidity graphs for all designated animal holding and research rooms as specified by the design team. All of this environmental data will also be saved on the host server BEMS PC and be accessible to end users through Client PCs or local servers

### 2.5 Time Control

All boilers should work on demand only, not timeclocks

Timeclocks should be on associated VT zones, AHU's, or other plant red from the boiler (see 2.8 Demand Control)

Full day shall be selectable from the graphics panel and this would normally be set at 8.00 to 17.00, typically during the winter period

Half day shall be selectable from the graphics panel and this would normally be set at 8.00 to 12.00, this would be applied typically to VT circuits where heat was required early in the morning until the building was occupied and operational, i.e. spring and autumn periods
2.6 Winter-Summer- Holiday Control

Winter setting allows all heating and ventilation systems to operate as normal. Both VT and CT demands active. Internal / external frost protection active.

Summer setting shuts down the VT pumps. Demand from AHU's active and acting on boilers. CT pump / boilers on if there is demand from one or more AHU, Boilers & CT pump(s) off if no demands.

Holiday setting shuts down all H&V and A/C systems. Internal / external frost protection active.

2.7 Alarms

Critical alarms are to be set up to typically signal the following criteria, Boiler Lock out, VT and CT Pump Start Failure, Gas Valve Tripped, AHU Start Failure, Fire Circuit Tripped,

Advisory alarms are typically, AHU Filter dirty, Change of state etc.

2.8 Demand Control

Relevant demands which act on boilers should be shown on the boiler/cooling plant graphic (e.g. VT Zone 1. Htg. Demand On/Off, 1st Floor AHU Demand On/Off etc. etc.)

In some instances these demands will be from a number of buildings - all demands should be shown

The ability to manually enable demand should be available through a tick box

Winter Demand Hierarchy is as follows:

1. Frost (See 5.2.5)
2. AHU Demand

Outside Air Temperature High Limit
Room Temperature set point
Timeclock

3. V.T Demand

Outside Air Temperature High Limit
Compensated temperature set point
Temperature set point
Timeclock

(Look at Annex A for a graphic explanation of the Control Demand)

2.9 Trending

Trending capability for inputs and outputs must be available as this will enhance the commissioning, tuning and fault detection of the control strategy

2.10 Time Clock Exceptions

Access to setting new time exceptions must be provided to cater for out of hours operation, i.e. weekends

Hourly time extensions to existing operational times must be provided

3.0 Control Panels

3.1 Panel Body

The control panel shall be constructed of sheet metal of 2mm minimum thickness and be of the totally enclosed, floor and/or wall mounting cubicle type suitable for front access, vertically hinged, and constructed to comply with all relevant British Standards

Panel construction shall typically be Form 2, with separate power and control sections linked together. The power section shall be door isolator interlocked with override facility. Door isolators shall be self-supporting and must engage without obstruction when closing the cabinet door.

The power section shall not contain any item of equipment which may have to be accessed, for maintenance or monitoring purposes, during normal running of the plant. Outstations, Motor Speed Inverters with displays and keypads, all 24
volt control relays, switching modules with manual overrides etc. shall all be located outside the power section. Motor Speed Inverters should normally be fitted external to the control panel to minimise the panel size.

Removable gasketed gland plates shall be provided on control panels as top or bottom entry, panel location to be agreed. Gland plates should be removed for any on-site drilling, to prevent ingress of metal cuttings into contactors and relays. The installation electricians so as to maintain the IP Rating of the panel must plug any unused holes in the control panel.

All doors, mounting and gland plates shall be earth bonded in accordance with the current edition of the IEE Regulations.

The power and control sections of the panel shall be lockable and must be supplied with the same key number for every panel. This will allow controlled access for the University Estate Support Service staff and Service Company engineering staff.

Each panel shall have a minimum of 10% surplus space on the back plate and 10% spare incoming terminal connections to allow for future modifications.

Each panel shall have a fixed document holder fitted on the inside of the control section door. This shall be large enough to accommodate the soft-backed O&M Manual supplied for that panel.

On completion of commissioning, the panel shall be cleaned, inside and out, and all redundant drawings and equipment removed before presentation for handover.

3.2 Control Panel Circuitry

Rigid, slotted plastic trunking, capable of accepting an additional 25% volume of wiring, shall be used for internal wiring. Incoming field wiring must not be routed through this trunking. However, where applicable, e.g. on larger panels or panels with vertical termination blocks down the side of the panel, additional slotted plastic trunking shall be provided by the panel manufacturer to accommodate the incoming field wiring.
DIN Rail mounted terminals shall be provided as required, each individually numbered with clip-on permanent markers, to correspond with the panel wiring diagrams. Sufficient space shall be left above the terminal rails for incoming cable looms and trouble-free connection of terminations. The smallest terminal must be capable of accepting 4mm² conductors.

Mains and three phase conductors shall be segregated from extra low voltage conductors. Under no circumstance should “Banked” terminal rails be installed. Both panel and field terminals should be easily accessible at all times.

All control circuits shall be 24 volts AC, supplied via a transformer with a minimum rating of 500VA to ensure proper operation in the event of a power-off / power-on situation. A separate 24 volt transformer shall be provided for equipment power supplies e.g. actuators, sensors etc.

All ELV power supplies shall have “panel healthy” lamps and be BEMS monitored. Transformers shall be protected by MCB’s on the primary and secondary sides. The secondary side shall be appropriately earthed. Fusible protections such as packaged internal fuses are unacceptable.

“Permanently Live” circuits should not be engineered unless it is a specified requirement of the installation i.e. critical plant. Plant that will automatically reset on resumption of power or gas circuits feeding such items do not require to be permanently live. All permanent live circuits should be properly shrouded and identified with "white on red" traffolyte labels.

All control circuits and transformers shall be fed from the L1 Phase.

All internal wiring to be in LSF cable with control wiring of 0.75mm² minimum. Power cables to be rated to the full load current according to the current IEE regulations. All cables to be colour coded as per the British Standard – for Harmonised cable colours:

- 3 Phase: L1, L2, L3
- 240-volt Neutral:
- Control Wiring: 24V AC White, 0V AC Blue
- ELV DC Supplies: +ve Violet, -ve Blue
• Care must be taken to ensure low voltage neutrals are clearly distinguished from 240-volt neutrals by alpha-numeric cable ferruling.

24-volt control circuits shall be wired in PVC cable with a cross sectional area capable of carrying the higher currents associated with ELV control circuits, in the event of a power-off / power-on situation.

Where multiple 24-volt AC control circuits are supplied from the same transformer, then the 24-volt and zero-volt leg of each circuit shall be protected by a two-pole MCB.

Critchley type ferrule markers shall be used to identify all control panel terminations in line with the panel wiring diagrams supplied by the Controls Specialist Contractor.

All internal cables shall be crimped at both ends and any screened cable insulated with Neoprene type sleeving to prevent accidental earthing.

All exposed live electrical connections and terminations within both the power and control sections shall be shrouded against accidental contact.

Critchley type markers shall identify the “Outstation Point Number” reference at the point of termination i.e. on the signal wire as it terminates at the outstation. The outer sleeve of the cable inside the outstation trunking is not acceptable; as it is not visible once the wiring loom is in place. Control panel drawings shall have these point numbers clearly identified to allow panel manufacturers and site electricians to label correctly.

Critical plant interlocks shall be designed such that all protection is hard-wired and fail-safe. These interlocks shall be duplicated on the BEMS system as software alarms but never used as a substitute for hard-wired interlocks. E.g. fire alarm, pressurisation units, airflow switches, water flow switches, damper end switches etc must be hard-wired.

Each control panel shall have a 13Amp switched socket outlet, supplied from the live side of the main panel isolator, fitted inside the control section to power a laptop computer for commissioning and service engineers. Socket to be labelled “For Laptops Only”.
3.3 **Panel Equipment**

Motor Starters shall be of the MCCB type.

MCBs shall provide electrical protection for all fans, pumps, and control circuits. Fuses shall not be used. Motor rated MCB's should be used throughout.

An MCB identification chart shall be supplied and permanently fitted inside the control section door of the panel inside a plastic wallet.

Fixed engraved traffolyte labels shall be used to identify all equipment within the control panel: i.e. relays, contactors, MCBs, thyristors, timers, inverters, transformers and associated equipment.

A hard wired 10 second delay timer shall be fitted in the control panel to prevent all the commands within an outstation switching on instantaneously after a power-off / power-on or fire alarm. This timer shall then initiate software hold-off timers within the outstation to facilitate a staggered start sequence of plant.

Control relays shall be Omron or approved equivalent with 8 or 11 pin plug-in bases. Relay coils shall be of a suitable size so that induced voltages or leakage currents do not maintain the relay when de-energised. All control relays shall have visual indication to show they are energised, e.g. flag or LED, and must have a "manual override lever" for test purposes and emergency overrides.

Where there is a combination of different coil voltages for plug-in relays within a control panel then the relay bases shall be of a different pin configuration to avoid the possibility of inadvertently plugging in a relay of one voltage into the base of another voltage.

3.4 **Fascia Equipment**

All fascia switches and indicating lamps shall be identified with fixed engraved black on white traffolyte labels. The name of the University project shall be engraved on a fascia plate located at the top centre of the power section door.

Fascia switches to override automatic functions of plant shall have "HAND/OFF/AUTO" engraved on their fascia plates.

Panel fascia lamps shall be provided to display all run and fault conditions of the plant and panel power supply statuses. These shall be duplicated on the
BEMS as software alarms and digital inputs. Where starters are provided, the run signal shall be from an auxiliary contact.

Field equipment such as Inverters, Boilers, Chillers, VSD pumps etc shall have a “true run” signal provided. Fascia indication lamps must not be switched directly from circuits in the field; pilot relays shall be used where necessary.

LED type lamps shall be used for panel fascia indication in the following colour configuration:

- **Green** Run/Enable indication for fans, pump motors etc.
- **Red** Trip/fault indication for fans, pumps, filters, fire alarms, flow fail etc.
- **White** 24 volt control circuit live indication
- **Amber** Power supplies “on” to boilers, humidifiers, chillers etc.

### 3.5 BEMS Systems Hardware

Outstations shall be complete with all necessary input/output cards, modules etc. required to provide a fully operational controls package. Care shall be taken during tender and design to ensure critical plant is controlled within a single outstation and remote / global control / data are kept to a minimum.

All outstations shall have 10% spare capacity for each point type.

The outstation power supply shall be fed from the live side of the main panel isolator, through a discrete MCB, to enable the outstation to remain on line when opening the power section of the panel.

Outstations are to be mounted within the control section of the panel and pre-wired to terminal rail.

All outstations/systems shall provide automatic time change from BST/GMT.

Command interface toggle switches shall be identified with a permanent label to assist in fault finding and servicing.

Where keypads/Network Display Pads are fitted, the display window shall be at 1500 mm above floor level, to enable local operator interrogation of the system.
Each outstation shall be capable of local communication via a laptop computer without any reconfiguring of the network.

Each outstation shall be clearly identified with a permanent label stating the Outstation and IP / Mac numbers on the front to assist in fault finding and servicing.

Outstation memory shall be sufficient to enable logging to be carried out on every sensor within that outstation at fifteen-minute intervals for a period of one week.

Where outstations are supplied and mounted within other Original Equipment Manufacturers’ supplied package plant (A/C Units, AHUs, Fan Coils etc), the Controls Specialist shall complete all the necessary work to connect into the networks, commission the communications and provide the necessary displays. They shall not change any pre-configuration of the OEM supplied control/monitoring strategies without written permission of the unit manufacturer. All OEM software strategies and flow charts must be made available to the university and included in the final As Fitted Controls O&M digital Manuals.

4.0 Field Wiring and Equipment

4.1 External Wiring

The Controls Specialist Contractor shall install all controls wiring between outstations, control panels and field equipment as an integral part of the Controls Package.

The installation shall comply with the current I.E.E. Regulations and the University’s Electrical Specification. These shall be adhered to in conjunction with the following specifications.

Critchley type ferrule numbers shall be used to clearly identify all field wiring at both the equipment and control panel ends. The numbers shall match the terminal numbers shown on control panel drawings.

Communication cables between outstations shall be clearly identified at both ends with Critchley type ferrule numbers and Dynotape label stating cable
destination. All LAN and WAN drawings shall be updated with this information after each project.

Electrical isolation of field equipment shall ensure complete isolation of ELV control circuits in addition to Phase power supplies. E.g. 24-volt control circuits to boilers, chillers, pressure units etc. Sufficient poles shall be provided to meet any design requirement.

Inverters shall be installed with full isolation on both the input and output sides. An early break contact on the output side should be allowed for as a fourth pole in accordance with the manufacturer's recommendations. All control circuits must be isolated on the input side through additional poles on the local isolator.

All low voltage input / output wiring from outstations to field equipment shall be wired in screened, twisted-pair cable (see Appendix A for exact specification) with the screen grounded to earth at the Outstation end only. The field end of the cable shall have the screen removed and the cable end insulated with Neoprene type sleeving to protect against inadvertent connection to earth.

Outstation communication cable (see Appendix A for exact specification) shall be installed in two core, twisted pair screened cable as standard with the screen earthed in accordance with the Control Specialist’s recommendations.

Where field equipment is supplied with "flying leads" attached, e.g. damper actuators, valve actuators etc, and then these must be left intact and joint boxes used for final terminations.

4.2 Field Equipment General

Field equipment shall be fully accessible for inspection and maintenance and due consideration should be given to the CDM Regulations when locating and installing equipment.

All field equipment shall be installed to the manufacturer’s recommendations. It shall be the Control Specialist Contractor’s responsibility to identify the optimum position of all field equipment at the appropriate time in the contract.

Special consideration should be given to the IP Rating of field equipment located externally. The Controls Specialist Contractor shall include for
weatherproof boxes/housings to protect all actuators, sensors, duct thermostats, pressure switches etc which shall be installed outside the weatherproof envelope of the building.

Any new or refurbished wet system which is to be connected to any of the University’s CHP Systems shall incorporate two-port valve control in any diverting application to assist in keeping return flow temperatures to the CHP to a minimum. Rotary shoe valves shall not be used in these applications.

All modulating control valves shall have characterised ports. Rotary shoe valves should not be used for control of coils or heat exchangers. Installed valves and actuators should meet the design specifications of temperature, medium, pressure and speed of control.

All field equipment, sensors, actuators, pressure switches, thermostats etc shall be clearly identified with a fixed traffolyte engraved label. These should be engraved as per the control drawing description and reflect mechanical plant references.

Safety interlocks to field equipment such as pressurisation units shall be designed and installed as hard-wired, fail-safe, to ensure panel interlocks are operated during local isolation. Sufficient poles shall be supplied on local isolators for this purpose.

Field switches where positive operation is required shall be designed as “normally open” i.e. makes on operation. E.g. airflow prove, water flow prove etc.

All critical systems and major AHUs, pumps and fans shall be monitored by Differential Pressure switches or other appropriate equipment. Where Variable Speed Inverter controlled pumps are installed, differential pressure switches shall be fitted to monitor positive flow condition. These switch signals shall be duplicated in software on the BEMS system with indicating lamps on the control panel fascia to indicate flow fail conditions.

Automatic gas valves should be of the 240-volt solenoid type with provision of an auxiliary contact for individual BEMS and control panel fascia lamp indication to indicate a valve open condition.
AHUs and zone re-heats/re-coolers shall have temperature sensors fitted after each heating/cooling/humidification stage.

Where humidification is used in an AHU then, as a minimum, duct fresh air, extract and supply air temperature and humidity sensors must be used.

All field keypads and local indication displays shall be installed at approximately 1500mm to facilitate safe access and ease of maintenance by university operational staff. E.g. motor inverter keypads, outstation displays, humidifier displays, heat meters etc.

4.3 Actuators

Actuators for all modulating valves and dampers shall have a power supply voltage of 24 volts AC and a control voltage of 0-10 volts DC. Actuators shall be fully open at 10 volts DC and fully closed at zero volts DC. On/off applications may use digital actuators in conjunction with auxiliary switches as appropriate. “Pulsed Pair” actuators shall NOT be used for modulating control. All actuators shall be capable of manual override with provision of a manual lever for this purpose.

Actuators requiring isolation of the 24-volt power supply for manual override shall have a local isolator installed for this purpose.

Fresh air dampers on full fresh air systems shall have 24-volt AC shut off damper actuators complete with end switches. Each end switch shall energise a dedicated relay in the control panel. One pole of this relay will interlock with the fan starter circuit and another pole will provide a dedicated damper open / closed signal to the BEMS system for software interlocking and graphic indication.

Fast-acting process actuators should be considered where steam valves serve low water content equipment. Actuators for steam valves shall be mounted horizontally to avoid damage to the actuator circuitry through heat transfer - unless stated otherwise in the manufacturer’s data sheets.

All High Limit Actuators shall be of the spring return type.
4.4 Sensors

All sensors must be capable of being removed from ductwork/pipework for inspection and maintenance purposes without removal of ductwork, pipework or thermal insulation.

All sensors shall be installed to operate within the design range of the medium and as close to the middle range as practicable. All sensors must be suitable for their operating environment, installed in the optimum position for control and calibrated as appropriate.

4.5 Utility Metering

Heat, Steam, Water, Gas and Electricity meters should be monitored by the BEMS unless a separate Monitoring & Targeting system is specified. No alternative M&T system shall be installed without written approval from University Energy Manager. See Metering Specification for further details.

5.0 Programming

5.1 General

Programming of the outstations shall be carried out in a consistent, structured manner using standard programs for: e.g. pump changeovers, compensated slopes, plant rotations, sequencing etc. Programmable points shall be kept as simple and uniform as possible.

Each outstation shall incorporate a software hold-off timer circuit to prevent all commands from switching on simultaneously after a power-off / power-on or fire alarm situation. The hard-wired timer previously described in the Panel Equipment section shall initiate this software timer.

A “dead band” shall be programmed, wherever building design permits, to allow economical running of plant whilst still maintaining temperature and humidity control within the desired limits for a given project.

All control loops requiring setpoints/knobs shall be fully adjustable at the Supervisory PC/ Server, in graphical and text format, using standard setpoints e.g.
all compensated/reset slopes should be fully adjustable without having to access engineering programming levels.

Where control sensors exceed their design ranges, e.g. static pressure surges, temperature overshoots etc, and then the software program shall be capable of returning the control loop to a stable condition by returning sensible default values for that specific application. Sensors must not "lock out" control loops due to unrealistic default values.

All setpoints must represent the actual value visible to the user in the user pages and user schematics e.g. when a return pipework second stage frost setting of 10°C is required, then the setpoint value shall be 10°C and not the midway value of a differential logic block.

### 5.2 Time Schedules

Calendar Schedules shall be incorporated and set up as part of the contract to allow all items and groups of plant to be pre-programmed up to one year in advance for conference bookings.

Schedules for specific AHU’s, VT zones etc. must either reference a ‘Master’ time schedule for the building, or reference its own ‘local’ schedule. A tick box to select whether the local or master clock is to be used must be provided on the graphic.

For each building a ‘Time Schedules’ graphic page (or pages) shall be provided allowing access to all time schedules within the building showing the master/local tick box for each AHU, VT zone etc.

The ability to program Holiday Schedules shall be incorporated for each building or site. A tick box at building level and, then, "Override Holidays" tick boxes for those specific AHUs and VT circuits that need to run on holiday time

### 5.3 Frost Protection:

Heating Circuits Supplied from Standard Boiler Systems

1st Stage - Switch all pumps on if outside air temperature falls below 3°C and switch off again at 5°C. All heating zone and AHU control valves shall be driven fully open during this frost period.
2nd Stage - Bring on the pumps and heating plant if return boiler immersion temperature sensor, or any other heating pipe sensor, falls below 10°C and switch off again when it reaches 30°C. In this event the heating plant shall be held on for a minimum of 30 minutes to prevent cycling of boilers on shunt loop systems where the return temperature would rise very quickly. All motorised heating zone and AHU control valves shall be driven fully open during this frost period.

3rd Stage - This occurs when fabric space temperature drops below 10°C. VT heating circuits will be initiated under boost control to fully open any VT valves. VT circuits should switch off once space temperature reaches 12°C.

4th Stage - Bring on the pumps and heating plant if the outside air temperature falls below -10°C and switch the plant off again when the outside air reaches -5°C.

Air Handling Units Supplied from Boilers and CT circuits

AHU Heating batteries will be protected from frost damage by a hard-wired duct frost thermostat wound across the battery face. This will be set to 3°C and when initiated, will fully open the heater battery valve actuator(s) via a hard-wired, dedicated 10volt DC power supply unit, mounted inside the control panel.

Heating Circuits & AHUs Supplied from CHP Systems

1st Stage - Switch all VT, DHW and CHW pumps on if outside air temperature falls below 3°C and switch off again at 5°C. All AHU heating and reheat valves to be opened to a fixed setting of 20% during this 1st stage frost period.

2nd Stage – This occurs when VT water temperature drops below 10°C. VT valves will open to control flow temperature at 30°C. Software timer will be programmed to give a fixed run period set to 30 minutes, adjustable through BEMS. Note that 2nd stage frost can only occur when 1st stage is active.

3rd Stage – This occurs when fabric space temperature drops below 10°C. VT heating circuits will be initiated under normal control to achieve calculated flow set point. VT circuits should switch off once space temperature reaches 12°C.
4th Stage – On outside air temperature dropping below -10°C, all heating circuits to be initiated under normal control operation and switch the plant off again when the outside air reaches -5°C.

5.4 Optimisation

During optimiser boost periods, all compensated heating valves associated with that optimiser shall be driven fully open until boost termination, after which they will return to normal compensated slope. The only exception to this is where the VT circuit is fed from a CHP system, in which case it will maintain normal compensated slope control during the boost period to prevent sudden surges of demand.

Optimiser reports shall be programmed to record Run-Up, Occupancy, Run-Down, Fabric Frost and Occupancy Off conditions to allow plant performance to be analysed.

Optimisers shall incorporate Space Fabric Protection during Occupancy Off periods to switch on the heating plant if the space temperature drops below 10°C and then switch off when the temperature reaches 12°C. Please also see Controls Philosophy section for specifications of specific accommodation.

5.5 Naming of Points

Proposals for Point Labelling, Outstation and LAN numbering shall be submitted, along with the proposed programme, for comment by the University's Engineers prior to starting the project. See Registering of New BMS Connections Work Instruction

Naming of the point labels for programming and graphic pages shall be as consistent as possible with each point type identified.

5.6 Compensation Slope

Compensation slopes shall normally be engineered with the following Outside Air and Radiator Flow Temperature settings:

<table>
<thead>
<tr>
<th>Outside Air Temperature</th>
<th>Flow Temperature</th>
</tr>
</thead>
</table>
### 5.7 Heating Hold-Off on Warm Days

Heating circuits shall be disabled if outside air temperature rises above a set value:

- V.T Circuits 16°C, for a period of one hour
- C.T Circuits 20°C, for a period of one hour

They shall be enabled again if the outside air temperature drops 1°C below setpoint.

The Outside Air Hold-Off setpoint must be fully adjustable to the user through the setpoint.

Any optimisers that relate to these disabled heating circuits should have their self-adaption facility inhibited during this period to prevent false adaption slopes being generated.

### 5.8 Alarms and Logging

A schedule of alarm priorities/routing and optimiser event reports shall be submitted for comment to the ESS Sustainability and Maintenance Teams ten working days prior to final commissioning of the project.

Controls Contractors must fully check their systems for any spurious alarms at time of commissioning. They must demonstrate to the University Engineer that there are no unnecessary alarms transmitted to the BEMS front-end PC / Servers at the handover stage.

### 6.0 Retrofits and Additions to Existing Systems

Where retrofit work is carried out in existing control panels and plant rooms, the following shall be closely adhered to in addition to the standard specifications:
6.1 Removal of Redundant Equipment and Software

The Controls Specialist Contractor shall remove all redundant cable, thermostats, sensors, control panel fascia switches and identification labels, panel indicating lamps, relays and relay bases from site. Any holes left in control panel doors shall be covered with permanent traffolyte labels. Holes left in trunking or ductwork shall be plugged.

Controllers, thermostats, and sensors remain the property of the University. Before disposal permission must be sought from the BMS Operation Group.

The Controls Specialist Contractor shall decommission all redundant software and graphic pages from the BEMS network.

6.2 Integration

All new controls within a given building shall be seamlessly integrated with existing controls at each stage of any phased work.

All new and re-used relays, switches, indicating lamps and command interface labels shall be clearly identified with fixed traffolyte engraved labels. Components shall be kept consistent with the existing installation where possible.

Where an additional interface panel is required to house new relays, transformers and command modules for the additional controls, then it shall be of similar construction to the existing control panel i.e. metal construction with a hinged lockable door, with a fixed traffolyte engraved identification label attached.

Where new controllers are to be installed, latest version of the work instruction “Registration of BMS New Connections” should be followed in order to obtain IT connection details. Copy of the work instruction can be obtained from the Energy Manager.

Revised wiring diagrams, flow charts, strategy diagrams, graphic pages, controls descriptions and O&M manuals shall be presented, in triplicate, to the University Engineers no later than two weeks after the practical completion of works. Revision dates shall be clearly indicated on all documents. (See O&M Manual Section)
New graphic pages shall be generated for all amendments unless existing graphics can be modified to incorporate the additional work. Allowance shall be made for full integration with existing plans and plant graphics.

Additions to existing systems shall be engineered to enable full integration with the existing plant e.g.:

- Boiler interlocking for heat demands and Chiller interlocking for cooling demands
- Frost protection specifications to start pumps and boilers and open zone valves and AHU valves
- Interlocking of Time Schedules, Holiday Schedules and Calendar Schedules in existing buildings

7.0 Active Graphics

Graphic Pages shall be supplied for each project in a consistent, structured format. Page contents and structure shall be provided for comment to the University BMS Operations Group as detailed in the Preamble Section.

Pages shall be structured in such a way that University Works Division staff can be guided through to the chosen building and its individual room temperatures or plant status, using ‘Hot Key Buttons’ on every page. Buttons should enable the operator to work forwards and backwards through the pages without having any prior knowledge of the building or its HVAC plant.

The University “Home” graphics page shall offer a list of each principal building, grouped in maintenance areas. In addition, other buttons for direct access to key summary pages shall be allowed space too, such as:

- OAT Overview
- Meters Overview
- etc.

Once a building name is clicked on, an initial building “Home” page listing each main Floor/Level or showing a floor map of each floor (preferred) should appear. In case of the latter, the floor maps will show the position where boiler and AHUs plant rooms sit. By clicking in a floor, 2 floor plans should be shown: one for
heating and other for ventilation. Floorplans can be obtained from the Project Engineer.

Each Floor Plan page shall clearly display the room number, location of room sensors, outside air sensors, zone valves and control panels / outstations, with a display of calculated or actual setpoint, together with the actual temperature sensed. If all these items cannot be displayed clearly, Hot Key Buttons for heating and ventilation shall allow access to individual pages for each. Floor plans shall map the areas covered by every single heating circuit or AHU. These areas will be labelled and, where possible, will provide direct access to the heating circuit or AHU by clicking on the area. A legend on one of the sides of the page shall indicate the labels names. If direct access from the map was not possible, legend’s buttons will provide direct access to the heating circuit or AHU by clicking on them.

A ‘North’ arrow shall be clearly displayed on such pages.

Pages shall also be provided which display the active components of each item of HVAC Plant. Again more than one item of related equipment should be placed on one graphic page to reduce overall number of pages. The outside air temperature should be displayed on pages where appropriate.

Only live data shall be displayed on the pages. “Previous Values” shall not be displayed on the graphic page i.e. during the process of the page being called up, or if the communication link has dropped, then this shall be reflected to the user in place of the dynamic data.

All Digital and Analogue Alarm values and text shall be displayed inside a text box that changes colour to red when in an alarm condition.

Pump and fan graphic symbols shall change colour when running - Grey for an ‘Off’ condition and Green for a ‘Run’ condition. Where differential airflow switches are installed, then the status signal from these shall be used to initiate the Green Run condition.

Feedback faults in pumps and fans shall be shown in red for “Stopped” and “No Flow” conditions (when equipment should actually be running).
Graphic page backgrounds shall be plain to prevent excessive colour printing.

For a visual description of a template, please refer to the Annex B at the end of this document.

8.0 O&M Manual

8.1 General Specifications

Two copies of the Controls Operation & Maintenance (O&M) Manuals shall be submitted in a CD / Electronic format to the University Controls Engineer within two weeks of completion of each project.

Manuals shall be titled with project name, Building Number and date on front cover and on the spine. Manuals shall be indexed with page numbers and sections clearly identified to assist navigation.

8.2 O&M Sections

Section 1 - Description of Operation.
This section shall contain floor plans and a plant summary followed by a general Controls Narrative with a detailed description of the operation of each item of plant controlled by the BEMS system.

Section 2 - Outstation Data Tables / Outstation Connection Drawings.
Manuals shall contain the input and output slot usage charts for the outstation hardware points and software points.

Section 3 - Outstation Strategy Drawings / Flow Charts and Points Display List.
As Flow Charts can be obtained live from the server, then paper copies are not required within the Controls O&M Manuals.

Section 4 - Control Panel Drawings / Wiring Diagrams.
This section shall contain all wiring diagrams and panel fascia layout drawings associated with the project including details of any revision changes that have
taken place. Wiring diagrams shall be presented in a standard, consistent, structured format. They shall contain all wiring core numbers and panel termination numbers. A relay cross-reference chart shall be included in this section to enable relay contacts to be traced. Outstation LAN communication wiring diagrams shall be included in this section clearly showing the “break in” connections to existing communications buses.

**Section 5 - Commissioning Details and Controls Settings.**
This section shall contain all commissioning test and record sheets for control panels, fans, pumps, inverters, valve actuators etc. It shall also include settings for all control loops including setpoints, proportional bands, integral action times, differentials etc.

**Section 6 - Maintenance Instructions.**
This section shall contain the relevant service schedule and instructions for maintaining all controls equipment to the standard that is required by the equipment supplier.

**Section 7 - Technical Literature.**
This section shall contain all relevant data sheets and instructions for control equipment on the project.

**Section 8 – Handover Documentation.**
This section shall contain copies of all completion/acceptance/handover documentation, duly signed by the Controls Systems Contractor and the University Controls Engineer, together with a Snagging List of items of works outstanding at time of handover, together with proposal dates for completion.
ANNEX A: Heating and Ventilation Control Hierarchy

Figure 1: Heating and Ventilation Control Hierarchy

ANNEX B: BMS Building graphics template

Figure 2. Template of the Main Menu Page
**Building Main Page**

**Option 1:** Floor list (with exceptional direct access to specific equipment)

**Option 2:** Floor plans (with physical location and direct access to specific equipment). PREFERABLE

*Note: Name of buildings, this is just a template.*

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**Floor page**

- **Heating**
  - Heating areas coloured by VT circuits
  - VT circuits’ direct access by clicking on the map area or via the legend

- **Ventilation**
  - Ventilation areas coloured by AHU
  - AHU direct access by clicking on the map area or via the legend

*Note: Floor plans should clearly show room numbers. If both floor plans would not fit in the page together, 2ns. Hot Key Buttons shall direct to individual pages for heating and vent.*

*Ignore name of buildings and the fact that both circuits are the same, this is just a template/example.*

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Figure 3. Template of the Building Main Page

Figure 4. Template of the Floor Page