NHS National Services Scotland

Scottish Health Technical Memorandum 08-05:

Specialist services
Building management systems
Part C
Validation and verification

Health Facilities Scotland
Engineering and Environment

April 2012

Contents

Acknowledgements

This new SHTM 08-05 Part C – Validation and verification has been developed, updated and expanded from SHTM 2005 which it replaces. SHTM 2005 was originally published in June 2001 by NHSScotland Property and Environment Forum Executive. The contributions from the National Ventilation Advisory Group and Stuart Robertson of Enterprise Control Engineers Ltd. are gratefully acknowledged.

Preface

About Scottish Health Technical Memoranda

Engineering Scottish Health Technical Memoranda (SHTMs) give comprehensive advice and guidance on the design, installation and operation of specialised building and engineering technology used in the delivery of healthcare.

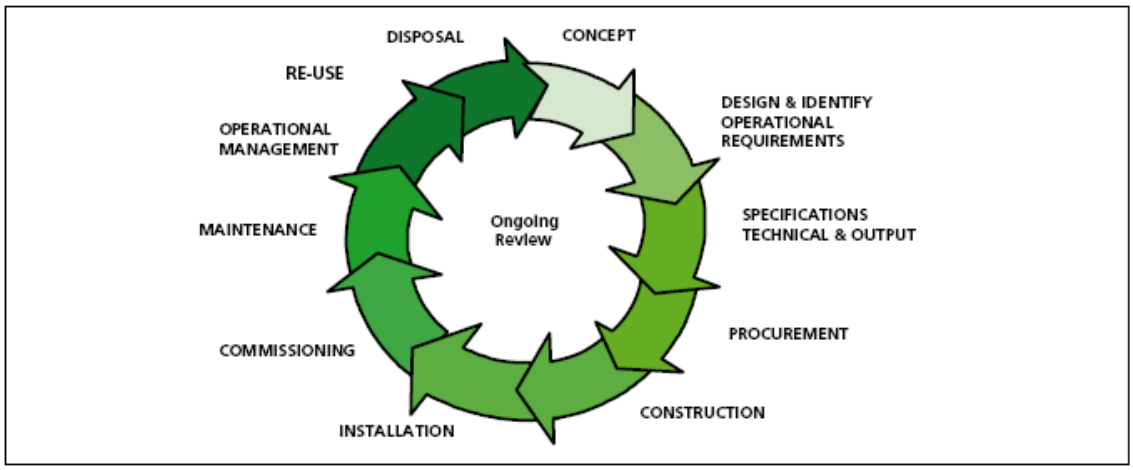
The focus of SHTM guidance remains on healthcare-specific elements of standards, policies and up-to-date established best practice. They are applicable to new and existing sites, and are for use at various stages during the whole building lifecycle: Healthcare providers have a duty of care to ensure that appropriate engineering governance arrangements are in place and are managed effectively. The Engineering Scottish Health Technical Memorandum series provides best practice engineering standards and policy to enable management of this duty of care.

It is not the intention within this suite of documents to repeat unnecessarily international or European standards, industry standards or UK Government legislation. Where appropriate, these will be referenced.

Healthcare-specific technical engineering guidance is a vital tool in the safe and efficient operation of healthcare facilities. Scottish Health Technical Memorandum guidance is the main source of specific healthcare-related guidance for estates and facilities professionals.

The core suite of eight subject areas provides access to guidance which:

- is more streamlined and accessible;
- encapsulates the latest standards and best practice in healthcare engineering;
- provides a structured reference for healthcare engineering.



Healthcare building life-cycle

Structure of the Scottish Health Technical Memorandum suite

The series of engineering-specific guidance contains a suite of eight core subjects:

Scottish Health Technical Memorandum 00: Policies and principles (applicable to all Scottish Health Technical Memoranda in this series)

Scottish Health Technical Memorandum 01: Decontamination

Scottish Health Technical Memorandum 02: Medical gases

Scottish Health Technical Memorandum 03: Heating and ventilation systems

Scottish Health Technical Memorandum 04: Water systems

Scottish Health Technical Memorandum 05: Reserved for future use

Scottish Health Technical Memorandum 06: Electrical services

Scottish Health Technical Memorandum 07: Environment and sustainability

Scottish Health Technical Memorandum 08: Specialist services

Some subject areas have been further developed into topics shown as -01, -02 etc and further referenced into Parts A, B etc.

Example: Scottish Health Technical Memorandum 06-02 Part A represents: Electrical safety guidance for low voltage systems

In a similar way Scottish Health Technical Memorandum 07-02 simply represents: Environment and Sustainability – EnCO_2de.

All Scottish Health Technical Memoranda are supported by the initial document

Scottish Health Technical Memorandum 00 which embraces the management and operational policies from previous documents and explores risk management issues.

Some variation in style and structure is reflected by the topic and approach of the different review working groups.

Health Facilities Scotland wishes to acknowledge the contribution made by professional bodies, engineering consultants, healthcare specialists and NHS staff who have contributed to the review.

Engineering guidance

Executive summary

A building management system (BMS) or Building and Energy Management System (BEMS) is a computer-based centralised procedure that helps to manage, control and monitor certain engineering services within a building or a group of buildings. Such a system ensures efficiency and cost-effectiveness in terms of labour and energy costs and provides a safe and more comfortable environment for building occupants.

The BMS has evolved from being a simple supervisory control to a totally integrated computerised control and monitoring system.

Some of the advantages of a BMS are as follows:

- simple operation with routine and repetitive functions programmed for automatic response;
- reduced operator training time through on-screen instructions and supporting graphic display;
- faster and better response to occupant needs;
- reduced carbon usage and energy costs through centralised control and energy management programmes;
- better management of the facility through historical records, maintenance programmes and automatic alarm reporting;
- improved operation through software and hardware integration of multiple sub-systems, for example direct digital control, security and access and lighting controls.

This part, 'Validation and verification', provides general advice to ensure that installed equipment has been formally tested and certified as to the contract. The importance of commissioning of the complete installation is emphasised, together with the handover procedures, provision of documentation, and training.

Management responsibilities in terms of compliance with statutory instruments are summarised in Section 2. The fundamental criteria of the commissioning processes are described in Section 3. All pre-commissioning checks, inclusive of works and site tests, are listed in Section 4. Detailed commissioning techniques are described in Section 5. Handover, training requirements and post-handover procedures are detailed in Sections 6, 7 and 8.

Definitions of selected staff functions and a glossary of terms are provided in Section 9 and 10 respectively.

The document also includes an Appendix containing sample commissioning and handover record sheets.

1. Scope

1.1 A building management system (BMS) is a management tool for the effective control of building engineering services, and can be applied equally to new and existing buildings.

1.2 A BMS can be used to manage the environmental conditions of all types of building. In healthcare premises, increasing energy efficiency, reducing CO_2 emissions and saving costs are a mandatory daily task. A BMS is particularly valuable in maintaining climate control and suitable conditions in critical areas, for example, operating departments, intensive care units, isolation suites, pharmacies and sterile supply departments. BMS provides alarm communication networks for the building services plant and equipment.

1.3 A properly installed and maintained BMS operated by fully trained staff offers considerable opportunities for 'energy and carbon management'. A BMS can support separate software packages for energy monitoring and targeting and also data evaluation and reporting. Consideration should also be given to web-based energy performance monitoring, reporting and analysis tools.

Note: Other areas that can be monitored and targeted include water consumption, sewage and waste disposal. As energy management is an important tool, installations are often described as 'Building and energy management systems' (BEMS). However, the abbreviation 'BMS' is used throughout this document. Section 7: 'Definitions', also refers.

1.4 A further use of the BMS is to help to establish the basis of the site's planned preventive maintenance operations.

1.5 A BMS should be specified with care and detail, focusing on the functionality and required performance of the systems under control, optimising the workflows and service processes to be more efficient. The specification should detail the commissioning and handover requirements. When a BMS is specified, especially if it is replacing existing controls, consideration should be given to the appropriate level of user control.

Note: When a BMS is specified, the NHS Model Engineering Specifications, with the appropriate supplements for Scotland, should be considered.

1.6 The commissioning of a BMS should be fully documented to ensure that all aspects of the system meet the specification. Adequate resources should be allocated to ensure satisfactory commissioning procedures are met.

1.7 To continue to meet specified environmental conditions and increase energy efficiency, a BMS should be regularly maintained and its performance tested.

1.8 It is important that BMS operators and maintenance staff receive adequate training as technical malfunctions have to be detected on time and reported so that appropriate measures can be immediately carried out.

1.9 The sophistication of building services in healthcare premises is increasing, with the task of combining energy efficiency and carbon usage reduction with comfort and secure energy supply. The BMS controls should be designed, installed, operated and maintained to standards that will enable the controls to fulfil the desired functions reliably, safely, economically and efficiently.

1.10 BMS controls should be designed to standards for the full spectrum of today's building services applications in keeping up with new energy-efficient technologies, with system functions such as alarm management, time scheduling, and trend logging, combined with sophisticated control functions, Intelligent networking of information and communication technology as well as web technology and open communications making a financially wise investment for the future.

1.11 The design of the BMS controls should be consistent in its support of open communications, making it easy to connect a wide variety of building services equipment on the basis of standard open data interfaces;

- BACnet;
- LONWORKS®;
- Konnex (KNX);
- M-bus;
- Modbus;
- OPC;
- TCP/IP network protocol.

2. Management responsibilities

2.1 It is incumbent on management to ensure that their BMS installations comply with all the statutory regulations applicable to BMS on their premises. Other functional guidance in terms of standards and codes of practice should also be noted.

Statutory requirements

2.2 Safety regulations are as laid down in the:

- Health and Safety at Work etc (HSW) Act 1974;
- Electricity at Work Regulations 1989;
- The Building Standards (Scotland) Regulations1990 (as amended);
- Management of Health and Safety at Work Regulations 1999;
- Provision and Use of Work Equipment Regulations 1998;
- Manual Handling Operations Regulations 1992;
- Workplace (Health, Safety and Welfare) Regulations 1992;
- Personal Protective Equipment at Work (PPE) Regulations 1992;
- Health and Safety (Display Screen Equipment) Regulations 1992;
- Construction (Design and Management) Regulations 1994;
- Electromagnetic Compatibility Regulations 1992;
- Electromagnetic Compatibility (Amendment) Regulations 1994.

Functional guidance

2.3 Guidance is as laid down in:

- British Standards and Codes of Practice;
- Health and Safety Executive Guidance;
- NHS Model Engineering Specifications;
- Scottish Health Technical Memoranda (SHTM);
- Scottish Hospital Planning Notes (SHPN);
- Scottish Hospital Technical Notes (SHTN);
- NHS in Scotland – Firecode;
- Health Building Notes and Health Technical Memoranda;
- The Technical Standards for compliance with the Building Standards (Scotland) Regulations 1998 (as amended).

For further details please refer to the ‘References’ section.

3. Criteria for commissioning

General

3.1 Management should be aware of the importance of thorough and complete commissioning of an installed BMS before it is formally handed over and put into use. Since the BMS contributes to safe and comfortable environmental conditions for the building's occupants, it is essential that the system is fully commissioned.

3.2 When a BMS installation is part of a larger project, the commissioning of the BMS is one of the last tasks in the construction process. If the project overruns, the commissioning in general and programmed resources tend to be compressed. This should be robustly resisted as it results in a poorly commissioned BMS which is ineffective, energy-inefficient, and which can suffer from false alarms resulting in complaints from the occupants. Much time, cost and effort will then be expended to resolve the problems.

Commissioning

3.3 The commissioning process is defined as the activity where the complete BMS is moved from a condition of static completion to a state of dynamic operation to provide functional and environmental control of the process within the design parameters. Commissioning incorporates several stages:

- pre-commissioning checks of the components:
  - wiring;
  - sensors and actuators;
  - major sub-assemblies (either on or off site);
  - control cabinets;
  - configured control strategies;
  - central station graphics slides;
- commissioning of the application software;
- commissioning of the complete system including:
  - checking alarms;
  - checking interlocks;
  - control loop tuning;
  - calibration of sensors;
  - performance tests to check the ability of the system to meet specified environmental performance parameters.

3.4 The commissioning of a BMS should only begin once the plant to be controlled has been fully tested and approved for work.

3.5 Commissioning should be undertaken by a BMS specialist and therefore should preferably be an approved partner to the BMS manufacturer of the system installed.

Specification

3.6 The BMS specification deals with the scope of the BMS specialist supplier/sub-contractor. It is intended to be a stand-alone document however it should be read in conjunction with all other contract documents. The specification should require that the BMS is commissioned systematically by the application of a commissioning procedure and the relevant code of practice. The completion of commissioning record sheets should be specified as a part of verification.

Management of commissioning procedures

3.7 Success of the project requires that commissioning is given the highest priority by those responsible for delivery. This ensures targets are met.

3.8 A detailed commissioning programme should be agreed formally with the main contractor. Possible commissioning actions are shown in a flow chart (Figure 1).

3.9 The project team should be informed of any actual or potential delays (due to the BMS installation or other parties). The project programme should be regularly reviewed in the light of this information.

3.10 There should be regular reporting on tasks completed to monitor and control the commissioning process. Commissioning stages should be formally approved and signed off by the project team. A commissioning record sheet could be used to record completed commissioning tasks. It is essential that checklists are collected together, incorporated into the commissioning manual and handed over to the client on completion of the contract together with the ‘as fitted’ drawings.

Note: Commissioning checklists are invaluable as they can be used to indicate tasks completed and form a future source of reference concerning the plant.

3.11 A successful commissioning process should begin before practical completion, as many of the parts of the system under control will become progressively less accessible.

3.12 At the design stage, the advice of potential BMS suppliers and commissioning specialists should be sought to ensure effective commissioning is provided for in the specification.

Note: Field devices should be positioned to facilitate commissioning and allow easy maintenance and replacement.

3.13 The project team, contractors and commissioning specialists should meet regularly to ensure good co-ordination of commissioning with the other services.

Commissioning personnel

3.14 Depending on the size of the project, a team of BMS commissioning specialists may be required.

3.15 The commissioning plan should identify the people involved, with their responsibilities and accountability.

3.16 The clients (or users) knowledge and understanding of the BMS system will be improved if they are involved with aspects of the commissioning.

3.17 Commissioning personnel will need means of communication between remote locations on the site.

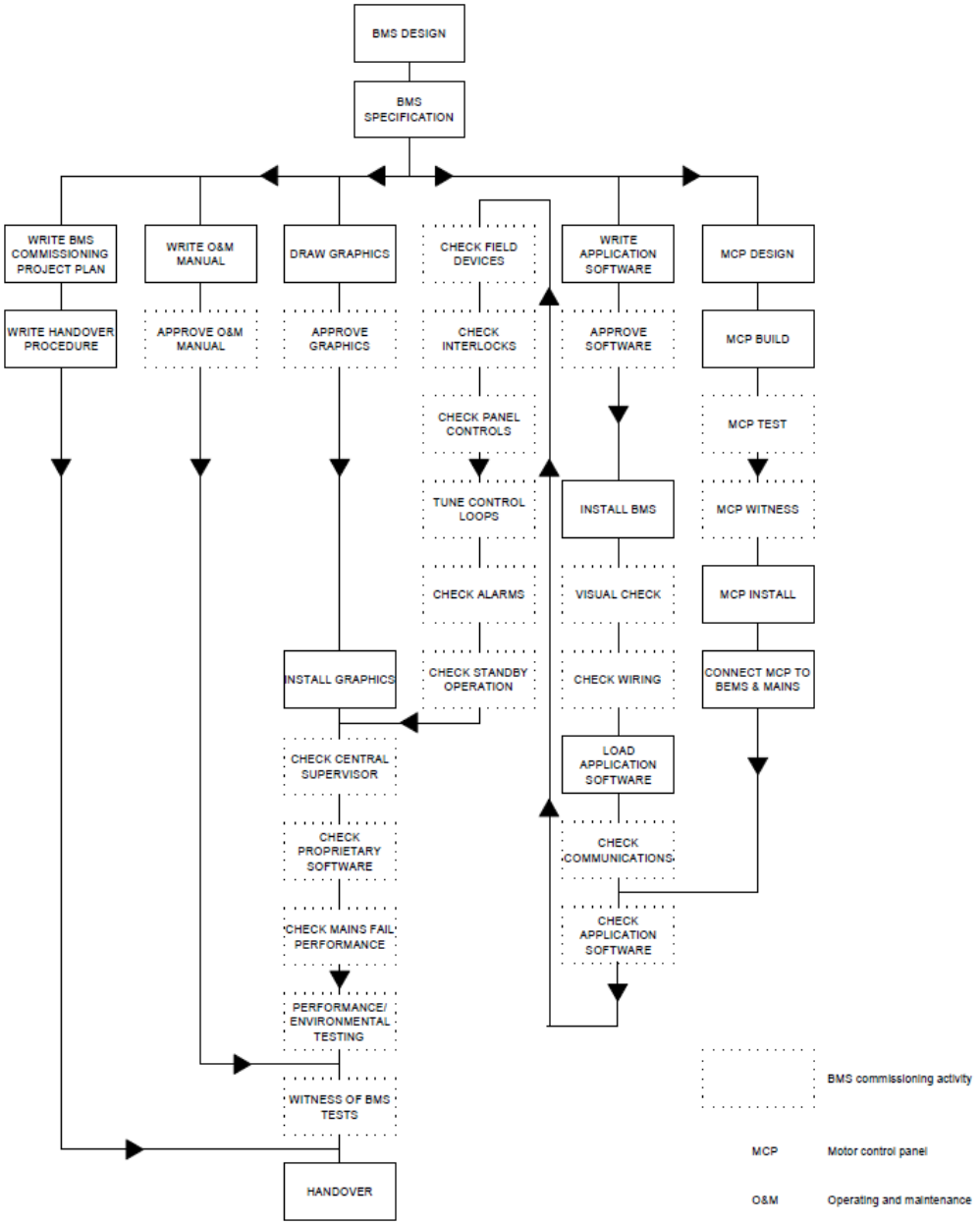


Figure 1: Flow chart for BMS installations (illustrating commissioning activities)

Commissioning brief

3.18 The commissioning team will require a detailed description of the design intent of the scheme. This should include:

- a ‘user’ brief comprising a description of the BMS, plant under BMS control and the intended mode of operation;
- precise design requirements with regard to physical parameters measured and controlled by the BMS, for example:
  - temperature;
  - pressure;
  - flow-rate;

  - velocity;
  - acceptable tolerances.
- full details of internal and external design conditions for summer and winter, including occupancy patterns and times;
- control performance specifications;
- description of control strategies;
- equipment manufacturers' type test data, commissioning, operation and maintenance recommendations;
- points lists for every outstation;
- drawings showing:
  - location of field devices;
  - location of test points to facilitate checking of field devices;
  - control strategy diagrams;
- wiring diagrams for all electrical equipment and control panels associated with the BMS.

3.19 All measuring and test instruments should be appropriate for the purpose and have their accuracy quality-assured.

3.20 On completion, the BMS should be fully demonstrated as a whole and must be subject to performance tests in accordance with the contract requirements.

Note: This may require several working days.

3.21 The handover documentation should confirm that the commissioned BMS meets the specification and the design intent. In the event of performance not being acceptable, the matter should be dealt with in accordance with the contractual arrangements.

Commissioning documentation

3.22 Record sheets should be completed to verify that items are commissioned and to create a permanent record for future reference. Variations should be noted and drawings and other documentation updated during the commissioning process to create a set of 'as installed' records.

Handover procedures

3.23 Handover requirements should be detailed in the specification. The client should witness the demonstration of various aspects of the BMS to their satisfaction. The handover procedure also includes the provision of all specified documentation including:

- record drawings;
- schematics;
- points lists;
- commissioning records;
- operating and maintenance manuals.

Note: For this purpose, the client needs to be informed and should have already received some training. Involvement in the commissioning process of clients key staff can consolidate the clients informed status.

Seasonal Commissioning and Fine tuning

3.24 The BMS should be fully commissioned as soon as the contract work is completed regardless of season. During the first year of operation the performance of the BMS will need to be optimised through a process of fine tuning. This is partly because the BMS most probably will have been commissioned before the building was occupied and invariably set-points and other items will need adjusting. The BMS should be revisited at a peak period during each season to observe full-load performance and to ascertain adequate performance during the different seasons. It would be estimated that this should be carried out over a 3-day period for each season or at 3, 6 and 9 month intervals to suit the client.

Note: Seasonal commissioning is a BREEAM requirement. This, and fine tuning carried out by the BMS contractor, should be detailed in the specification.

4. Pre-commissioning checks

4.1 Pre-commissioning covers the works testing and on-site checking of installed hardware (for example wiring, field devices and outstations), and the works testing of control panels, application software and any items of plant with built-in controllers.

Works testing

4.2 The benefits of works testing should be pursued by requiring contractors to check the control panels, integral controllers, application software and BMS graphics slides. The factory check and witnessing of functionality should be part of the project specification.

4.3 All packaged plant interfaced with the BMS should be fully tested and commissioned by the manufacturer or installer.

Control strategy/application software

4.4 The BMS control strategy and/or application software should be works tested prior to installation as part of the pre-commissioning process.

4.5 Control strategy/application software should be checked to ensure that it meets the BMS functional specification.

4.6 The following checks should be carried out to ensure compliance with the specification:

- **set-points:** all set-points should be checked for entry of realistic values and operating ranges;
- **time control:** all timed routines should be checked for entry of suitable on/off times;
- **interlocks:** all interlocks should be checked.

Note: Life-safety interlocks must be hard-wired and not software-dependent

- **control loops:**
  - all control loops should be checked to ensure that suitable default values are entered prior to testing;
  - the operation of the control loops should be checked (if possible).
- **sequencing:** all sequence controls should be checked to ensure that they are installed and operating in the specified manner.

- **start-up and shut-down:**
  - the start-up routine for correct sequence or control operations should be checked;
  - the defined restart routine should be effective when power is reinstated;
  - the shut-down routine and status of valves, dampers etc. should be checked.
- **plant changeover:**
  - the automatic changeover of plant due to plant failure and hours run should be checked;
  - the sequence of events following the failure of the second or standby item of plant should be checked.
- **alarm functions:**
  - the operation of each alarm function should be checked;
  - the time delay on each alarm function should be checked;
  - the level or category of alarm, its destination and reporting method should be checked;
  - the operation of alarm masking should be checked.
- **graphics:**
  - hard copies of BMS graphics pages should be checked;
  - inconsistent use of mnemonics and abbreviations between text display and graphics should be checked.

Control panels

Construction

4.7 The following should be checked and the relevant checklist completed (reference can be made to the sample checklist in Appendix 1); this list is not exhaustive:

- colour and finish (no sharp edges);
- metalwork including doors;
- common key for all panels;
- secure operation of door locks;
- safe access to BMS equipment;
- eyebolts fitted to panels weighing more than 50 kg;
- location and labelling of switches and indicators;
- rivets or screws used to mount labels (not adhesive);
- scale of analogue/digital devices.

Interior

4.8 The following should be checked and the relevant checklist completed (reference can be made to the sample checklist in Appendix 1); this list is not exhaustive:

- all doors on any panel containing exposed dangerous voltages are provided with interlocking isolators;
- equipment which requires on-line adjustment and testing by non-electrically-qualified personnel is accessible and usable without interrupting the supply or overriding the safety interlocks;
- access for incoming cables;
- access for outgoing power and control cables;
- provision of suitable gland plates;
- all doors/gland plates are earthed;
- bus bars and power cabling to specification;
- tightness of all connections;
- neatness of cable looms;
- 25% spare capacity in all cable trunking;
- colour coding and numbering of all cables;
- all terminals are numbered;
- shrouding of un-isolated equipment;
- shrouding of switches, lamps etc. on door;
- segregation of electronic equipment;
- trunking lids are cross-referenced;
- link-type terminals for BMS cables;
- drawing holder;
- circuit breaker type and ratings against chart;
- circuit breaker chart against drawings;
- layout of equipment against drawings;
- spare back panel space is provided;
- no equipment is mounted on the bottom or sides of panel;
- labelling of equipment in panel;
- access to all equipment, especially devices requiring adjustment;
  - power outlet is provided;
  - flexible loom across door hinge is arranged to avoid pinching or looping as door is closed, and is fully supported at each end;

- screen and earth cabling and connections associated with BMS equipment comply with manufacturers' instructions.

Function tests

4.9 The following control panel function tests should be completed and the relevant documentation completed (reference can be made to sample checklist in Appendix 1); this list is not exhaustive:

Note: A control panel should not be accepted on site until it has been fully function-tested. The client should witness the test.

- lamp test facility;
- wiring interlocks;
- indicators and signals out from the panel;
- fuse or circuit breaker size and overload range;
- correct labelling of circuit breakers;
- starter operates correctly and power is provided to outgoing terminals;
- starter de-energises and the trip indicator lights up when the starter is tripped;
- flash test.

Site testing

4.10 The standard of installation should be checked before commissioning.

4.11 All the equipment should be checked for physical damage.

4.12 The following should be checked, and the relevant checklists completed (reference can be made to sample checklists in Appendix 1); this list is not exhaustive:

- sensors and actuators:
  - correct location/orientation;
  - good access;
  - type as specified;
  - identification;
  - correct wiring connections;
  - multi-mode actuators should be site-configured and permanently marked with ‘as commissioned’ switch position;
- outstations:
  - type;

  - size;
  - number;
  - location (height and access);
  - mechanical fixing;
  - identification;
  - all cables terminated and identified;
  - all terminals utilised;
  - power available;
  - circuit breakers;
  - hardware configuration according to design;
  - all electronic ‘cards’ in place;
  - all connecting cables plugged in;
  - document wallet containing: wiring diagram; points list; control strategy diagram and functional specification;
- central station:
  - type;
  - location;
  - power;
  - cleanliness for operation;
- wiring:
  - cable as specified;
  - cable identified at both ends;
  - screening continuity;
  - electrical continuity;
  - correct polarity;
  - correct input/output;
  - correct and secure termination;
  - separation of mains and signals cables;
  - no short circuits;
  - security of fixing/protection.

5. Commissioning

Preparation

5.1 Commissioning involves the completion of checks and the entering of control values to ensure the correct operational state of the installation. Before commissioning can begin the following requirements should be met:

- all application software should be loaded and proved;

Note: Backup copies should be available on site.

- the procedure for resetting the software should be proved;
- all variable parameters and switches should be set to appropriate values and settings to ensure compliance with the specification;
- where installed, local Hand/Off/Auto facilities should be demonstrated and proved in 'Hand/Off' functions and then switched to 'Auto';
- building and plant are complete;
- plant and all necessary services are available;
- there is unhindered access to all relevant areas of the building;
- plant and control panels are commissioned;
- BMS pre-commissioning is completed;
- all the electro-mechanical safety interlocks and fail-safe devices are operational.

5.2 A complete record should be made of all the values of the variable parameters and switches which have been set as a result of the commissioning process. This record should be included with the documents handed over on completion. An outstation commissioning checklist should be completed (reference can be made to the sample checklist in Appendix 1).

5.3 In a retro-fit situation, liaison and co-operation of building occupiers will be required. This may dictate the overall programme. Operational staff should be available to make any plant adjustments required for commissioning and testing purposes, and to ensure safe operation.

5.4 Complete commissioning of the BMS can often be prevented by unserviceable plant or seasonal factors. Items that have not been fully commissioned should be identified and arrangements made for their subsequent commissioning.

Note: The specification should cater for this eventuality.

Strategy checking

5.5 The application software should have been works tested but it is still necessary to test it on site once the software is installed. If the application software was not works checked, it should be checked at this stage.

Alarm inhibit

5.6 To prevent the inappropriate activation of alarms, inhibit times should be set. These should be the minimum times required for the plant to attain operating conditions.

Note: Comprehensive alarm masking should be in place to prevent secondary alarms being raised.

5.7 All alarms that have been disabled for commissioning purposes should be re-enabled after commissioning.

Communications

5.8 The BMS communications between outstations and the central station, whether via dedicated cables, telephone network or radio, should be checked.

Field mounted equipment and devices

5.9 All the field mounted equipment and devices should be checked to ensure that the correct status or values are displayed.

Note: Labelling of field devices should be checked at outstations and on central supervisor graphs.

Sensors

5.10 All, or a representative number as detailed by the specification, of the sensors should be checked (in-situ where possible) under normal operating conditions using a calibrated test instrument. The appropriate checklist should be completed (reference can be made to the sample checklist in Appendix 1).

Actuators

5.11 All the actuators should be checked as follows and the relevant checklist completed (reference can be made to the sample checklist in Appendix 1); this list is not exhaustive:

- correct direction and extent of movement of actuator to give the required travel of the final control device;

- linkage adjustments for rotation, lift or close-off have been suitably set;
- correct position is assumed upon interruption of the power supply where spring-return motors are fitted;
- smooth and repeated movement of the actuating motor and connected device throughout this procedure.

Digital inputs/outputs

5.12 The following checks should be made:

- all digital input signals are sensed correctly by the BMS;
- all digital outputs cause the correct plant or device operation;
- each volt-free contact is volt-free;
- each volt-free contact assumes its correct normally open or closed state, and signals the relevant change in status of the correct item of plant;
- pulsed outputs from meters are correctly processed to display the correct value.

Interlocks

5.13 All electro-mechanical interlocks and fail-safe devices should be checked to ensure they function as specified.

Control routine tests

5.14 **Tuning of control loops**: all control loops should be systematically tuned to optimise the performance of control systems to provide stable operation over the complete range of control. After tuning each loop, the set-points should be recorded on the checklist.

Note: Where possible, load simulation should be utilised to verify performance of system and setting.

5.15 **Alarms**: BMS alarms should be checked for correct operation and priority protocol, message and destination. The response to sensor failures should be as specified.

5.16 **Interlocks**: software interlocks written within the configuration software should be checked, both positively in that an action will only occur if other parameters are in place, and negatively in that interlocked activities cannot occur in isolation.

5.17 **Optimisers**: the performance of optimisers should be checked in terms of outside and inside air temperatures and the time required to meet room conditions. The time should be within specified limits.

5.18 **Compensators**: the outside and room air temperatures and the compensated flow temperature should be logged to verify that the compensator is functioning and environmental conditions are being met.

5.19 **Sequencing**: the correct operation of sequence control for multiple plant items should be checked for switch-on and switch-off, rotation of lead unit, and correct operation when one or more units have tripped out.

5.20 **Load cycling**: the period of load disconnection and any BMS control limits should be checked. Temperature, humidity and carbon dioxide levels should remain within specified limits during load cycling operation.

5.21 **Load shedding**: the shedding of loads and their cumulative restoration should be checked to verify compliance with the specification.

5.22 **Fresh air**: the control of fresh air entering a building should be checked by logging air flow rates or levels of carbon dioxide and the operation of dampers. The interaction with enthalpy controls should be checked.

5.23 **Enthalpy**: system performance should be checked by monitoring fresh air enthalpy, exhaust air enthalpy and the fresh air damper position over time.

5.24 **Carbon dioxide**: the control of fresh air levels according to carbon dioxide concentrations should be checked by monitoring damper positions and carbon dioxide levels.

5.25 **Lighting**: lighting control operation should be checked by examining the daily control settings against work patterns and the operation of light-level sensors or occupancy controls.

Stand-alone operation

5.26 All outstations shall consist of all necessary hardware and software to provide a totally ‘Stand Alone’ unit capable of all monitoring, corrective action, and control functions as detailed herein.

Each outstation shall be 'freely programmable' to allow total flexibility, controlling its plant independently of the control of any central computer. The outstations shall continue to operate fully in the event of a possible total failure of the central computer and/or any other outstations. Outstations should be checked to ensure they function independently and in real time, irrespective of any failure elsewhere in the BMS.

Central station

5.27 The following should be checked and recorded (reference can be made to the sample checklist in Appendix 1); this list is not exhaustive:

- from switch-on the central station reaches operational state unaided;

- central station real-time clock is operational;
- calendar functions, seasons, day of week, and day/night functions are set;
- central station establishes communications;
- central station responds to incoming communications;
- operation of peripheral equipment, for example printers, loggers etc;
- satisfactory data acquisition speed (for example from sensors to outstation and the latter to the central station);
- data logging routines and graph functions (for example trend logs);
- updating of control parameters;
- alarm system;
- entry and operation of security passwords;
- data archiving system;
- reporting and monitoring function;
- all the graphics slides;
- operation of supplementary software, reading data from the BMS, data analysis and presentation.

Interruption of electrical power supply

5.28 The BMS should be checked to verify its operation meets the specification when the electrical supply is interrupted.

5.29 The operation of the BMS under standby power should be checked.

5.30 The ability of the central station and outstations to preserve existing software and data for the specified period while the electrical power is lost should be checked.

5.31 The operation of the central station, outstations and associated plant should be checked after the restoration of the electrical power supply.

5.32 Any re-start programme which may be required following power interruption or system resets should be checked.

5.33 BMS outstations should have the power source backed up with a battery backup system to prevent loss of trend logs and historical data in the event of power failure

6. Handover procedure

6.1 Handover requirements should be detailed in the specification. The client should witness the demonstration of various aspects of the BMS to their satisfaction. The handover procedure also includes the provision of all specified documentation including:

- BMS performance specification;
- control strategy diagrams;
- schematics;
- points list;
- plant diagrams showing locations of field devices;
- software backup copies;
- record drawings;
- commissioning records;
- operating and maintenance manuals;
- any special tools and spare parts, including backup software for all aspects of the system.

Note: For this purpose, the client needs to be informed and should have already received some training. Involvement in the commissioning process of clients key staff can consolidate the clients informed status.

Commissioning records

6.2 Details of the design and actual performance, the 'as-installed' layout, and details of the correct and safe operation of the BMS must be collected together and handed over to the client. A minimum list of records required after commissioning is given below (reference can be made to the sample checklist in Appendix 1); this list is not exhaustive:

- field and communications wiring checklists;
- field device checklists;
- control panel checklists;
- overload settings;
- outstation checklists;
- central station checklists;
- alarm test records;
- interlock test records;

- control loop tuning records;
- start-up/shut-down test records;
- environmental performance test records.

Demonstration

Note: Ideally the clients representative should be the officer who will be responsible for the operational management of the BMS.

6.3 The following should be demonstrated to the client prior to, or as part of, handover (reference can be made to the sample checklist in Appendix 1); this list is not exhaustive:

- field device wiring identified at device and control panel/outstation;
- field devices identified;
- as-commissioned setting of sensors and actuators permanently identified;
- outstations identified;
- points schedules, strategy diagrams etc. located in each outstation;
- purpose of field devices;
- each control panel location and function;
- operation of outstation under mains power failure;
- specified outstation control functions;
- central station alarm handling;
- central station graphics;
- central station printing of specified reports;
- BMS network communications;
- integrated fire/security systems – alarm handling;
- operation of third party software on central station.

7. Training

Service and maintenance staff

7.1 Training of all staff involved with the operation or maintenance of the BMS is essential to realise the benefits of the capital investment.

7.2 Maintenance staff should be trained in any special maintenance procedures. The depth of training will depend on the level of required maintenance, and should at least draw attention to any hazards arising due to the maintenance activities.

Note: Training on BMS strategy configuration may have to be undertaken off-site.

7.3 Other personnel who monitor plant or the building via BMS terminals, or carry out routine plant maintenance, should be trained in:

- understanding the displays;
- acknowledging and cancelling alarms;
- taking required actions following alarm messages;
- obtaining the best use of the system.

Building occupiers

7.4 The BMS and its operation should be explained to the occupiers of areas where there is an interface with the BMS (for example manual override, adjustable set-point). Occupiers of areas where manual control has been replaced by BMS control should also have the control operation explained to them together with the conscientious use of energy.

8. Post-handover

Operational procedures

8.1 The following operational procedures should be implemented by the user when the BMS is handed over and taken into use. The procedures may need to be modified in the light of experience gained in the actual operation of the BMS:

- user logging on, operation and logging off;
- creation of record of system users;
- password protection of all levels for different classes of user;
- routine application-software backup;
- operation of alarm log;
- recovery of system from:
  - power failure;
  - central station failure;
  - BMS communications failure;
- integration of BMS with fire and security alarm systems – correct alarm override;
- archiving of historical data;
- record of alterations made to the BMS software;
- record of observed defects (plant and BMS) and corrective action taken, with dates;
- systems which ensure that best use of the BMS information is made for maximum benefit.

Maintenance procedures

8.2 In order that the BMS can be properly maintained, it is essential that maintenance staff have access to the information provided at handover (see paragraph 6.1).

8.3 Schedules of routine maintenance activities, suggested spares lists and operational information should be prepared.

8.4 Monitoring of data from the BMS enables faults to be rectified at an early date.

Guarantee and defect liability period

8.5 Performance tests are usually carried out at a particular time of the year; however, the response of the building will be different at other times. Levels of occupancy can also influence the response. During the first 12 months (guarantee period) a certain degree of fine tuning will be required to optimise control loops, set-points etc. to improve environmental and energy performance.

Note: Where the specification includes for fine-tuning during the first 12 months to be carried out as part of the contract, the contractor should be advised of any necessary adjustment. All revised settings should be recorded on the appropriate commissioning records.

8.6 Any defect appearing within the contract defect liability period should be formally brought to the attention of the main contractor, and its clearance monitored.

Design-in-use study

8.7 A design-in-use or post-evaluation study should be undertaken after the BMS has been in operation for a year. The designer, installer, commissioning team, plant maintenance manager and a representative of the user should meet to discuss to what extent the BMS system has met the original expectations.

Note: This study is valuable for future schemes.

9. Designated staff functions

9.1 Only trained and competent persons should be appointed by management to operate and maintain the BMS.

9.2 **Management**: the owner, occupier, employer, general manager, chief executive officer or other person who is accountable for the premises and is responsible for issuing or implementing a general policy statement under the Health and Safety at Work etc. (HSW) Act, 1974.

9.3 **Employer**: any person or body who:

- employs one or more individuals under a contract of employment or apprenticeship;
- provides training under the schemes to which the Health and Safety (Training for Employment) Regulations 1990 (SI No 1990/1380) apply.

9.4 **Designated person (electrical)**: an individual who has overall authority and responsibility for the premises containing the electrical supply and distribution system within the premises and has a duty under the HSW Act 1974 to prepare and issue a general policy statement on health and safety at work, including the organisation and arrangements for carrying out that policy. This person should not be the authorising engineer.

9.5 **Duty holder**: a person on whom the Electricity at Work Regulations 1989 impose a duty in connection with safety.

9.6 **Authorising Engineer (low voltage)**: a chartered engineer or incorporated electrical engineer with appropriate experience and possessing the necessary degree of independence from local management who is appointed in writing by management to advise on and monitor the safety arrangements for the low voltage electrical supply and distribution systems of that organisation to ensure compliance with the Electricity at Work Regulations 1989, and to assess the suitability and appointment of candidates in writing to be authorised persons (see SHTM 06-02: 'Electrical safety guidance for low voltage systems').

9.7 **Authorised person (LV – electrical)**: an individual possessing adequate technical knowledge and having received appropriate training, appointed in writing by the authorising engineer (LV), to be responsible for the practical implementation and operation of management's safety policy and procedures on defined electrical systems (see SHTM 06-02).

9.8 **Competent person (LV – electrical)**: an individual who in the opinion of an authorised person has sufficient technical knowledge and experience to prevent danger while carrying out work on defined electrical systems (see SHTM 06-02).

9.9 **Commissioning specialist (BMS)**: an individual or organisation authorised to carry out commissioning, validation and routine testing of BMS.

9.10 **Maintenance person (BMS)**: a member of the maintenance staff, BMS manufacturer or maintenance organisation employed by management to carry out maintenance duties on BMS.

9.11 **BMS operator**: any authorised individual who operates a BMS.

10. Definitions

Actuator: an electromechanical device that positions control devices (such as valves or dampers) in relation to a supplied control signal.

Alarm: the annunciation of an event that the system operator needs to be aware of.

Analogue: pertaining to data that consists of continuously variable quantities.

BACnet: a communication protocol for building automation and control networks, suited for the management and automation levels, especially for HVAC, lighting control, life safety, security and fire alarm systems.

BAS – building automation system: synonymous with BMS.

BEMS – building and energy management system: synonymous with BMS.

BMS – building management system: a system comprising electronic equipment and software with the prime function of controlling and monitoring the operation of building services within a building, including heating, air-conditioning, lighting, and other energy-using areas.

BMS contractor: the organisation responsible for the supply and/or installation of the BMS. The contractor may be either the manufacturer or a systems house. It is often the case that the BMS contractor will commission the BMS.

Bus: a means of connecting a number of different devices, sensors, controllers, outstations, etc. to act as a means of data exchange.

Central station: the primary point of access to a BMS; the usual point from which all operations are supervised.

Client: the individual or group of individuals ultimately responsible for paying for and using the BMS.

Commissioning: the advancement of an installed system to working order to specified requirements.

Commissioning specialist: the individual responsible for the commissioning of the BMS. He/she may be employed by the BMS contractor or a specialist commissioning company.

Communications network: a system of linking together outstations and a central station to enable the exchange of data. Usually a dedicated cable system, but radio or mains-borne signalling may be used.

Compensator: a control device whose control function is to either:

- reduce heat supply with decreasing building heat load; or

- reduce cooling energy supply with decreasing building cooling load, in response to outside and (sometimes) inside temperatures.

Completion: the state of being finished in its entirety, according to the specification, ready for use by the owner.

Configuration software: software (in the form of 'building blocks') resident in an outstation which can be configured to create different control strategies.

Control function: a term used to describe a specific, discrete form of control, for example compensation, optimisation etc. These can be linked together in a control strategy.

Control loop: proportional, or proportional + integral, or proportional + integral + derivative control strategy where the output is related to a function of the input signal.

Control strategy: a description of the engineered scheme to control a particular item of plant or perform a series of control functions.

Data: a representation of information or instruction in a formalised manner suitable for communication, interpretation, or processing by humans or computer.

Derivative control: a control algorithm in which the control output signal is proportional to the rate of change of the controlled variable.

Direct digital control (DDC): a term used to define products that are based on microprocessor control.

Distributed intelligence: a description of a system where data processing and control is carried out at outstations, not at a central point.

Duty cycling: a control function that rotates the use of items of plant so that each item undergoes equal usage.

EMS – energy management system: synonymous with BMS.

Field device: the controls that are placed in the field level, that is, switches, sensors, actuators, etc.

Gateway: software written to enable data to be exchanged between two different communications protocols.

Handover: the transfer of ownership of all or part of a building or system, usually to the client.

Integral control: a control algorithm in which the output signal is proportional to the integral of the error.

Load cycling: a control method where management of plant energy demand is achieved by means of fixed on/off periods of operation.

Load shedding: the function of switching off electrical equipment if the load exceeds a limit. This function therefore reduces the risk of maximum demand penalty charges.

LonWorks: Collective term for LON technology as a whole.

M-Bus - (Meter-Bus): Standardised field bus system (conforming to EN 1434) for the transmission of energy consumption data.

Modbus: Open standard protocol for industrial use.

OPC: Software interface defined in process automation.

Optimiser: a control device whose function is to vary the daily on and off times of heating, ventilation and air-conditioning (HVAC) plant in order to produce an acceptable environment with lowest energy usage.

Outstation: a device to which sensors and actuators are connected, capable of controlling and monitoring building services functions. It also has the facility to exchange information throughout the BMS network.

Performance tests: tests carried out to demonstrate that the system functions according to specification.

Point: a physical source or destination for data in the form of analogue or digital signals.

Pre-commissioning checks: systematic checking of a completed installation to establish its suitability for commissioning.

Proportional control: a control algorithm in which the output signal is proportional to the error in the controlled variable.

Proportional and integral control: a control algorithm in which the output signal is proportional to the error plus the integral of the error in the controlled variable.

Proportional and integral and derivative control: a control algorithm in which the output signal is proportional to the error plus the integral of the error and the rate of change of the controlled variable.

Protocol: a set of rules governing information flow in a communication system.

Sensor: a hardware device which measures, and provides to a control strategy, a value representing a physical quantity (for example temperature, pressure etc); or activates a switch to indicate that a preset value has been reached.

Soft point: a point that can be referenced as if it were a monitoring or control point in a BMS, although it has no associated physical location. It may have a set value or be the result of a given calculation or algorithm.

Stand-alone control: during normal operation, an item of equipment which can operate normally when isolated from the remainder of the system.

TCP/IP: Transmission Control Protocol/Internet Protocol

Testing: the evaluation of the performance of a commissioned installation tested against the specification.

Witnessing: the observation (by the client or his/her representative) of tests and checks of BMS hardware and operation prior to completion.

Appendix 1

Sample commissioning and handover record sheets

These sample checklist sheets are included for guidance purposes only. For similar guidance reference can also be made to the NHS Model Engineering Specification, C54, 'Building management systems'.

- Commissioning record sheet;
- Control panel checklist;
- BMS wiring checklist;
- Field devices checklist;
- Outstation commissioning checklist;
- Central station commissioning checklist;
- Operating and maintenance manual checklist;
- Completion checklist.

References

Note: Where there is a requirement to address a listed reference, care should be taken to ensure that all amendments following the date of issue are included.

Acts and Regulations

NB: Access to information related to the following Acts and Regulations can be gained via www.legislation.gov.uk.

BS7671: 2008 (IEE Wiring Regulations, 17th Edition). British Standards Institution, 2008.

Building (Scotland) Regulations 2004 and (Amendment) Regulations 2006, 2007.

Chemicals (Hazard Information and Packaging for Supply) Regulations 2002. SI 2002 No1689.TSO,2002.

Clean Air Act 1993. TSO, 1993.

Construction (Design and Management) Regulations 2007.SI 2007 No 320.TSO, 2007.

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Water Environment (Oil Storage) (Scotland) Regulations 2006, SI 2006 No133 Stationery Office
http://www.opsi.gov.uk/legislation/scotland/ssi2006/20060133.htm

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Control of Pollution (Amendment) Act 1989.TSO, 1989.

Control of Substances Hazardous to Health Regulations (COSHH) 2002.SI 2002No 2677.TSO, 2002.

Disability Discrimination Act 2005 (DDA).TSO, 1995.

Electrical Equipment (Safety) Regulations 1994.SI 1994 No 3260.TSO, 1994.

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Health and Safety at Work etc Act 1974.TSO, 1974.

Health and Safety Information for Employees Regulations 1989.SI 1989 No 682.TSO, 1989.

Lifting Operations and Lifting Equipment Regulations 1998. SI 1998 No 2307.TSO, 1998.

Management of Health and Safety at Work Regulations 1999.SI 1999 No 3242.TSO, 1999.

Manual Handling Operations Regulations 1992.SI 1992 No 2793.TSO, 1992.

Noise and Statutory Nuisance Act 1993.TSO, 1993.

The Control of Noise at Work Regulations 2005.SI 2005 No 1643.TSO, 2005.

Packaging (Essential Requirements) Regulations 2003.SI 2003 No 1941.TSO, 2003.

Personal Protective Equipment at Work Regulations 1992.SI 1992 No 2966.TSO, 1992

Pressure Equipment Regulations 1999.SI 1999 No 2001 and (Amendment) Regulations 2002.TSO, 1999.

Pressure Systems Safety Regulations 2000. SI 2000 No 128.TSO, 2000.

Provision and Use of Work Equipment Regulations 1998.SI 1998 No 2306.TSO, 1998.

Radio Equipment and Telecommunications Terminal Equipment Regulations 2000 and Amendment 2003.SI 2000 No 1903.TSO, 2000.

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR 95).SI 1995 No 3163.TSO, 1995.
http://www.opsi.gov.uk/SI/si1995/Uksi_19953163_en_1.htm

The Planning etc. (Scotland) Act 2006.TSO, 2006.

Water Environment and Water Services (Scotland) Act 2003.TSO, 1991.

The Water Industry (Scotland) Act 2002 (Consequential Modifications) Order 2004 SI 2004 No. 1822.TSO, 2004.

Workplace (Health, Safety and Welfare) Regulations 1992.SI 1992 No 3004.TSO, 1992.

British Standards

BS4737: 1988 Intruder alarms in buildings, British Standards Institution 1988

BS5445: 1984 Components of automatic fire detection systems, British Standards Institution 1984

BS9999: 2008 Code of Practice for safety in the design, management and use of buildings, British Standards Institution 2008

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Health Facilities Scotland (HFS)

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Scottish Hospital Technical Note 4: General purposes Estates and facilities model safety Permit-to-Work system, 1998

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Programmable electronic systems in safety-related applications, 1987

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EH40: Occupational exposure limits, 2003 (and amendments 2007)

BSRIA

AH2/92: Commissioning of BMS, a Code of Practice, 1992

AG2/94: BMS performance testing, 1994

BAH 01/01: Applications handbook Vol. l – Guide to BEMS centre standard specification, 1990

BAH 01/02: Applications handbook Vol. ll – Standard specification for Building Management Systems, Version 3.1, 1990

Library of system control strategies, 1998

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CIBSE Commissioning Code C: Automatic controls, 2001

CIBSE Commissioning Code M: Commissioning management, 2003

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