HEALTH TECHNICAL MEMORANDUM 2005

Building management systems
Validation and verification

1996

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About this publication

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

They are applicable to new and existing sites, and are of use at various stages during the inception, design, construction, refurbishment and maintenance of a building.

Health Technical Memorandum 2005

HTM 2005 focuses on the:

a. legal and mandatory requirements;

b. design;

c. testing and commissioning;

d. operation and maintenance

of building management systems (BMS) in all types of healthcare premises.

It is published as four separate volumes, each addressing a specialist discipline:

- **Management policy** – outlines the overall responsibility of chief executives and managers of healthcare premises, and details their legal and mandatory obligations in installing and operating a reliable, efficient and economic BMS. It summarises the technical aspects and concludes with guidance on the management of systems;

- **Design considerations** – outlines BMS technology and details the requirements and considerations that should be applied to the design of this service up to the contract stage;

- this volume – **Validation and verification** – gives general advice for ensuring that the installed equipment has been formally tested and certified as to contract. The importance of commissioning the completed installation is emphasised. The handover procedure, including the provision of documentation and training, is set out;

- **Operational management** – provides information for those responsible for overseeing and operating day-to-day running and maintenance procedures. Coverage includes routine tests, planned preventive maintenance and trouble-shooting.

Guidance in this Health Technical Memorandum is complemented by the library of National Health Service Model Engineering Specifications (MES) and, where applicable, the Scottish and Northern Ireland supplements. Users of the guidance are advised to refer to the relevant specifications for 'Building management systems'.

The contents of this Health Technical Memorandum in terms of management policy, operational policy and technical guidance are endorsed by:

a. the Welsh Office for NHS Wales;

b. the Health and Personal Social Services Management Executive in Northern Ireland;

c. the National Health Service in Scotland Estates Environment Forum.

References to legislation appearing in the main text of this guidance apply in England and Wales. Where references differ for Scotland and/or Northern Ireland, these are given as marginal notes.

Where appropriate, marginal notes are also used to amplify the text.

Executive summary

A building management system (BMS) 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 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 volume – 'Validation and verification' – provides general advice to ensure that installed equipment has been formally tested and certified as to 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 Chapter 2. The fundamental criteria of the commissioning processes are described in Chapter 3. All pre-commissioning checks, inclusive of works and site tests, are listed in Chapter 4. Detailed commissioning techniques are described in Chapter 5. Handover, training requirements and post-handover procedures are detailed in Chapters 6, 7 and 8.

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

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

Contents

1.0 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.

Throughout this document, healthcare premises will include "social services premises" in Northern Ireland

1.2 A BMS can be used to manage the environmental conditions of all types of building. In healthcare premises, a BMS is particularly valuable in maintaining suitable conditions in critical areas, for example operating departments, intensive care units, isolation suites, pharmacies and sterile supply departments. A BMS provides alarm communication networks for the building services plant.

Other areas that can be monitored and targeted include water consumption, sewage and waste disposal

1.3 A properly installed and maintained BMS operated by fully trained staff offers considerable opportunities for "energy management". A BMS can support separate software packages for energy monitoring and targeting.

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

When a BMS is specified, the NHS Model Engineering Specifications, with the appropriate supplements for Scotland and Northern Ireland, should be considered

1.5 A BMS should be specified with care and detail, focusing on the functionality and required performance of the systems under control. 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.

1.6 The commissioning of the 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.

1.9 The sophistication of building services in healthcare premises is increasing, and therefore BMS controls should be designed, installed, operated and maintained to standards that will enable the controls to fulfil the desired functions reliably and safely.

2.0 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:

a. Health and Safety at Work etc (HSW) Act 1974;

b. Electricity at Work Regulations 1989;

c. Building Act 1984 and the Building Regulations 1991 (including Approved Documents);

d. Management of Health and Safety at Work Regulations 1992;

e. Provision and Use of Work Equipment Regulations 1992;

f. Manual Handling Operations Regulations 1992;

g. Workplace (Health, Safety and Welfare) Regulations 1992;

h. Personal Protective Equipment at Work (PPE) Regulations 1992;

j. Health and Safety (Display Screen Equipment) Regulations 1992;

k. Construction (Design and Management) Regulations 1994;

m. Electromagnetic Compatibility Regulations 1992;

n. Electromagnetic Compatibility (Amendment) Regulations 1994.

Functional guidance

2.3 Guidance is as laid down in:

a. British Standards and Codes of Practice;

b. Health and Safety Executive guidance;

c. NHS Model Engineering Specifications – NHS Estates;

d. Health Building Notes – NHS Estates;

e. Technical Standards (Scotland);

f. Health Technical Memoranda and Firecode – NHS Estates.

For further details please refer to the "References" section.

a. Health and Safety at Work (Northern Ireland) Order 1978;
b. Electricity at Work Regulations (Northern Ireland) 1991;
c. Building Regulations (Northern Ireland) 1994 and Technical Booklets; Building Standards (Scotland) Regulations 1990;
d. Management of Health and Safety at Work Regulations (Northern Ireland) 1992, and Management of Health and Safety at Work (Amendment) Regulations (Northern Ireland) 1994;
e. Provision and Use of Work Equipment Regulations (Northern Ireland) 1993 and Provision and Use of Work Equipment (Amendment) Regulations (Northern Ireland) 1995;
f. Manual Handling Operations Regulations (Northern Ireland) 1992;
g. Workplace (Health, Safety and Welfare) Regulations (Northern Ireland) 1993;
h. Personal Protective Equipment at Work Regulations (Northern Ireland) 1993;
j. Health and Safety (Display Screen Equipment) Regulations (Northern Ireland) 1992;
k. Construction (Design and Management) Regulations (Northern Ireland) 1995

There are forthcoming CEN standards on BMS from CEN Technical Committee TC247

3.0 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 over-runs, the programmed resources tend to be compressed. This can result 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 Commissioning describes the testing and inspection of an installed BMS to ensure it is working and able to meet specified requirements (normally contained within the specification). Commissioning incorporates several stages:

a. pre-commissioning checks of the components:
   (i) wiring;
   (ii) sensors and actuators;
   (iii) major sub-assemblies (either on or off site);
   (iv) control cabinets;
   (v) configured control strategies;
   (vi) central station graphics slides;

b. commissioning of the application software;

c. commissioning of the complete system including:
   (i) checking alarms;
   (ii) checking interlocks;
   (iii) control loop tuning;
   (iv) calibration of sensors;
   (v) 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.

Specification

3.6 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 a high priority by the project/construction teams.

This ensures that 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.

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.

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 client's (or user's) 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.

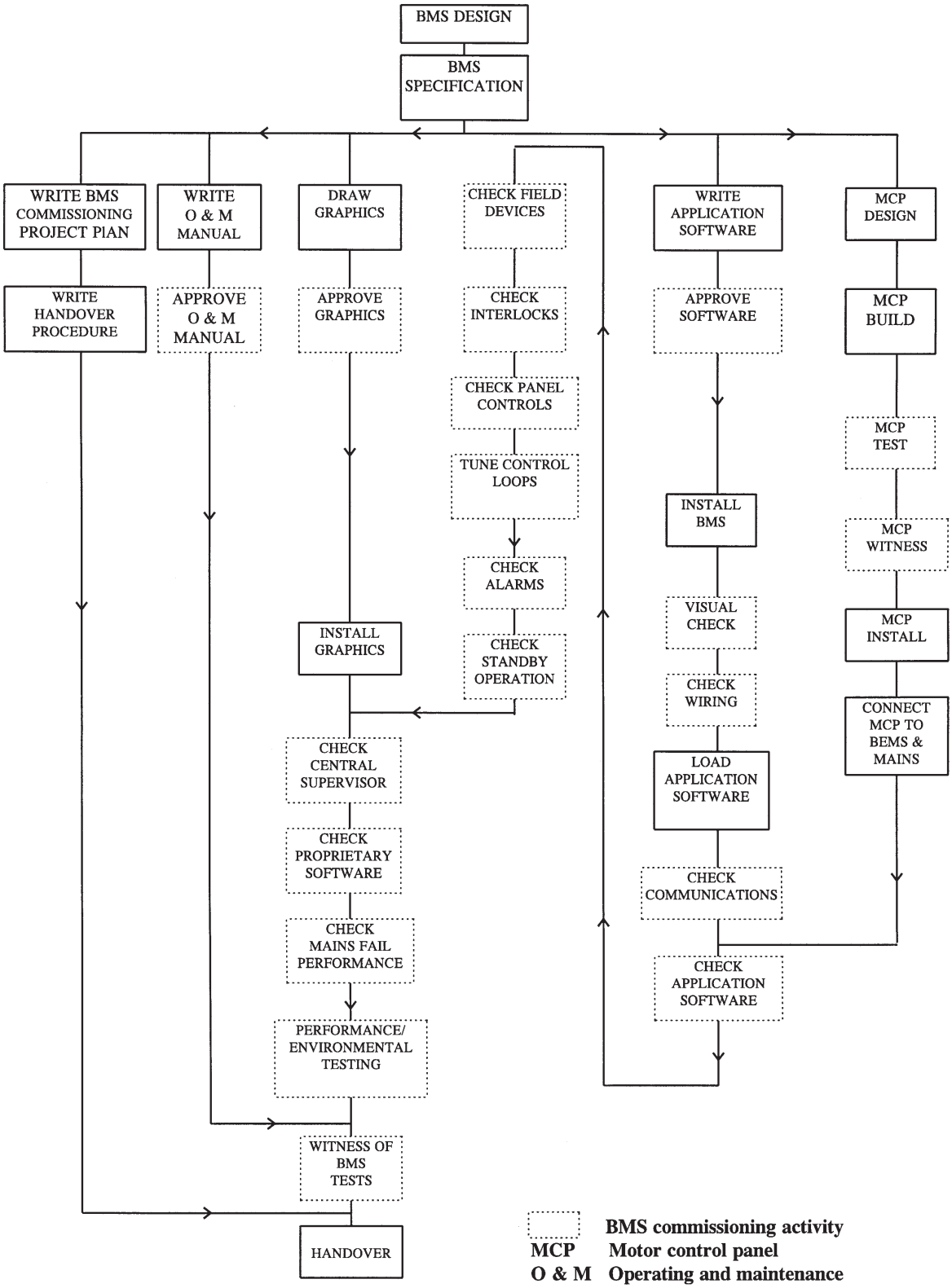

Figure 1 Flow chart for BMS installations (illustrating commissioning activities)

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:
  (i) temperature;
  (ii) pressure;
  (iii) flow-rate;
  (iv) velocity;
  (v) 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:
  (i) location of field devices;
  (ii) location of test points to facilitate checking of field devices;
  (iii) 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 should be subject to performance tests in accordance with the contract requirements.

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. All documentation should reflect the "as installed" state of the plant.

Handover procedures

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

3.23 Handover requirements should be detailed in the specification. The client should witness the demonstration of various aspect 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.

Fine tuning

If the client wishes to have fine tuning carried out by the BMS contractor, it should be detailed in the specification

3.24 During the first year of operation the performance of a BMS will need to be optimised through a process of fine tuning. This is partly because the BMS may have been commissioned before the building was occupied, and invariably set-points and other items will need adjusting.

Safety

Refer to Chapter 2 and the References section for details of applicable safety Acts and regulations

3.25 Construction sites are potentially dangerous places of work, and all site workers have a responsibility for site safety. Engineers working on the commissioning of building services and controls are exposed to normal construction site dangers.

3.26 The Construction (Design and Management) Regulations 1994 place health and safety responsibilities on the client, including:

- the selection and appointment of a competent planning supervisor;
- ensuring that construction work does not begin until a health and safety plan has been prepared; and
- on completion, making the health and safety file available for inspection.

3.27 All employees should receive adequate training in safety matters before working on site.

3.28 Management should provide the necessary safety equipment. It is the duty of all employees to make use of it.

4.0 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.

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:

a. **set-points:** all set-points should be checked for entry of realistic values and operating ranges;

b. **time control:** all timed routines should be checked for entry of suitable on/off times;

c. **interlocks:** all interlocks should be checked;

Life-safety interlocks should be hard-wired and not software-dependent

d. **control loops:**

   (i) all control loops should be checked to ensure that suitable default values are entered prior to testing;

   (ii) the operation of the control loops should be checked (if possible);

e. **sequencing:** all sequence controls should be checked to ensure that they are installed and operating in the specified manner;

f. **start-up and shut-down:**

   (i) the start-up routine for correct sequence or control operations should be checked;

   (ii) the defined restart routine should be effective when power is reinstated;

   (iii) the shut-down routine and status of valves, dampers etc should be checked;

g. **plant changeover:**
   (i) the automatic changeover of plant due to plant failure and hours run should be checked;
   (ii) the sequence of events following the failure of the second or standby item of plant should be checked;

h. **alarm functions:**
   (i) the operation of each alarm function should be checked;
   (ii) the time delay on each alarm function should be checked;
   (iii) the level or category of alarm, its destination and reporting method should be checked;
   (iv) the operation of alarm masking should be checked;

j. **graphics:**
   (i) hard copies of BMS graphics pages should be checked;
   (ii) 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:

a. colour and finish (no sharp edges);
b. metalwork including doors;
c. common key for all panels;
d. secure operation of door locks;
e. safe access to BMS equipment;
f. eyebolts fitted to panels weighing more than 50 kg;
g. location and labelling of switches and indicators;
h. rivets or screws used to mount labels (not adhesive);
j. 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:

a. all doors on any panel containing exposed dangerous voltages are provided with interlocking isolators;
b. 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;
c. access for incoming cables;
d. access for outgoing power and control cables;
e. provision of suitable gland plates;

f. all doors/gland plates are earthed;

g. bus bars and power cabling to specification;

h. tightness of all connections;

j. neatness of cable looms;

k. 25% spare capacity in all cable trunking;

m. colour coding and numbering of all cables;

n. all terminals are numbered;

p. shrouding of unisolated equipment;

q. shrouding of switches, lamps etc on door;

r. segregation of electronic equipment;

s. trunking lids are cross-referenced;

t. link-type terminals for BMS cables;

u. spare fuses and fuse-ways;

w. drawing holder;

x. fuse type and ratings against fuse chart;

y. fuse chart against drawings;

z. layout of equipment against drawings;

aa. spare back panel space is provided;

ab. no equipment is mounted on the bottom or sides of panel;

ac. labelling of equipment in panel;

ad. access to all equipment, especially devices requiring adjustment;

ae. power outlet is provided;

af. flexible loom across door hinge is arranged to avoid pinching or looping as door is closed, and is fully supported at each end;

ag. screen and earth cabling and connections associated with BMS equipment comply with manufacturer's 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:

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

a. lamp test facility;

b. wiring interlocks;

c. indicators and signals out from the panel;

d. fuse or circuit breaker size and overload range;

e. correct labelling of fuses/circuit breakers;

f. starter operates correctly and power is provided to outgoing terminals;

g. starter de-energises and the trip indicator lights up when the starter is tripped;

h. 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:

a. **sensors and actuators:**
   (i) correct location/orientation;
   (ii) good access;
   (iii) type as specified;
   (iv) identification;
   (v) correct wiring connections;
   (vi) multi-mode actuators should be site-configured and permanently marked with "as commissioned" switch position;

b. **outstations:**
   (i) type;
   (ii) size;
   (iii) number;
   (iv) location (height and access);
   (v) mechanical fixing;
   (vi) identification;
   (vii) all cables terminated and identified;
   (viii) all terminals utilised;
   (ix) power available;
   (x) fuses;
   (xi) hardware configuration according to design;
   (xii) all electronic "cards" in place;
   (xiii) all connecting cables plugged in;
   (xiv) document wallet containing: wiring diagram; points list; control strategy diagram and functional specification;

c. **central station:**
   (i) type;
   (ii) location;
   (iii) power;
   (iv) cleanliness for operation;

d. **wiring:**
   (i) cable as specified;
   (ii) cable identified at both ends;
   (iii) screening continuity;
   (iv) electrical continuity;
   (v) correct polarity;
   (vi) correct input/output;
   (vii) correct and secure termination;
   (viii) separation of mains and signals cables;
   (ix) no short circuits;
   (x) security of fixing/protection.

5.0 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:

a. all application software should be loaded and proved;

Back-up copies should be available on site

b. the procedure for resetting the software should be proved;

c. all variable parameters and switches should be set to appropriate values and settings to ensure compliance with the specification;

d. where installed, local Hand/Off/Auto facilities should be demonstrated and proved in "Hand/Off" functions and then switched to "Auto";

e. building and plant are complete;

f. plant and all necessary services are available;

g. there is unhindered access to all relevant areas of the building;

h. plant and control panels are commissioned;

j. BMS pre-commissioning is completed;

k. 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.

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

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

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.

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 devices

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

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

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:

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

b. linkage adjustments for rotation, lift or close-off have been suitably set;

c. correct position is assumed upon interruption of the power supply where spring-return motors are fitted;

d. 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:

a. all digital input signals are sensed correctly by the BMS;

b. all digital outputs cause the correct plant or device operation;

c. each volt-free contact is volt-free;

d. 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;

e. pulsed outputs from meter 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.

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 Where stand-alone operation is a requirement of the specification, items 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:

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

b. central station real-time clock is operational;

c. calendar functions, seasons, day of week, and day/night functions are set;

d. central station establishes communications;

e. central station responds to incoming communications;

f. operation of peripheral equipment, for example printers, loggers etc;

g. satisfactory data acquisition speed (for example from sensors to outstation and the latter to the central station);

h. data logging routines and graph functions (for example trend logs);

j. updating of control parameters;

k. alarm system;

m. entry and operation of security passwords;

n. data archiving system;

p. reporting and monitoring function;

q. all the graphics slides;

r. 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.

6.0 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.

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

a. field and communications wiring checklists;

b. field device checklists;

c. control panel checklists;

d. overload settings;

e. outstation checklists;

f. central station checklists;

g. alarm test records;

h. interlock test records;

j. control loop tuning records;

k. start-up/shut-down test records;

m. environmental performance test records.

Demonstration

Ideally the client's 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:

a. field device wiring identified at device and control panel/outstation;

b. field devices identified;

c. as-commissioned setting of sensors and actuators permanently identified;

d. outstations identified;

e. points schedules, strategy diagrams etc located in each outstation;

f. purpose of field devices;

g. control panel's location and function;

h. operation of outstation under mains power failure;

j. specified outstation control functions;

k. central station alarm handling;

m. central station graphics;

n. central station printing of specified reports;

p. BMS network communications;

q. integrated fire/security systems – alarm handling;

r. operation of third party software on central station.

7.0 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 Staff responsible for the daily operation of the BMS should be available to observe the commissioning results being demonstrated by the contractor to provide a greater in-depth understanding of the system.

7.3 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.

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

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

a. understanding the displays;

b. acknowledging and cancelling alarms;

c. taking required actions following alarm messages;

d. obtaining maximum benefit from the investment.

Building occupiers

7.5 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.

8.0 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:

a. user logging on, operation and logging off;

b. creation of record of system users;

c. password protection of all levels for different classes of user;

d. routine application-software backup;

e. operation of alarm log;

f. recovery of system from:

   (i) power failure;

   (ii) central station failure;

   (iii) BMS communications failure;

g. integration of BMS with fire and security alarm systems – correct alarm override;

h. archiving of historical data;

j. record of alterations made to the BMS software;

k. record of observed defects (plant and BMS) and corrective action taken, with dates;

m. 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

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

8.5 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.

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.

This study is valuable for future schemes

9.0 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 or other person who is accountable for the premises and is responsible for issuing or implementing a general policy statement under the HSW Act 1974.

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

a. employs one or more individuals under a contract of employment or apprenticeship;

b. provides training under the schemes to which the Health and Safety (Training for Employment) Regulations 1988 (SI No 1988/1222) apply.

Health and Safety (Training for Employment) Regulations (Northern Ireland) 1994

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 implement, administer 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 HTM 2020 – 'Electrical safety code 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 HTM 2020).

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 HTM 2020).

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.

10.0 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.

BAS – building automation system: synonymous with BMS.

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

BMS – building management system: a system comprised of 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 installed system to working order to specified requirements.

Commissioning specialist: the individual responsible for the commissioning of the BMS. He 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:

a. reduce heat supply with decreasing building heat load; or

b. 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 a 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: description of a system where data processing and control is carried out at outstations and 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 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.

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

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.

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

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

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

11.0 References

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2011 Emergency electrical services. NHS Estates, HMSO 1993. (issued in 4 parts)

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Systems structure and definition of terms

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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".

1. Commissioning record sheet
2. Control panel checklist
3. BMS wiring checklist
4. Field devices checklist
5. Outstation commissioning checklist
6. Central station commissioning checklist
7. Operating and maintenance manual checklist
8. Completion checklist

1. COMMISSIONING RECORD SHEET

Installation began .....
Commissioning began.....
Commissioning method statement.....

Contract No. .....
Location .....
Client .....

Check off when complete	Outstation No.								
Checked items	1	2	3	4	5	6	7	8	Central Station
Works testing									
Application software									
Control panel									
On-site checking									
Wiring									
Visual inspection									
Pre-commissioning									
Application software loaded									
Hardware points tested									
Application software checked									
Outstation completed									
Outstation witnessed									
Communications									
Central station									
Graphics									
Central station witnessed									
Drawings/documentation									
O & M manual									
Training									

Signed for and on behalf of:-.....

Signed .....

Date .....

2. CONTROL PANEL CHECKLIST

Contract No.....
Location.....
Panel No. .....

	Checked Items	Satisfactory Yes / No	Checked By / Date
1.	**Preliminaries**		
1.1	Manufacturer's test OK		
1.2	Latest design specifications & drawings		
1.3	"As built" drawings incorporating modifications		
1.4	Switches wired over inputs		
2.	**Visual outside**		
2.1	Colour & finish		
2.2	Common panel key		
2.3	Secure door locks		
2.4	Safe access to BMS		
2.5	Eyebolts		
2.6	Switches-location & labelling		
2.7	Labels - plastic screws		
2.8	Ammeters etc - scaling		
3.	**Visual Inside**		
3.1	Door interlocked isolators		
3.2	Access for on-line adjustment		
3.3	Access for incoming cables		
3.4	Access for outgoing cables		
3.5	Gland plates		
3.6	Doors & gland plates earthed		
3.7	Bus bars & power cables		
3.8	Tightness of connections		
3.9	Neatness of cable looms		
3.10	25% spare capacity		
3.11	Cable identification		
3.12	Terminals numbered		
3.13	Un-isolated equipment shrouded		
3.14	Switches & lamps on door shrouded		
3.15	Segregation of electronic equipment		
3.16	Trunking lids cross referenced		
3.17	BMS cables - link type terminals		
3.18	Spare fuses & fuse ways		
3.19	Drawing holder		
3.20	Fuses - fuse chart		
3.21	Fuse chart - drawings		
3.22	Equipment layout - drawings		
3.23	Spare back panel space		
3.24	No equipment on bottom or sides		
3.25	Labelling of equipment		
3.26	Access to equipment		
3.27	Power outlet		
3.28	Door looms		
4.	**Function Test**		
4.1	Lamp test facility		
4.2	Wiring interlocks		
4.3	Fuse/circuit breaker - drawings		
4.4	Starter operation		
4.5	Trip starter		
4.6	Flash test		

Signed for and on behalf of:-.....
Signed .....
Date .....

3. BMS WIRING CHECKLIST

Contract No.....
Location.....
Client.....

Enter details		Check if satisfactory (Yes/No)							
Terminal ref.	Field device ref.	Cable type	Ferruled both ends	Continuity checked	Short circuit	Terminated field end	Terminated outstation	Screen continuity field-outstation	Screen earth connection sound

Signed for and behalf of:.....
Signed.....
Date.....

4. FIELD DEVICES CHECKLIST

Contract No. .....
Location .....
Outstation Ref. .....

Field device point ref	Installed	Wired	Identified	Sensor		Actuator			Digital input	Digital output	Volt free contact	Snags (if none state none)	Date cleared	Date commissioned
				Reading (field)	Check reading	Span	Start	Stroke						
Signed..... Date.....						Outstation totally commissioned and tested to central station						Signed..... Date.....		

5. OUTSTATION COMMISSIONING CHECKLIST

Contract No. .....
Location .....
Outstation Ref.....

	Checked items	Satisfactory	Checked	
		Yes / No	By	Date
1.	**OUTSTATION FITTING**			
1.1	Physical inspection of outstation			
1.2	Power supply connection			
2.	**OUTSTATION TERMINALS**			
2.1	Outstation field terminal separation			
2.2	Outstation field terminal labelling			
3.	**OUTSTATION OPERATION**			
3.1	From 'switch on' outstation reaches operational state unaided			
3.2	User information panel accepts commands & gives reports			
3.3	Outstation makes correct attempts to establish communications			
3.4	Outstation responds to incoming communications			
3.5	Outstation acquires & retains particular systems software			
3.6	Outstation continues to operate correctly on failure of communications equipment / network			
3.7	Outstation operates correctly on standby power supply (where fitted)			
3.8	Annunciation of alarms			
4.	**OUTSTATION FUNCTIONS**			
4.1	Reported sensor signals are valid & in the correct units			
4.2	Outstation cannot override hard wired safety interlocks			
4.3	Alterations of settings by the user at the outstation can be achieved			
4.4	Security code prevents unauthorised access			
4.5	Systems operate in real time			
4.6	Analogue alarm limits operate & are adjustable			
5.	**CONTROL LOOP CHECKING**			
5.1	Control loop reference			
5.2	Control loop description			
5.3	Type: P, PI, PID			
5.4	Tuning method			
5.5	Proportional gain			
5.6	Integral action time Ti			
5.7	Derivative action time Td			
5.8	Other noted parameters (depending on method)			
6.	**OPTIMISER SETTING**			
6.1	Optimiser reference			
6.2	Start time			
6.3	Earliest start time			
6.4	Rate of self learning			
6.5	Stop time			
6.6	Earliest stop time			
6.7	Rate of self learning			

Signed for and on behalf of:- .....
Signed ..... Date .....

6. CENTRAL STATION COMMISSIONING CHECKLIST

Contract No.....
Location.....
Client.....

	Checked items	Satisfactory Yes / No	Checked By	Checked Date
1.	**INSTALLATION OF CENTRAL STATION**			
1.1	Physical inspection of facility			
1.2	Power supply connection			
2.	**CENTRAL OPERATION**			
2.1	From 'Switch On' Central reaches operational state unaided			
2.2	Central real time clock operational			
2.3	Central makes correct attempts to establish communications			
2.4	Central responds to incoming communications			
2.5	Operation of peripheral equipment			
2.6	Data acquisition speed satisfactory			
3.	**CENTRAL FUNCTIONS**			
3.1	Data logging routines			
3.2	Control parameter update			
3.3	Alarm system			
3.4	Security system			
3.5	Data archiving system			
3.6	Reporting & monitoring functions			
3.7	Graphics			
3.8	Integrated systems			
4.	**COMMISSIONING SUCCESSFUL & DOCUMENTED**			
5.	**DOCUMENTATION, SPARES & SOFTWARE BACKUP**			
6.	**TRAINING COMPLETE**			
7.	**OTHER FUNCTIONS**			

Signed for and on behalf of:-.....
Signed ..... Date .....

7. OPERATING & MAINTENANCE MANUAL CHECKLIST

Contract No.....
Location.....
Client.....

	Check item	Satisfactory Yes/No	Checked By	Checked Date
1	Description of operation			
2	Equipment schedule			
3	Points listings			
4	Controller settings			
5	System application software configuration			
6	Comprehensive operating instructions			
7	Fault finding instructions			
8	Instructions for dealing with emergency conditions			
9	Instructions for any necessary precautionary measures			
10	Servicing instructions			
11	Instructions for creating routines and graphics etc			
12	User adjustable points			
13	Provision for updates and modifications.			
14	Technical literature			
15	Copies of any relevant certificates of compliance			
16	CHECKLIST FILE Copies of all test and commissioning records			

Signed for and on behalf of:-.....
Signed .....
Date .....

8. COMPLETION CHECKLIST

Contract No.....
Location.....
Client.....

All the tests shall be documented and signed by the testers and witnesses. A completion certificate shall only be issued by the client when all the tests have been successfully completed.

Each item to be dated and initialled.

	Checked item	Initial	Date
1.	Audit of the cabling and hardware installation		
2.	Demonstration that sensors and actuators are correctly connected and addressed		
3.	Demonstration of the physical and logical integrity of the system.		
4.	Demonstration of all control actions		
5.	Demonstration of sensor calibrations		
6.	Demonstration of successful system software commissioning. (This should include loading software and documented commissioning data from media and subsequent operation)		
7.	Verification of specified graphics		
8.	Verification of specified training requirements		
9.	Verification of handover of all specified operating manuals, documentation and drawings		
10.	Verification of handover of backup copies of software		
11.	Verification of handover of consumable spares		

Completed..... Initial..... Date.....
Signed for testers..... Date.....
Signed for witnesses ..... Date .....

Other publications in this series

Given below are details of all Health Technical Memoranda available from HMSO. HTMs marked (*) are currently being revised, those marked (†) are out of print. Some HTMs in preparation at the time of publication of this HTM are also listed.)

1 Anti static precautions: rubber, plastics and fabrics†
2 Anti static precautions: flooring in anaesthetising areas (and data processing rooms), 1977.
3 –
4 –
6 Protection of condensate systems: filming amines†
2007 Electrical services: supply and distribution, 1993.
8 –
2009 Pneumatic air tube transport systems, 1995.
2010 Sterilizers, 1994, 1995.
2011 Emergency electrical services, 1993.
12 to 13 –
2014 Abatement of electrical interference, 1993.
2015 Bedhead services, 1994, 1995.
16 –
17 Health building engineering installations: commissioning and associated activities, 1978.
18 Facsimile telegraphy: possible applications in DGHs†
19 Facsimile telegraphy: the transmission of pathology reports within a hospital – a case study†
2020 Electrical safety code for low voltage systems, 1993.
2021 Electrical safety code for high voltage systems, 1993, 1994.
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2025 Ventilation in healthcare premises, 1994.
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2027 Hot and cold water supply, storage and mains services, 1995.
28 to 29 –
2030 Washer-disinfectors, 1995.
2031 Steam supply for sterilization*
32 to 34 –
2035 Mains signalling*
36 to 39 –
2040 The control of legionellae in healthcare premises – a code of practice, 1993.
41 to 44 –
2045 Acoustics, 1996.
46 to 49 –
2050 Risk assessment in the NHS estate, 1994.
51 to 54 –
2055 Telecommunications (telephone exchanges), 1994.

Component Data Base (HTMs 54 to 80)

54.1 User manual, 1993.
55 Windows, 1989.
56 Partitions, 1989.
57 Internal glazing, 1995.
58 Internal doorsets, 1989.
59 Ironmongery†
60 Ceilings, 1989.
61 Flooring, 1995.
62 Demountable storage systems, 1989.
63 Fitted storage systems, 1989.
64 Sanitary assemblies, 1995.
65 Health signs*
66 Cubicle curtain track, 1989.
67 Laboratory fitting-out system, 1993.
68 Ducts and panel assemblies, 1993.
69 Protection, 1993.
70 Fixings, 1993.
71 Materials management modular system*
72 to 80 –

Firecode

81 Firecode: fire precautions in new hospitals*
81 Supp 1, 1993.
82 Firecode: alarm and detection systems, 1989.
83 Fire safety in healthcare premises: general fire precautions, 1994.
85 Firecode: fire precautions in existing hospitals, 1994.
86 Firecode: fire risk assessment in hospitals, 1994.
87 Firecode: textiles and furniture, 1993.
88 Fire safety in health care premises: guide to fire precautions in NHS housing in the community for mentally handicapped/ill people, 1986.

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