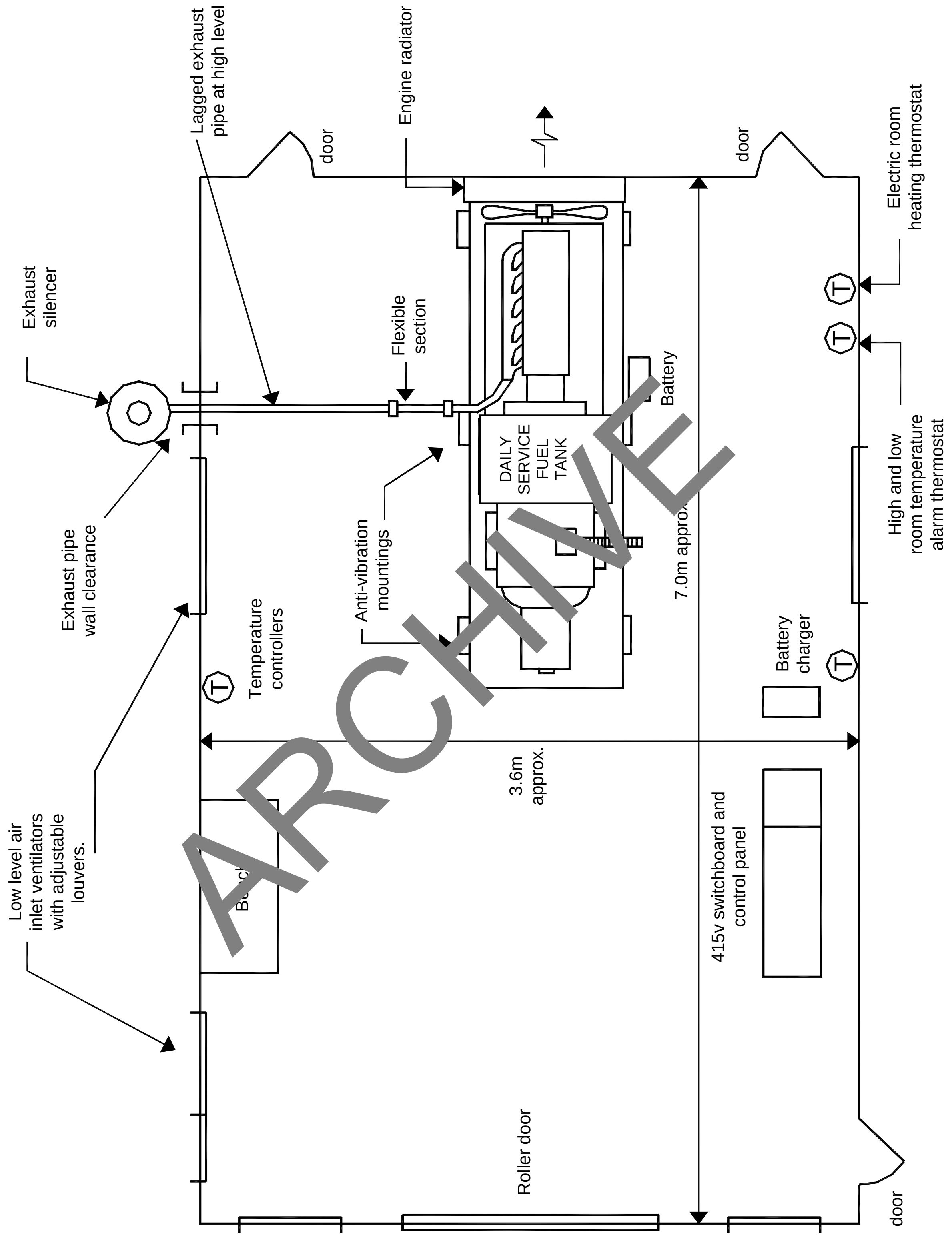
Figure 10: Typical diesel generator installation (100kW)



Note: Typical operating values for engine room temperature alarms:

High temperature	35°C
low temperature	7°C

Remote indicator lamps and audible alarm positioned at a permanently manned station, for example in the boiler house.

Figure 13: Controls for automatically synchronising a diesel generator running in parallel with the main supply

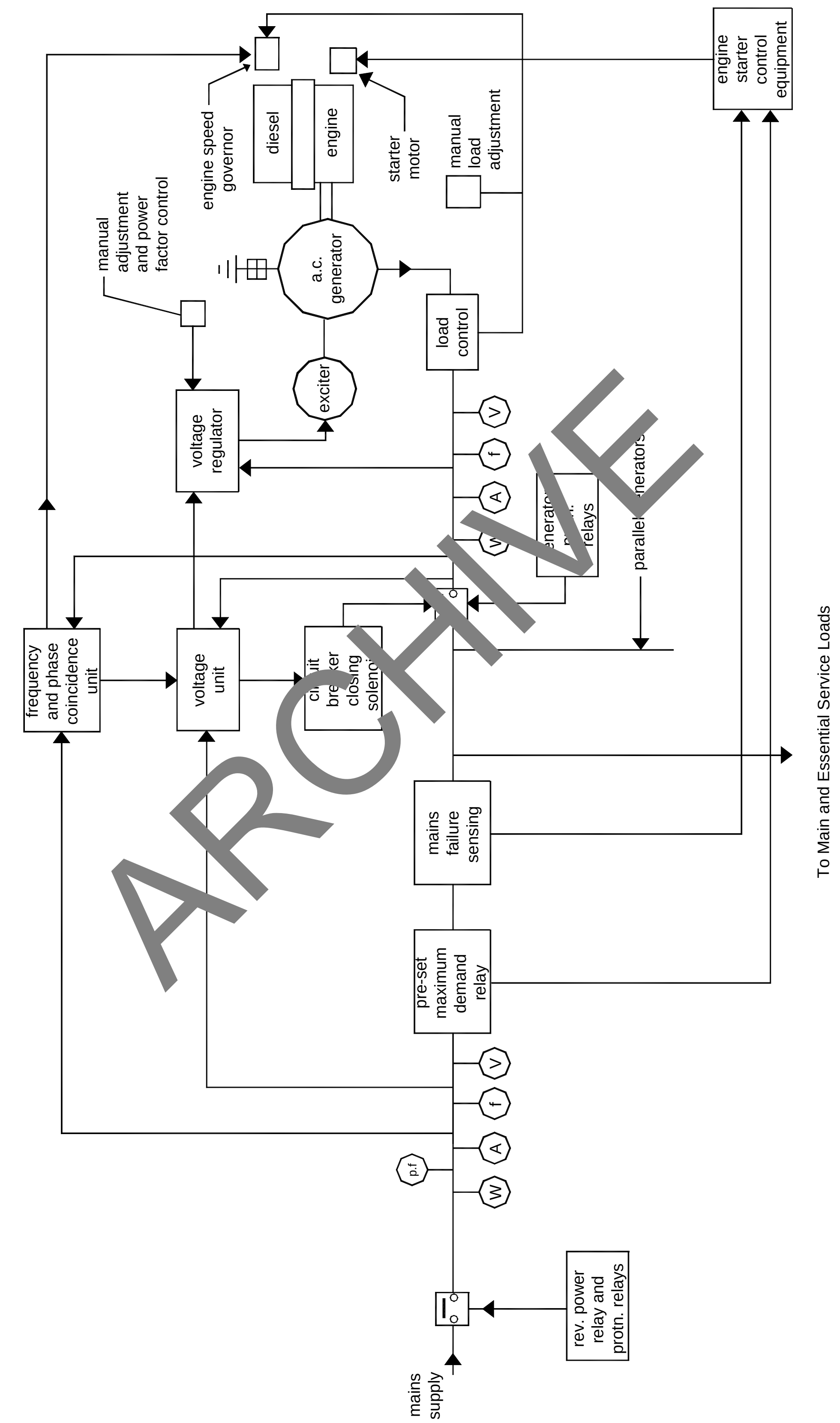


Figure 14: Arrangement for a large hospital where some of the electrical power is generated at 11000 volts

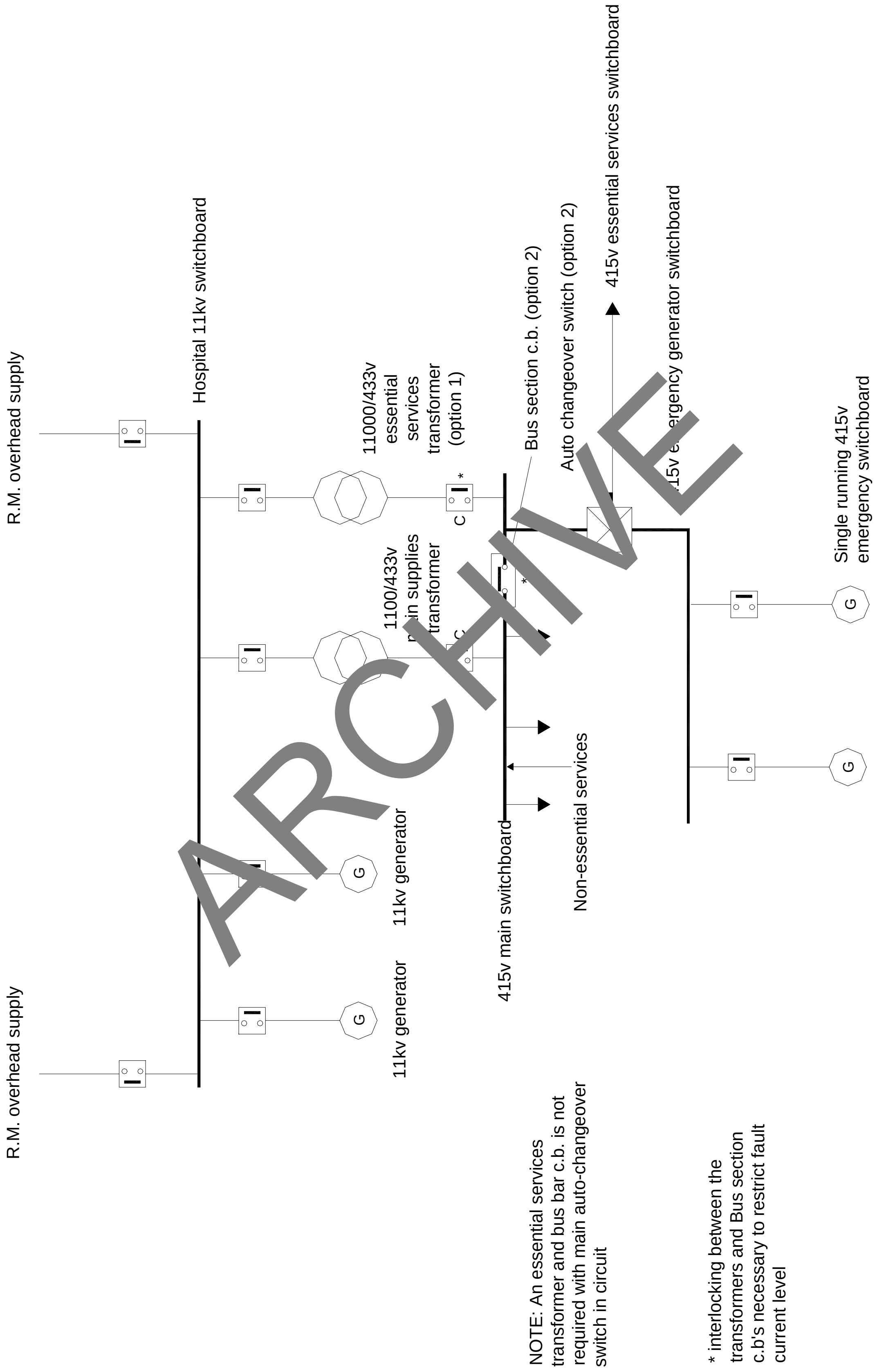
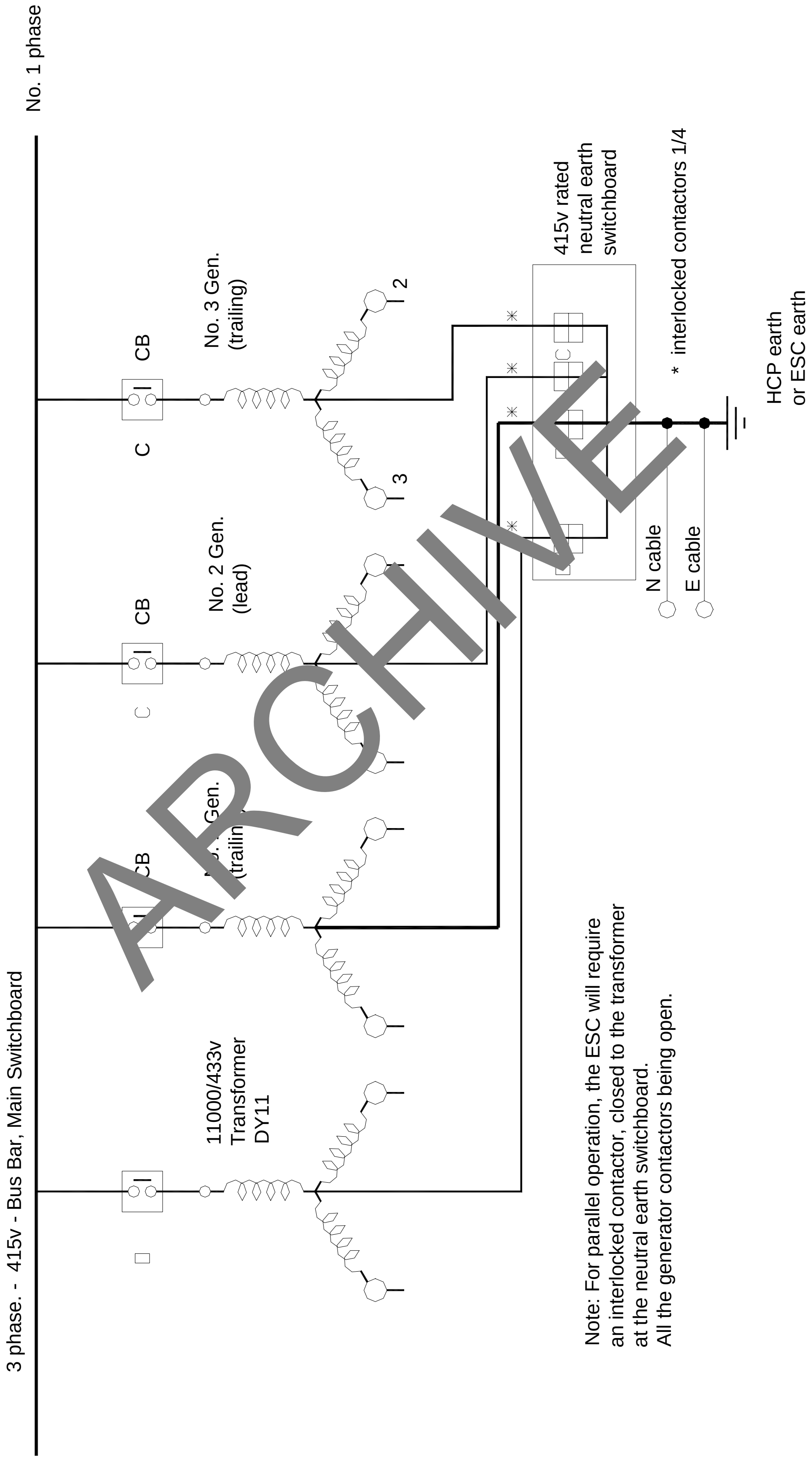


Figure 15: Typical arrangement showing No.2 generator solid earth connection (ITN-S) at the neutral earth switchboard for island operation



3. Lighting and power supplies

Emergency services – lighting requirements

General

3.1 There are two main categories of emergency lighting, “escape” and “standby” as defined in BS 5266, Part 1, 1988 ‘Emergency lighting’. Standby lighting is further subdivided into two grades, (a) and (b) – see also paragraph 3.11. Refer to Schedule, item 4 and Chartered Institution of Building Services Engineers (CIBSE) – ‘Lighting Guide for Hospitals and Health Care Buildings’ and/or ‘NHS in Scotland Firecode’ for hospital requirements as applicable.

3.2 In hospital design the emergency lighting requirements vary considerably from those of older health care and social services premises. This is a result of the building design incorporating discrete fire-resisting standard containment areas, more natural light into the building and the layout of main street escape routes. Agreement and guidance of the local fire authority should be obtained during the planning and installation phases of construction.

Escape lighting

3.3 The escape luminaires can be of either the maintained or non-maintained variety. They can be powered by a suitable battery supply connected by auto-changeover switch or they can be adequate self-contained luminaires. In less hazardous locations standby luminaires are permitted when supplied within 15 seconds by the emergency generator.

3.4 Escape lighting is required to define easy to follow exit paths, especially in premises of old, labyrinth-type design and those with satellite buildings with complicated exit paths. Requirements for lighting are as follows:

a. at each exit door;

b. within 2m of each change of direction and each intersection of corridors;

c. within 2m of each staircase, giving direct light on each flight;

d. within 2m of any other change of floor level, for example a dais;

e. outside, and close to, each final exit;

f. within 2m of all fire alarm call points and extinguishers;

g. to illuminate all exit and safety signs;

h. floor level lighting in smoke stagnant spaces;

i. fluorescent floor markers.

3.5 Lighting should give a positive indication of escape routes to the outside of the premises and all illuminated signs giving such direction should be adequately lit. Light indicating an escape route should originate from more than one emergency luminaire.

3.6 After determination of the premises' exit locations, the positions of intermediate luminaires will depend upon the floor to ceiling available height, obstructions, the spacing factor of luminaires and the need for a minimum illumination of 0.2 lux at the centre line at floor level. Fifty per cent of the floor area for all escape routes, up to a width of 2 m, should be illuminated at 0.1 lux minimum

3.7 In general the higher the intensity of normal illumination, the higher should be the level of escape route illumination.

3.8 Escape signs should conform to BS 5378, Part 1: 1980, 'Safety signs and colours', BS 5499, Part 1: 1990, 'The Health and Safety (Safety Signs and Signals) Regulations' 1996.

3.9 Luminaires and wiring used in defined escape routes must comply with the non-flammability requirements of BS 4533: Section 102.22, 1990, 'Luminaires for emergency lighting', and BS 5266, and BS 6387: 1994.

Standby lighting

3.10 Standby lighting energised from the essential services supply is provided to enable normal activities to continue during loss of normal lighting supply. In critical work areas such as operating theatres, delivery rooms and high dependency units the quality and intensity of standby lighting should be equal or nearly equal in illuminance to that of the normal lighting at the task points. General standby lighting in the surrounding areas may be reduced if considered acceptable.

3.11 Two grades of standby lighting are recommended, as defined in the CIBSE Lighting Guide – 'Hospitals and Health Care Buildings' and BS 5266, Part 1, 'Emergency Lighting':

a. Grade (a) – lighting of intensity and quality equal or nearly equal to that provided by the normal lighting;
b. Grade (b) – a reduced standard of lighting, about one third to one half of normal lighting intensity, sufficient to enable general health care and social services premises activities to continue.

Typical standby lighting

3.12 The schedule opposite is intended as a general guide to typical grades of standby lighting requirements. Reference should be made to the Chartered Institution of Building Service Engineers' 'Lighting Guide for Hospitals and Health Care Buildings' and 'Lighting for Communal Residential buildings', LG9 for more specific design details.

Schedule 1. Typical grades of standby lighting in departments/ locations

Department or location	Area	Grade of lighting
Operating department	critical working areas	grade (a)
	general working areas	grade (b)
Maternity department	critical working areas	grade (a)
	general working areas	grade (b)
Accident and emergency department	critical working areas	grade (a)
	general working areas	grade (b)
Administrative department	general working areas	grade (b)
Out-patient department and special treatment clinic	critical working areas	grade (a)
	general working areas	grade (b)
Dispensary	dispensing areas	grade (a)
Patient care areas	general working areas	grade (a)
Bed areas in wards, etc	general working areas	grade (b)
Treatment rooms	general working areas	grade (a)
Drug stores and DDA cupboards	general working areas	grade (a)
Kitchen	general working areas	grade (b)
Psychiatric department treatment areas	critical working areas	grade (a)
	general working areas	grade (b)
Pathology department	essential working areas	grade (a)
	general working areas	grade (b)
Rehabilitation department	treatment and general areas	grade (b)
Diagnostic X-ray department	critical working areas	grade (a)
Radiotherapy department	critical working areas	grade (a)
	general working areas	grade (b)
Mortuary and post mortem room	general working areas	grade (b)
Kitchens and dining rooms	general working areas	grade (b)
Lifts, landings and lobbies		grade (b)
Laundries	general working areas	grade (b)
Sterile supplies	general working areas	grade (b)
Boiler house and plant rooms	working areas	grade (b)
Generator room		grade (a)

Arrangements of emergency lighting circuits and luminaires

Standby lighting circuits

3.13 Where maximum standby lighting (grade (a)) is required under emergency conditions, all circuits should be connected to the essential services supply.

3.14 In areas where a reduced intensity of standby illumination is acceptable (grade (b)), selected circuits only should be connected to the essential supply.

3.15 Where continuous or task lighting is required in dark, unsafe or emergency working areas, maintained emergency luminaires should be provided. These should be of adequate luminosity to bridge extended blackouts or losses in illumination due to delays in the stationary emergency generator starting, for example inside the diesel generator room, switch room, kitchens, plant rooms or operating theatres. Non-maintained emergency luminaires may be used in areas falling outside these safety or emergency working categories.

3.16 Where economically viable the essential and normal mixed small power and lighting in each area should be energised by cable having segregated supply routes to safeguard against total loss of lighting supply.

Escape lighting circuits

3.17 Definitions are given in paragraph 2.55.

3.18 All escape luminaires, except self-contained luminaires, should be energised by segregated and dedicated fire resistant emergency circuits. The wiring circuits should be routed to avoid, where possible, passing through areas of high fire risk or high fire loading. These escape luminaires should be controlled by an automatic changeover switch, jointly supplied as slave maintained lighting, or supplied only as slave non-maintained lighting from either the essential services supply or a battery source. The response time should be to operate immediately from a battery or within 15 seconds from an emergency generator, subject to the agreement of the local fire authority. Item 3.3 refers.

Battery operated escape lighting

3.19 A storage battery should be of suitable rating and capacity to supply the total load energy to the circuits supplying emergency escape lighting for a period of three hours, as required in BS 5266, Part 1, 1988, ‘Emergency Lighting’. However, a period of one hour applies if emergency power generated lighting is also provided in areas occupied by only ambulant patients, staff or public within the maximum 15 second delay requirement.

3.20 Provision of a 24V low capacity battery of at least one hour duration is required as an emergency alternative supply for main and satellite operating theatre table luminaires used in all forms of acute surgery. Figure 4 shows a typical circuit. Fully charged battery powered hand torches should always be available.

3.21 The general lighting in an operating department should be connected to the essential services supply.

3.22 BS 5266, Part 1, 1988 gives guidance on the choice of capacity for battery power packs.

3.23 In health care and social services premises where the AC emergency generator sets are also used for combined heat and power functions, connection of escape lighting to a segregated three-hour battery supply by operation of an auto-changeover switch is recommended.

Luminaires

3.24 Self-contained emergency luminaires fed from the normal services lighting supply may be used in all areas.

3.25 Self-contained emergency luminaires are available in maintained and non-maintained versions as escape lighting and escape lighting exit signs with battery packs of one hour or three hours' duration.

3.26 Voltages to emergency luminaires vary from 24V, 50V, 110V and 240V with output ranges of 4 watts, 8 watts and 16 watts for fluorescent lamps and 8 watts, 15 watts and up to 100 watts for incandescent tungsten lamps.

3.27 High frequency fluorescent self-contained surface luminaires have been introduced for maintained use. These have one- or three- hour batteries with inverters to provide the HF/AC supply on loss of normal supply. They operate at one-third to one-half illumination level when in the battery mode, and may be connected to the normal supply as a switchable supply in working areas acceptable for energy economies.

Emergency services – Power equipment requirements

Socket-outlets

3.28 As a general guide, in any area where standby lighting is provided to enable normal activities to be carried out during loss of normal supply, all power socket-outlets conforming to BS 1362 or IEC harmonised standards should be connected to the essential/unified circuit supply. This arrangement is recommended to simplify and standardise the electrical installation and choice of socket-outlet positions on the walls. Only essential equipment required at the time should be plugged into socket-outlets connected to essential supply circuits or remain in service during periods when only the emergency AC generators are providing the power supply to the premises.

3.29 Essential supply socket-outlets are recommended to be labelled differently from those connected to segregated or unified non-essential supplies.

Special sockets or locations

3.30 In locations where an assembly of related low powered life-support equipments are in regular use, dedicated essential supply or no-break supply ring or radial main multi-socket arrangements should be provided for each assembly. The installation must conform BS 7671: Requirements for electrical installations – IEE Wiring Regulations, Sixteenth Edition, as a TN-S system or, in special intercardiac or wet areas, as an IT system. (IEC 364-7-710 refers.)

3.31 Where standby lighting is provided for the well-being and/or security of patients, such as in long stay, geriatric or psychiatric health care and social services premises, socket-outlets should only be connected to the essential supply where the socket-outlets are required to supply essential equipment.

Sterilizing equipment

3.32 Electrical services, including alarms, automatic controls and ancillary circuits essential for the safe operation of sterilizing equipment should be connected to the essential supply.

Dirty utility rooms

3.33 An essential power supply should be provided for bedpan washers and macerating machines.

Patient care and life-support equipment

3.34 All special patient care and patient monitoring equipment should be supplied from the essential supply and given first priority in the event of loss of normal supply. In specifically designated areas where life-support power equipment is in use the need for uninterruptible power supplies (UPS) with at least a one hour duration battery and electronic and/or manual bypass switch should be considered. The UPS input should be connected to the essential supply circuit. (See paragraphs 3.68-3.89.)

Blood banks etc.

3.35 Blood banks and other clinical refrigeration equipment are sufficiently thermally insulated to retain low preserving temperatures for several hours. As a precaution it is recommended to supply this type of equipment from the essential supplies. Where haematology analysis is conducted it may be necessary to provide a small UPS with battery support to prevent damage to tests in progress during the change over from normal to emergency AC generator supply.

Deep-freeze refrigerators and food stores

3.36 These refrigerators will normally operate within a range of minus 12°C to minus 23°C and be fitted with a temperature alarm to give warning when the refrigerator temperature approaches the upper safety limit. As the electrical loading is comparatively small they may be supplied from essential circuits as a safeguard against prolonged supply interruptions.

Ward kitchens

3.37 Refrigerators in food preparation rooms, special care baby units and children's wards should be supplied from essential circuits. Heat regeneration trolleys for cook-chill foods should have the essential power demand controlled to prevent sudden overloading of the emergency generators.

Cold stores

3.38 These usually operate within a temperature range of 0°C to minus 2°C and are normally provided with sufficient insulation to prevent undue rise in temperature during power failure. It may, however, be desirable to have an alternative supply from the emergency plant available where this can be conveniently arranged.

Post mortem room

3.39 Refrigerating plant for body chambers should be supplied from an essential circuit.

Kitchens

3.40 The use of essential electricity supplies will not normally be justified for electric cooking. Where the main kitchen equipment is electrically heated it may be considered advisable to provide alternative non-electric heating facilities as a safeguard.

Boiler plant

3.41 Essential supplies should be restricted to those items of auxiliary plant that are necessary to enable the plant with its associated alarms, safety controls and ancillary circuits to continue to provide its primary heating function in the event of loss of normal supply. The essential auxiliaries include the following:

a. mechanical coal stokers or oil burner pressure pumps;

b. oil storage tank and fuel pipework trace heating;

c. forced and induced draught fans and other mechanical ventilation equipment necessary for safe boiler operation;

d. boiler feed pump and condensate pump;

e. heating and flue gas control circuits and/or air compressors;

f. circulating water pumps for space heating and hot water services;

g. heat exchanger stations.

Diagnostic X-ray machines

3.42 Where X-ray apparatus is used in diagnostic rooms at least one room must be supplied from the essential circuits. Socket-outlets on essential circuits should be provided to permit long duration clinical procedures on a patient connected to a life-support machine to continue. The X-ray machine may be required to monitor clinical progress, but should not be used for high power film work.

Ventilation

3.43 Essential supply facilities should be provided for ventilation plant where mechanical ventilation is required for clinical reasons.

Central piped medical gases

3.44 This section includes medical compressed air and medical vacuum installations (see also Scottish Health Technical Memorandum 2022; *Medical gas pipeline systems*). The associated electrical services of piped medical gases, including any safety controls and ancillary circuits, should be connected to essential circuit supplies. Alarms should have a no-break battery supply. It is desirable that the motor compressor installation should have an auto-start selection mode of pressure control for motor contactor operation to ensure re-starting of motors after operation of the changeover switch. The provision of a time-delayed auto-start mode of control will require a local/remote/auto control selector switch mounted on the starter panel. The stop push button located at the motor should be of the shrouded type to prevent inadvertent operation.

Water supplies

3.45 Where electric motor driven pumps are used to maintain essential water supplies it is necessary to provide suitable time delayed auto-start control arrangements for the pump electric motors to be reconnected to the essential circuit supplies.

3.46 Essential services equipment should not be dependent on cooling water directly from the mains water supply.

Essential supporting services

3.47 Central supporting services, such as laundries and food preparation cook-chill facilities that operate on a 24-hour a day basis, should be able to maintain an essential service. These services should be provided with 100% emergency AC generator set capacity to replace total loss of normal power supply for an extended period.

Sewage disposal

3.48 Where sewage does not directly flow into the municipal sewerage system, but is processed partially or wholly at a health care and social services premises sewage farm, the installation should be protected with an alternative essential services supply.

Lifts

3.49 Where lifts are provided for the movement of patients, it is recommended that at least one lift of orthopaedic bed capacity is installed in each section of the hospital. All such lifts should be connected directly to the essential services supply.

3.50 The ability of the generator, essential services system and electronic control circuitry to withstand harmonic or transient voltage effects injected by the lift motor should be established.

3.51 Emergency self-contained luminaires, of minimum 1 watt rating, should be provided in all lift cars. The illumination should be adequate to alleviate distress in passengers.

Telephone exchanges, communications, security equipment and fire alarms

3.52 The following battery chargers and equipment should be supplied by a switchboard or distribution board energised directly from the essential services supply:

a. telephone exchanges;

b. communication systems used for direction and control during external and hospital emergencies;

c. security equipment for safety of personnel and protection of property;

d. fire alarm equipment.

Nurse call and staff call equipment

3.53 The electrical load for this equipment is very small and there is no reason why it may not be connected directly to the essential services supply.

Computer systems and data communications equipment

3.54 Computer supply systems should be no-break and should ensure an interference-free input voltage.

3.55 Ventilation equipment supplied from the essential services supply should be provided for all computer equipment suites. A high degree of filtration of the admitted air together with close limits on humidity and temperature control must be provided.

3.56 Inlet and outlet ventilation ductwork to computer equipment suites must be protected by auto-close fire dampers controlled by smoke- and heat-sensitive detectors.

3.57 Electrical services supplying computer suite ventilation equipment and luminaires should be provided with a means of shutdown isolation at the main point of exit from the computer suite.

3.58 An alarm panel should be provided to monitor UPS and ventilation control excursions.

Segregation of essential and non-essential circuits

Fire and segregation

3.59 Where the same cable route is used for essential and non-essential circuits in an installation, all possible efforts should be taken to provide cable segregation and to reduce the possibility of a single cable fault damaging both circuit cables.

3.60 In essential circuits, flexible fire-resistant cables tested to BS 6387 may be used where essential and non-essential cable circuits cannot be segregated in ductwork or on traywork.

3.61 In important areas where there are a large number of essential sub-circuits, separate traywork should be used for the routing of essential and non-essential circuit cables.

3.62 Mineral insulated metal sheathed (MIMS) cable or any fire-resistant cable conforming to the category B test requirements of BS 6387, 'Performance Requirements of Cables Required to Maintain Circuit Integrity Under Fire Conditions' should be used for all escape lighting and fire alarm control circuits required to function under fire conditions. (See the NHS in Scotland Firecode suite of documents.)

3.63 Complete segregation of category 3 escape lighting cable and fire protection wiring routes is required. IEE Regulations refer.

3.64 MIMS cable should not be routed on equipment subject to continuous vibration such as on engines or transformers, as vibration may cause cracking of the metal sheath. Where MIMS is installed, the sheath materials are usually copper, but stainless steel may be used if preferred.

Marking of essential circuits

3.65 Switchboards and distribution boards that marshal essential circuits should be clearly and indelibly marked to indicate their function. Switching devices and circuit equipment connected by the same cable should be identically labelled for function and plant item number.

3.66 All cables should be numbered and labelled at both the far and near ends adjacent to the terminating glands with the cable number corresponding to the entry in the cable schedule.

3.67 It is recommended that BS 1710, 1984, ‘Identification of Pipelines’ is used as the guiding colour code for identification of plant pipework and cables. The recommended colour for electrical services is light orange. It is also recommended that a “red on light orange” be used to indicate essential circuits and installations. For example, a red spot on a light orange background for switchboards and distribution boards and a red band on a light orange band for conduit and trunking that contain only essential supply circuits.

Uninterruptible power supplies

General

3.68 Uninterruptible power supplies (UPS) may be required to provide a no-break single or three-phase supply to specific equipment during the period of blackout, from the loss of normal supply to the start-up and subsequent electrical power generation of the emergency generator. Without UPS even very short power breaks may cause loss or corruption of data in computer systems, laboratory tests may be jeopardised and the well-being of patients undergoing intensive care or surgical treatment may be threatened. A “UPS” to supply computer equipment can sometimes be justified on the grounds that it will also provide a stable and transient-free input voltage.

3.69 All specialised types of electronic equipment without or with less than substantial internal battery support and requiring a no-break supply should be supplied by a UPS. The UPS should be either from a permanent central source or from a portable desk top or side unit. The UPS units should preferably be rated for maximum power factor and provide output power as specified by the electrical/electronic equipment manufacturer. They should also ensure that non-linear load peak currents can be suitably absorbed without equipment stress.

3.70 A support battery of at least one hour full load capacity with an electronic and/or manual bypass switch should be provided. The choice of bypass switch depends on the level of service required by medical or computer staff. The UPS should be connected to the essential services supply.

3.71 The capacity of a UPS battery for a computer installation may sometimes be based on the relatively short period between mains failure and the provision of a satisfactory supply from a standby generator. In practice many large computers will only function for a brief period without air conditioning, that is, a load which must be supplied from an emergency generator in the event of mains failure. If the generator fails to start, the UPS battery merely provides a supply for the orderly shut down of the computer.

Combined heat and power and uninterruptible power supply

3.72 In some health care and social services premises electrical power is generated by a combined heat and power (CHP) system provided by retro-fitted emergency generators. Where this represents a large part of the total energy requirement, a UPS should be utilised to provide a no-break supply for grade (a) standby lighting and life support equipment in the event of CHP breakdown.

3.73 UPS should be considered as a source of supply to overlap any short or unexpected long periods of emergency generation (see Figure 1).

Types of uninterrupted power supply

3.74 UPS comprises two basic types: battery connected static inverters and rotary motor-generator assemblies. Neither are cheap installations. Overall efficiencies vary from 70% to 90%. The rotary type is the more expensive, but becomes competitive with the static type in large central data processing systems above 200kVA rating.

3.75 A typical static inverter UPS (see Figure 2) may consist of:

a. single conversion – a constant voltage, line filtering ferroresonant transformer supplied through a solid state switch and connected directly to the load. The transformer is in parallel with a battery charger, floating battery and inverter. On mains power failure the solid-state switch opens. This permits the battery to supply the load via the DC/AC inverter through the ferroresonant transformer;

b. double conversion on-line – an input rectifier battery charger connecting to both a battery of suitable capacity on float charge and a DC/AC output inverter. A no-break supply.

To permit maintenance, or in the event of a complete UPS failure, the whole UPS should be bypassed by an isolating transformer in series with a solid-state bypass switch or a mechanically operated overall bypass switch fed from another point of essential services supply.

A further safeguard would be to have a second 100% rated UPS as passive standby or sharing load in parallel, with an auto isolating switch, in the event of failure of the duty UPS.

3.76 A typical rotary UPS consists of:

a. an input rectifier with a floating battery supplying a DC motor/AC generator set. The DC motor speed is regulated by a time clock controller, comparing the supply and generator frequencies to give a constant output frequency and a no-break supply;

b. a universal AC machine, operating in parallel with the normal supply, drives a combination flywheel/induction motor which augments the flywheel speed to almost twice synchronous speed. On loss of normal supply, the high speed flywheel magnetically slips, maintaining a constant speed torque to the universal AC machine now driven as a generator, to provide the initial supply. A diesel engine concurrently runs up to speed and magnetically couples to the flywheel to drive the universal AC machine at constant speed as an emergency generator to replace the normal supply.

Noise

3.77 The location of highly rated UPS equipment should be carefully selected, as the audible noise level increases as the transistor/thyristor switching speed is reduced with increased rating. The noise distribution curve in decibels should be obtained from the manufacturer. Typical switching speeds of 15 to 20kHz give noise levels of the order of 52dBA for ratings of 3 to 20kVA. At 2kHz, a noise level of 60dBA for ratings up to 80VA should be expected. Reference should be made to 'The Noise at Work Regulations 1989', and HSE Guides.

Waveform

3.78 Present designs of static double conversion UPS use pulse width modulation (PWM) inverters. This type of inverter shapes an approximate sine wave from DC square wave impulses by variation of the impulse width. The impulses are generated at high frequency for minimal harmonic distortion, which contributes to the reduction of the capacity of inverter output filters. The overall size of the UPS is reduced with PWM as no large transformers are involved. Ferroresonant transformers are used in single conversion UPS. These give improved voltage regulation and line filtering with increased efficiency but are limited for ratings up to 240V, 20kVA.

3.79 In comparison with the above, the rotary UPS AC output generator produces an almost pure sine wave for the largest rating required.

3.80 Load-generated voltage distortion can be reduced by providing low-pass filter traps at the inverter output terminals. This filters harmonics from the voltage output waveform and helps to reduce any over-rating of the UPS required to match the load.

3.81 The load characteristics of electronic equipment such as computers tend to be non-linear and, as a result, it may be that the UPS required will be almost twice the kVA rating that would be expected from a linear load. The UPS manufacturer should analyse the equipment load waveform crest factor and harmonic distortion to determine the correct UPS rating.

3.82 Methods of earth connection at the UPS output side may differ to suit the load. This difference may be required to avoid mains-borne interference and transients, or, for example, for safety reasons in Medical Locations Group 2 where intercardiac surgery may be used. SHTM 2007 refers.

Harmonic distortion in uninterrupted power supplies and generators

3.83 Emergency generator output can suffer harmonic voltage distortion as a result of non-linear loads injected into the supply by the rectifiers in UPS and battery charger systems. Typical UPS values are third harmonic at 40%, fifth harmonic at 30% and seventh harmonic at 7%, all relative to the fundamental voltage. The effect of this harmonic voltage may be reduced by filters at the input terminals, provided by the inverter manufacturer. Guidance on the level of harmonic injection at the normal supply point of common coupling is given in Electricity Association Engineering Recommendation G5/3 (1976),' Limits of Harmonics in the UK Electricity Supply System'.

3.84 The generator winding reactance combined with each rectifier-generated harmonic current produces distortion of the generated voltage fundamental 50Hz waveform. It is recommended that total non-linear rectifier loads should not exceed 40% of the generator rating.

3.85 Non-linear voltages also affect the operation of AVRs, the indicated values of metering and the accuracy of speed measuring devices owing to the divergence from standard voltage form factors. It follows that, where installations have such non-linear loads, the following considerations should be made:

a. the rectifier UPS may need a larger rating than apparent to supply the non-linear load and may need to be provided with frequency discrimination in the event of generator instability;

b. the generator rating may need to be increased owing to various rectifier-generated harmonic current heat losses within the generator windings. This is in addition to any extra rating required owing to motor starting currents;

c. the engine rating may need to be adjusted to suit the generator non-linear and dynamic start load current demanded, this being influenced by the engine load acceptance category.

Protection of uninterrupted power supplies

3.86 The maximum energy that can be passed by a static PWM inverter UPS is 150% for one minute in the event of an overload, or a low impedance load fault, limited to a fuse clearance of 10 milliseconds without resorting to the AC static bypass switch. Where large capacitive filters are included in the inverter output circuit, the additional capacitance in these filters may be sufficient to assist the load short-circuit current for a period long enough to clear a suitably rated fast acting fuse or miniature circuit breaker. The high impedance electronic devices used in PWM designs with minimal output filters may not be of sufficient capacitance to operate the overcurrent protection devices in the faulty load circuit. Ferroresonant transformer UPS are normally current-limited to an overload capacity of 150% for 10 minutes.

3.87 A three-phase output UPS should be able to cope with 100% unbalanced loads on each phase, while still providing a closely regulated output voltage and phase control.

3.88 In high impedance UPS outputs, voltage or current sensitive inverter protection should be considered. This can also be designed to synchronise the inverter output voltage with the supply voltage, then autoclosing the solid-state bypass switch into circuit with the load. The low impedance normal power supply will assist the load circuit protective devices. It is essential that suitable primary protection is installed on the supply side and graded to the load circuit.

Installation

3.89 The range of UPS available is extensive and spans desk top installations to large, single room assemblies. Where large installations are required, the best location is separate from, but near to, the data equipment and in the central area of a building. Owing to the concentration of equipment such as batteries and transformers, structural design must consider the extra floor loading, space for extra air-conditioning cooling and cableworks, and the lifting, access and possible removal of large equipment cubicles during and after constructions.

4. Engines

Emergency supply equipment

General

4.1 The emergency supply required will be AC, with the same number of phases, rated voltage and frequency as the normal supply. In general, an engine-driven 415V, three-phase 50Hz AC generator set will be the most convenient and economical means of providing an emergency supply for the load demands of health care and social services premises.

4.2 The engine-driven generator set for the supply of essential circuit power and lighting is normally mounted on a permanent bed plate. It is designed for automatic starting in the event of a prolonged fall in normal supply voltage. A short delay of between 0.5 to 6 seconds is normally chosen at the voltage detector device to discriminate against a fall in normal voltage due to a voltage transient or auto reclose switching operation. When the chosen time delay confirms the loss of normal supply voltage the engine start is initiated. A time delay of up to 15 seconds is allowed in BS 5266 between loss of normal supply and connection of the emergency generator to the essential services supply circuits. The AC emergency generator circuit-breaker should close when the generated voltage and frequency are at 95% of nominal values and before the auto-changeover load switch operates.

Diesel engines

4.3 Generating sets of various rating are available designed for the generation of AC emergency electrical power. The choice of prime mover is usually the diesel engine, as it has a more rapid response time for load acceptance from a cold start (see paragraph 4.45).

4.4 The difference between makes of generator set can be arbitrary in performance and cost. Most set manufacturers can provide a specific make and design of engine to drive an AC generator at the request of the purchaser. Two basic types of diesel engine are available: truck and industrial. Owing to differing applications, the truck engine does not have the same proven long term life or reliability as the industrial engine, but it will normally be cheaper. Care must be taken when evaluating tenders.

Gas engines

4.5 The main alternative choice of prime mover is the gas engine supplied from the gas mains. It is basically a modified and derated diesel engine with spark ignition and carburettor control. For a given rating it is bulkier than a diesel engine (see paragraph 4.31).

Gas turbines

4.6 Gas turbines are available over a wide range of ratings for the generation of electrical power. However, even at the smallest rating of 500kW, health care and social services premises essential electrical loads are not likely to be sufficient to justify the cost of installation.

4.7 Their main disadvantage is the time of one to two minutes required to reach full speed and the lack of ability then to accept large step loads up to full load when cold.

Combined heat and power

4.8 Since the 1983 Energy Act there has been an upsurge in the use of combined heat and power (CHP) systems for efficient fuel utilisation and economy (see Appendix).

4.9 With CHP a wider application of electrical generating plant in health care and social services premises is possible. AC generator sets may be installed not only to supply emergency power, but also as an in-house electrical base load generator. This can result in a considerable reduction in the cost of electricity from the Public electricity supply company and directly provides heat for steam and hot water production, in place of oil/gas/coal fired steam boilers. This utilisation of almost total heat in the fuel oil gives overall efficiencies of up to 90%, compared with efficiencies of 30% for solely electricity generation. For CHP to be economically viable it must operate at high load factors, ideally over 80%, but it is economic for load factors down to 50%. Below the 50% level the savings obtained from steam/water heating do not justify the extra investment for heat exchange equipment.

4.10 The direct involvement of AC emergency generators in CHP schemes requires considerable equipment retrofit and a change in the philosophy originally accepted for operation in the passive emergency role. A large increase in planned maintenance and operating supervision on engine plant required to operate over say 6000 hours per year instead of 50 hours a year must be expected. In the role as an AC emergency generator set, only limited essential overhaul work is required, but in the role as a base load generator, a long overhaul will become a summer event every second year, particularly with ageing plant. To offset the planned outage of plant, there will be a need for extra or replacement plant, not only to maintain routine supply but also in the event of an engine breakdown during an emergency.

4.11 When generators are run together in parallel or in synchronism with the Public electricity supply company supply, more rigorous attention to prospective fault current capacity and the stability of both the health care and social services premises and Public electricity supply company systems must be given.

4.12 The advice of the Public electricity supply company must be obtained when CHP or peak lopping operation with parallel generators is planned.