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BUREAU OF INDIAN STANDARDS

Doc. No. : PRTD/AR/**PF:03**	Issue No. : 2	Issue Date 30 Sept. 2020	**Report of Action Research**

1.	**Action Research Project No.**	AR/0057
2.	**Title of Action Research Project**	To study the special requirements of Electrical installations in Medical Locations (hospitals)in order to provide inputs/working draft for revision of National Electrical Code (NEC).
3.	**Name & Designation of Officer**	Ritwik Anand, Scientist- D
4.	**Employee No.**	65158
5.	**Deptt./BO/RO & Place of Posting**	ETD, BIS HQ
6.	**Date of Approval of the Project**	12 June 2020
7.	**Objective of the Project**	National Electric Code (NEC),2011 is a special publication of BIS which covers the requirements relating to electrical installations in specific occupancies. It provides assistance on economic selection, installation and maintenance of electrical equipment employed in the usage of electrical energy. Over the years, there have been numerous developments in the technology; new practices are being evolved. The task for revision of NEC has been taken up by the Electrical Installations Sectional Committee ETD 20 and new drafts for accommodating the latest practices under various parts of NEC are being prepared. One of the important subject of NEC for which working drafts are developed as a part of this project is , Electrical Installations in various Non-industrial buildings such as Hospitals. The objective of this project is to study the latest technological advancements and regulatory practices on the above mentioned subject and develop working drafts, which will act as pre-standardization report for revision of NEC.
8.	**Report of Action Research Activities**	Please see report enclosed.
9.	**Conclusion & Recommendations**	Please see report enclosed.
10.	**Any other information relevant to the Project**	The project helped in preparation of National Standard on Safety of Electrical Installations at Medical Locations enhanced the safety of Electrical Installations and as well as, help to reduce the causalities due to fire accidents.

(Ritwik Anand)
Scientist-D, ETD

FOREWORD

Safety and reliability of electrical networks in any building is vital. But in case of hospitals, it is even more critical. While most commercial facilities witness less or no human activity after closing hours, hospitals are bustling with people and activity 24X7. Even so, high-power medical machinery entail the need for uninterrupted high-voltage power at hospitals. To add to this, hospitals are home to patients undergoing treatments for critical ailments. In case of electrical fire accident, moving these patients becomes a formidable challenge. All these factors cumulatively make hospitals the most vulnerable place for electrical accidents which may prove fatal if not addressed in a right way at right time.

Thousands of people die every year in India due to electrical accidents. Millions worth property is damaged due to fire. Data reveals that 42 % of fire in buildings are due to electrical short circuit & approximately 5000 deaths are due to electrical reasons. Majority of electrical accidents such as fire happen in LV system. 1000's of crores of rupee worth property damages and losses happen due to electrical accidents.

Good quality electrical installation shall not create an accident such as electrocution, fire and shall offer trouble free long life for the connected equipment. With increasing accidents happening due to careless handling of electrical and wiring equipment, it has become even more important to have an elaborate code of practice.

The objective of this project is to study the latest technological advancements and regulatory practices on the above mentioned subject and develop working drafts, which will act as pre-standardization report for revision of NEC.

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1. SCOPE

Hospitals in the country vary in size from simple premises used for medical purposes in villages to a well-equipped, multidisciplinary hospital in big cities. The lattser type will have several units functioning simultaneously with a variety of support services to cater to the needs of doctors and patients. Safety requirements for electrical equipment used in medical practice are covered IS 13450 series. Additional safety provisions in the electrical installations of medically used rooms and medical establishments are covered in this report.

Power hungry electrical equipment such as, CT Scanners, MRI and X-Ray machines, Ventilators and other medical devices used in hospitals, need uninterrupted power supply. A durable cable network is thus absolutely essential to carry this power supply without overheating. However, *hospitals in India are inclined to use low grade conductor wires in order to save costs, which results in overheating.* To add to this, PVC insulation used in cables creates a lot of smoke in case of a fire incident. Statistics show that more people die due to smoke than due to actual fire in a fire incident. The ventilation system in a hospital also has a role to play in this scenario. If the hospital is air-conditioned, efficient mechanical ventilation system must be installed to stop electrical fires from spreading.

The scope of this project is to study the latest technological advancements and regulatory practices on the above mentioned subject and develop working draft, which will act as pre-standardization report for revision of NEC

2. INTRODUCTION

Safety and reliability of electrical networks in any building is vital. But in case of hospitals, it is even more critical. While most commercial facilities witness less or no human activity after closing hours, hospitals are bustling with people and activity 24X7. Even so, high-power medical machinery entail the need for uninterrupted high-voltage power at hospitals. To add to this, hospitals are home to patients undergoing treatments for critical ailments. In case of electrical fire accident, moving these patients becomes a formidable challenge. All these factors cumulatively make hospitals the most vulnerable place for electrical accidents which may prove fatal if not addressed in a right way at right time.

In medical locations stringent measures are necessary to ensure the safety of patients likely to be subjected to the application of medical electrical equipment. Shock hazards due to bodily contact with the 50 Hz mains supply are well known and documented. Currents of the order of 10 mA passing through the human body can result in muscular paralysis followed by respiratory paralysis depending on skin resistances, type of contact, environmental conditions and duration. Eventual ventricular fibrillation can occur at currents just exceeding 20 mA. These findings are listed in IEC/ TR2 60479-1 Effects of current on human beings and livestock – General aspects. The natural protection of the human body is considerably reduced when certain clinical procedures are being performed on it. For example, patients undergoing treatment may have their skin resistance broken or their defensive capacity either reduced by medication or nullified while anaesthetized. These conditions increase the possible consequences of a shock under fault conditions.

Electrical safety in Hospitals – WHY ITS SPECIAL

- Electrical & Electronic systems design in health care facility is an extraordinary challenge. Required technical knowledge exceeds typical residential and industrial construction.
- Eg Patients may be undergoing surgery and in life support systems. Any break in electrical supply for more than few seconds could be fatal for them.
- Further some patients may have conductive instruments in contact with the bloodstream or heart muscle where the possibility for serious injury and/or death if that metal becomes energized (even to a very low level). Other dangers include wet areas, hazards due to flammable liquids and the presence of oxygen
- Due to magnetism and self inductance, you don’t need to touch a live wire to get electrocuted
- Current flows from live insulated wire through conductive surfaces through patient to earth

3. RESEARCH METHODOLOGY

The action research entailed the following:

A. Literature Survey - Study the various international standards/journal/papers on the subject.
B. Study the regulatory practices in India and around the world.
C. Interaction with manufacturer associations/electrical installers to understand different technologies used in the industries through webinars

A. Literature Survey - Following international standards/journal/papers are referred on the subject.

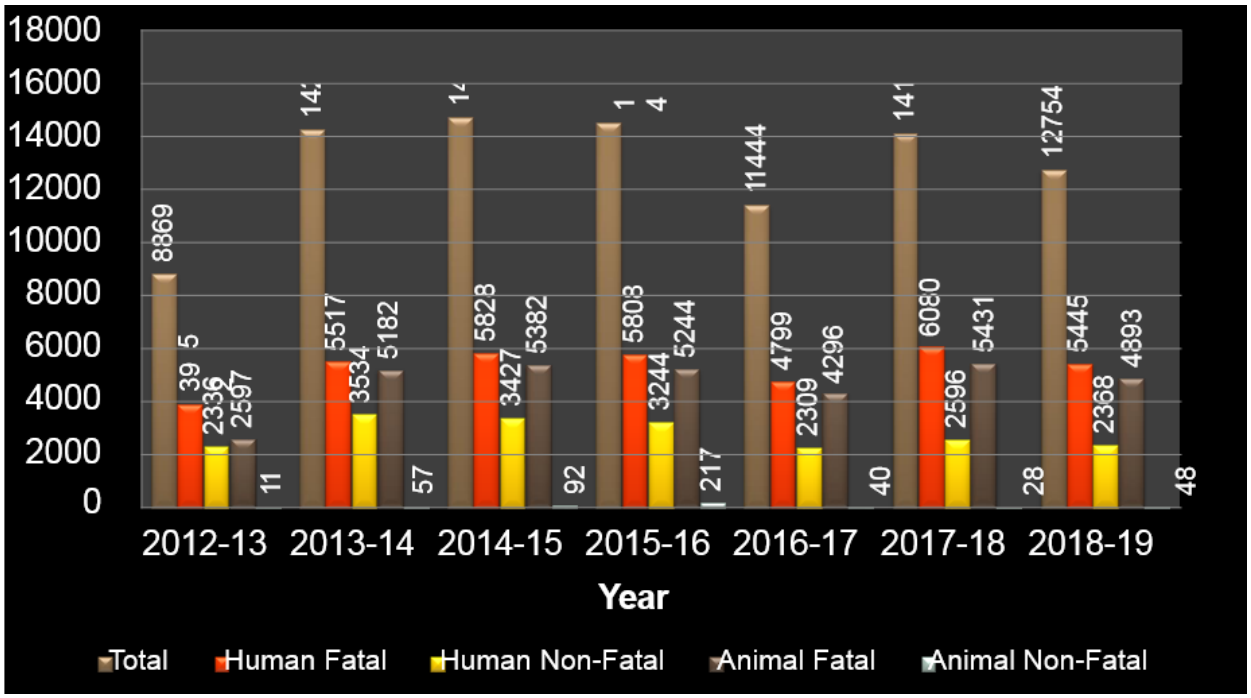
IS/IEC/ISO Number	*Title*
732: 2019	Code of practice for electrical wiring installations (*fourth revision*)
12032 (Part 1): 1987	Graphical symbols for diagrams in the field of electrotechnology: Part 1 General information
12032 (Part 11): 1987	Graphical symbols for diagrams in the field of electrotechnology: Part 11 Architectural and topographical installation plans and diagrams
13450 (Part 1): 2018	Medical electrical equipment: Part 1 General requirements for basic safety and essential performance (*second revision*)
14700 (Part 3/Sec 2 and 3) : 2018	Electromagneticcompatibility (EMC): Part 3 Limits
IEC 61000-2 series	Electromagnetic compatibility (EMC) — Part 2: Environment
IEC 61082-1:2014	Preparation of documents used in electrotechnology — Part 1: Rules
IEC 61557-8:2014	Electrical safety in low voltage distribution systems up to 1000Vac. and 1500Vdc. — Equipment for testing, measuring or monitoring of protective measures — Part 8:Insulation monitoring devices for IT systems
IEC 61558-2-15:2011	Safety of transformers + reactors + power supply units and combinations thereof — Part 2-15: Particular requirements and tests for isolating transformers for the supply of medical locations

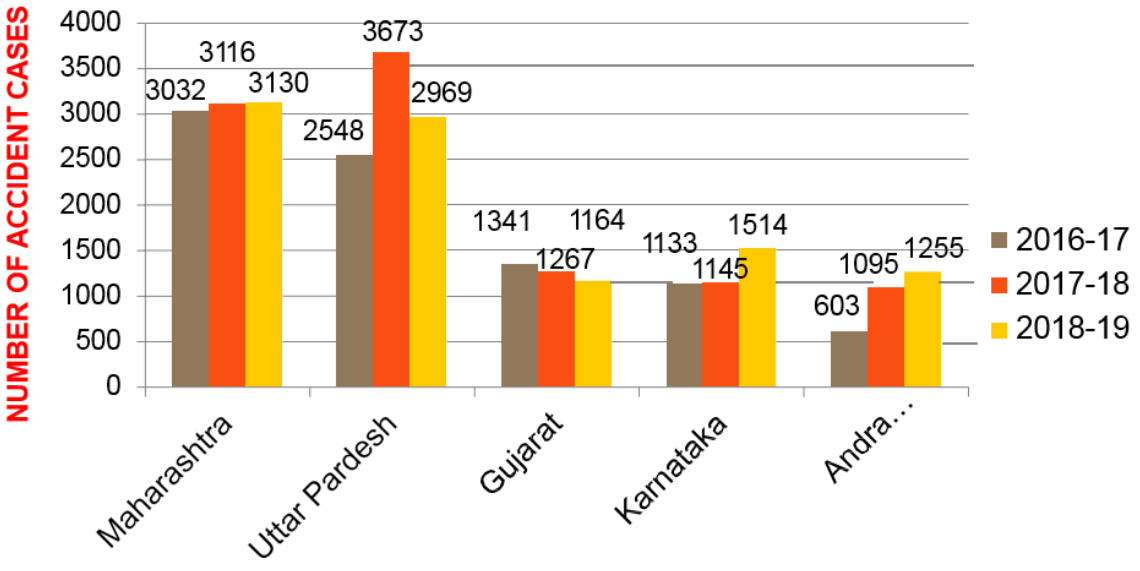
- Study the regulatory practices in India and around the world.
  - Statutory Provisions for Electrical Safety
  - Indian Electricity Act 2003
  - Central Electricity Authority (Measures related to Safety and Electric Supply) Regulations 2010 and further amendments 2015 and 2018
  - Reg. 5 Electrical Safety Officer

- Reg. 5A Chartered Electrical Safety Engineer
- Reg. 30 Periodical Inspection
- Reg. 31 Testing of Consumer's Installation
- Reg. 32 Testing of Generating Units
- Reg. 36 Provisions for multistoried buildings
- Reg. 43 Prior Approval before commissioning
- Electrical Safety: Standards, Codes and Guidelines
- National Electrical Code 2011
- National Building Code 2016
- IS 732 2019
- International Electro-technical Commission (IEC)
- National Fire Protection Association (NFPA 70, 70A, 70B, 70E)
- Institution of Electric and Electronics Engineers (IEEE)
- Occupational Safety and Health Administration (OSHA)

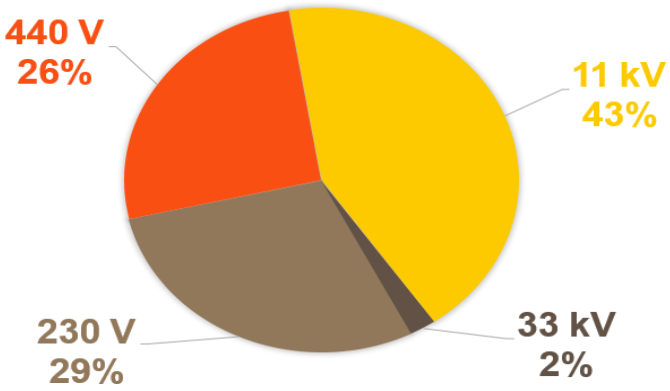
- Interaction with manufacturer associations/electrical installers to understand different technologies used in the industries through webinars

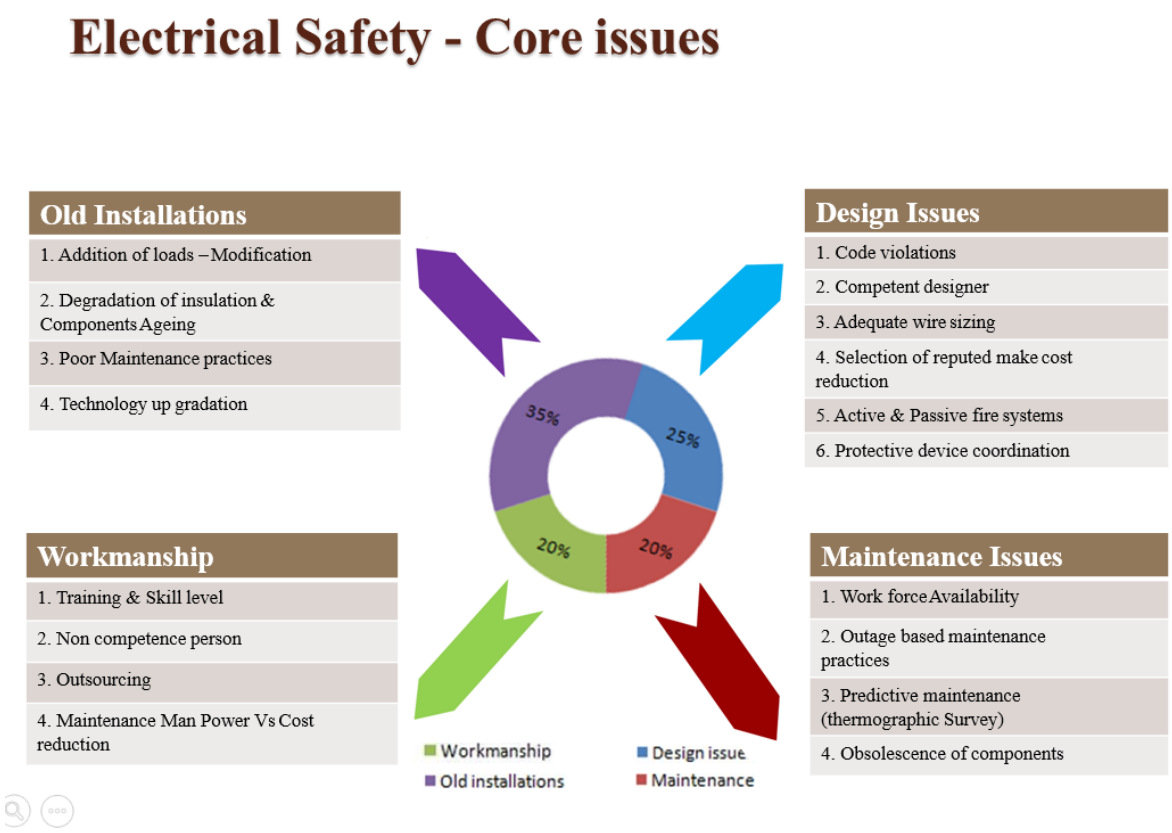
Statistics of Electrical Accidents





Voltage level and % of electrical accidents





4. The risk involved in Medical Locations

In medical locations stringent measures are necessary to ensure the safety of patients likely to be subjected to the application of medical electrical equipment.

Shock hazards due to bodily contact with the 50 Hz mains supply are well known and documented. Currents of the order of 10 mA passing through the human body can result in muscular paralysis followed by respiratory paralysis depending on skin resistances, type of contact, environmental conditions and duration. Eventual ventricular fibrillation can occur at currents just exceeding 20 mA. These findings are listed in IEC/TR2 60479-1 Effects of current on human beings and livestock – General aspects.

The natural protection of the human body is considerably reduced when certain clinical procedures are being performed on it. For example, patients undergoing treatment may have their skin resistance broken or their defensive capacity either reduced by medication or nullified while anaesthetised. These conditions increase the possible consequences of a shock under fault conditions.

In patient environments where in tracardiac procedures1 are undertaken, the electrical safety requirements are more stringent. Prolonged loss of the mains supply may put the patient's life at risk. Patient leakage currents from applied parts introduced directly to the heart can interfere with cardiac function at current levels that would be considered safe under other circumstances. In order to protect the patient against 'micro shock' the requirements of the medical equipment are enhanced.

Patient leakage current that can flow into an earthed patient is normally greatest when the equipment earth is disconnected (single fault condition). A limit is set to the amount of leakage current that can flow in the patient circuit when the protective earth conductor is connected or disconnected. Patients' leakage currents2 of the order of 10μA have a probability of 0.2 per cent for causing ventricular fibrillation or pump failure when applied through a small area of the heart. At 50 μA (micro shock), the probability of ventricular fibrillation increases to the order of 1 per cent (refer to BS EN 60601-1).Equipment constructed to the BS EN 60601 series of standards ensure the leakage currents produced by medical equipment meet the required levels to ensure patient safety, which is why only ME equipment meeting the standards should be used clinically. It should also be noted that the allowable levels of patient leakage current depend on the classification of the applied parts B, BF or CF, the strictest being CF(cardiac floating) parts as these are expected to be used inside (in tracardiac) or near the heart.

Additional to the consideration of risk from electric shock, some kinds of electrical equipment (life-support equipment, surgical equipment) perform such vital functions that loss of supply would pose an unacceptable risk to patients. Medical locations where such equipment is used require secure supplies. This has implications not only for the provision of safety (emergency) power supplies, but can also render some conventional protective measures unsuitable. Hence, for example, when protecting circuits supplying critical medical equipment, restrictions are stipulated on the use of RCDs.

Notes:

(a) Further guidance on modelling of shock to the human body can be found in IET publication A Guide to Electrical Installations in Medical Locations.

(b) Where the requirements of are properly fulfilled, the risk of a dangerous touch leakage current occurring inadvertently, from medical staff simultaneously touching an in tracardiac conductor and the electrical installation earth (e.g. via the enclosure of ME equipment), are negligible.

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1 A procedure whereby an electrical conductor is placed within the heart of a patient or is likely to come into contact with the heart, such conductor being accessible outside the patient’s body. In this context, an electrical conductor includes insulated wires such as

cardiac pacing electrodes or in tracardiac ECG electrodes, or insulated tubes filled with conducting fluids (catheter).

2 'Patient leakage current': current flowing from a medical electrical equipment applied part via the patient to earth.

5. Assessment of general characteristics

In order to determine the classification and group number of a medical location, it is necessary that the relevant medical staff indicate which medical procedures will take place within the location. Based on the intended use, the appropriate classification for the location shall be determined.

Notes:

(a) Classification of a medical location is related to the type of contact between applied parts and the patient, the threat to safety of the patient owing to a discontinuity (failure) of the electrical supply, as well as the purpose for which the location is used.

(b) Guidance on the allocation of a group number and classification of safety services for medical locations is shown in Table A.

(c) To ensure protection of patients from possible electrical hazards, additional protective measures are applied in medical locations. The type and description of these hazards can vary according to the treatment being administered. The purpose for which a location is to be used may justify areas with different classifications (Group 0, 1 or 2) for different medical procedures.

(d) Applied parts are defined by the particular standards for ME equipment.

(e) The possibility that certain medical locations could be used for different purposes may require a higher group allocation

▼Table A Group number and classification of safety services for medical locations

	Medical location	Group			Classification	
		0	1	2	≤0.5 s	>0.5 s ≤ 15 s
1	Massage room	X	X			X
2	Bedrooms		X			X
3	Delivery room		X		X[a]	X
4	ECG, EEG, EHG room		X			X
5	Endoscopic room		X[b]			X[b]
6	Examination or treatment room		X			X
7	Urology room		X[b]			X[b]

8	Radiological diagnostic andtherapy room		X	X	X	X
9	Hydrotherapy room		X			X
10	Physiotherapy room		X			X
11	Anaesthetic area		X		X[a]	X
12	Operating theatre		X		X[a]	X
13	Operating preparation room		X		X[a]	X
14	Operating plaster room		X		X[a]	X
15	Operating recovery room		X		X[a]	X
16	Heart catheterization room		X		X[a]	X
17	Intensive care room		X		X[a]	X
18	Angiographic examination room		X		X[a]	X
19	Haemodialysis room	X				X
20	Magnetic resonance imaging (MRI) room	X	X		X	X
21	Nuclear medicine	X				X
22	Premature baby room		X		X[b]	X
23	21 Nuclear medicine		X		X	X

Notes:

(a) Luminaires and life-support ME equipment requiring a power supply within 0.5 s or less.

(b) Not being an operating theatre.

Notes:

(i) A definitive list of medical locations showing their assigned group and classification is impracticable. The above list is a guide only and should be read in conjunction with 9.4.

(ii) Changes to the above list based on 'Risk Assessment', and agreed locally by clinicians and management, are also acceptable provided that all relevant risk sassociated with the installation are mitigated by an appropriate measure.

(iii) Further guidance on the application of Table A and grouping and classification of haemodialysis rooms can be found in IET publication *A Guide to Electrical Installations in Medical Locations.*

6. Types of system earthing

PEN conductors shall not be used in medical locations and medical buildings downstream of the main distribution board.

Note: In Great Britain, Regulation 8(4) of the ESQCR 2002 (as amended) prohibits the use of PEN conductors in a consumer's installation.

7. Supplies

In medical locations, the distribution system shall be designed and installed to facilitate the automatic changeover from the main distribution network to the electrical safety source feeding essential loads.

7.1 Power supply for medical locations of Group 2

In the event of a first fault to earth, a total loss of supply in Group 2 locations shall be prevented.

Note: This is not solely referring to medical IT supplies, it applies equally to the level of resilience a designer must apply to the distribution circuits supplying a Group 2 location. For example, that the loss of one distribution circuit through fault or fire will not cause total loss of supply to that location.

8. Protection against electric shock

Protective measures providing basic protection (protection against direct contact)utilizing obstacles or placing out of reach are not permitted.

Protective measures of a non-conducting location), earth-free local equipotential bonding or electrical separation for the supply of more than one item of current-using equipment are not permitted.

Notes:
(a) Only protection by insulation of live parts or by the use of Class II equipment are permitted.

(b) A medical IT system does not use electrical separation as the sole means of protection against electric shock .

9. Requirements for fault protection (protection against indirect contact)

9.1 Automatic disconnection in case of a fault

Care shall be taken to ensure that simultaneous use of many items of equipment connected to the same circuit cannot cause unwanted tripping of the residual current device (RCD).

Notes:

(a) This applies to all circuits (including lighting circuits) supplied by a TN or TT system.

(b) Designers should take note of the inherent high protective conductor (earth leakage) currents associated with a variety of electronic equipment. Examples of these are information technology equipment and mobile X-ray equipment, which can produce a higher allowable earth leakage current than normal medical electrical equipment.
In Group 1 and Group 2 medical locations, where RCDs are required, only type A(complying with BS EN 61008 or BS EN 61009) or type B (complying with IEC 62423)shall be selected, depending on the possible fault current arising. Type AC RCDs shall not be used.

Notes:

(a) This applies to all circuits (including lighting circuits) supplied by a TN-S system.
(b) Type A RCDs ensure tripping for:
(i) residual sinusoidal alternating currents.
(ii) residual pulsating direct currents.
(iii) residual pulsating direct currents superimposed by a smooth direct current of 6 mA, with or without phase-angle control, independent of the polarity.
(c) Type B RCDs ensure tripping for Type A and:
(i) residual sinusoidal currents up to 1000 Hz.
(ii) residual sinusoidal currents superimposed by a pure direct current.
(iii) pulsating direct currents superimposed by a pure direct current.
(iv) residual currents resulting from various configurations of rectifier circuits.

For example, a typical X-ray generator uses a rectifier circuit to generate a d.c. intermediate voltage. Due to this, equipment manufacturers often advise the use of a Type B RCD.

(d) Type AC RCDs ensure tripping for only residual sinusoidal alternating currents. In Group 1 and Group 2 medical locations, the following shall apply:

(a) for IT, TN and TT systems, the voltage presented between simultaneously accessible exposed-conductive-parts and/or extraneous-conductive-parts shall not exceed 25 V a.c. or 60 V d.c.; and
(b) for TN and TT systems, the requirements of Table B shall apply.

Table B Maximum disconnection times for TN and TT systems in Group 1 and Group 2 medical locations

System	25V< U0≤ 50V (seconds)		50V< U0≤ 120V (seconds)		120V< U0≤ 230V (seconds)		230< U0≤ 400V (seconds)		U0 > 400V (seconds)	
	a.c	d.c	a.c	d.c	a.c	d.c	a.c	d.c	a.c	d.c
TN	5	5	0.3	2	0.3	0.5	0.05	0.06	0.02	0.02
TT	5	5	0.15	0.2	0.05	0.1	0.02	0.06	0.02	0.02

Note: In TN systems, a value of 25 V a.c. or 60 V d.c. may be met with protective equipotential bonding, complying with the disconnection time in accordance with Table B.

9.2 Additional protection

Where a medical IT system is used, additional protection by means of an RCD shall **not** be used.

9.3 TN systems

In final circuits of Group 1 medical locations rated up to 63 A, RCDs with a rated residual operating current not exceeding 30 mA .

In final circuits of Group 2 medical locations (except for the medical IT system), RCD shaving the characteristics specified shall be used in circuits for:

(a) the supply of movements of fixed operating tables;
(b) X-ray units; and
(c) large equipment with a rated power greater than 5 KVA.

Notes:

(i) The list of circuits (a) to (c) above is not exhaustive. This implies that the designer is not restricted to providing only medical IT final circuits in a Group 2medical location, but should also consider the wider implications of Group 2medical location design.

(ii) The requirement in (b) of the listed circuits is mainly applicable to mobile X-ray units brought into the patient environment. Correct selection of the RCD that is insensitive to leakage spikes caused by capacitance will meet the requirement for mobile X-ray units. The maximum leakage current in normal condition, as defined in BS EN 60601-2-54, is 2.5 m A for a mobile X-ray unit and 5 m A for a permanently installed X-ray unit.

(iii) Other items of equipment include mobile imaging and diagnostic equipment brought into the patient's environment. These types of equipment may draw a substantially high current and, if connected to the IT system, have been known to overload the IT transformer (see 9.9).

(iv) Equipment supplied by RCD-protected circuits provides adequate safety to the user and patient where the supply failure, caused by a single fault to earth, does not present danger to the patient's life.

(v) Whilst Residual Current Monitoring is not mandated, insulation monitoring maybe considered appropriate. In using this type of monitoring, designers will need to consider the threshold of alarm and how this alarm will be identified/acted upon.

(vi) Designers and stakeholders have to ascertain the suitability of any electrical equipment brought into the patient environment and whether it is connected to an IT, TN or TT system, where the latter should be RCD protected. Special consideration should be given when current-carrying equipment possessing non-specified leakage currents is permanently installed in a Group 2 medical location.

(vii) Designers must fully consider the impact of assigning medical IT circuits for use in non-life support applications. That is, not all socket-outlets in a theatre environment need to be connected to the IT system; for example, supplies to shavers, music systems, computerized records (PACS) etc. These may be required to be supplied by UPS. However, for simplicity designers may wish to provide non-IT circuits that are UPS backed.

9.4 TT systems

In Group 1 and Group 2 medical locations, RCDs shall be used as protective device sand the requirements of 11.3 apply.

9.5 IT system

In Group 2 medical locations, an IT system shall be used for final circuits supplying medical electrical equipment and systems intended for life support, surgical applications and other electrical equipment located within the 'patient environment'.

Note: Any non-medical electrical equipment located or brought into the patient environment has to be assessed for its suitability for use in this environment.

For each group of rooms serving the same function, at least one IT system is necessary. The IT system shall be equipped with an insulation monitoring device(IMD) in accordance with BS EN 61557-8:2007, with the following additional specific requirements:

(a) a.c. internal impedance shall be ≥100 kΩ;

(b) internal resistance shall be ≥ 250 kΩ;

(c) test voltage shall be ≤ 25 V d.c.;

(d) injected current, even under fault conditions, shall be □ 1 mA peak;

(e) indication shall take place at the latest when the insulation has decreased to 50kΩ. If the response value is adjustable, the lowest decreased possible set point value shall be ≥ 50 kΩ. A test device shall be provided; and

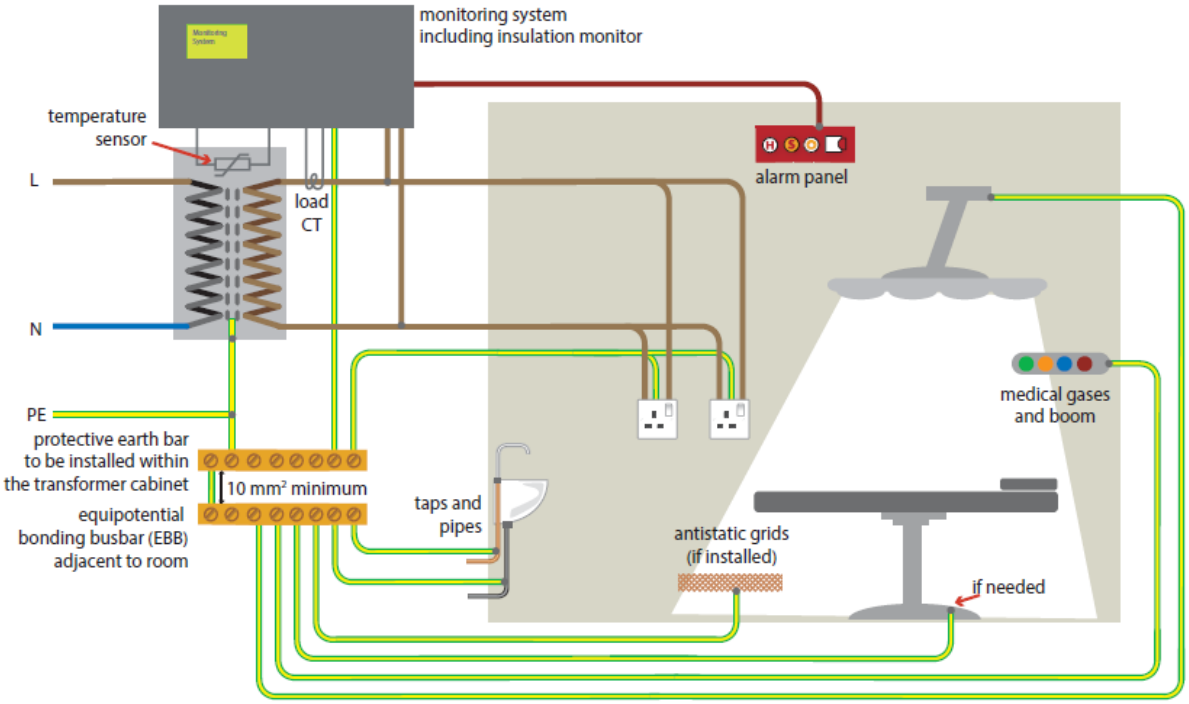
(f) response and alarm-off time shall be ≤ 5 s.

Notes:

(i) An indication is recommended if the protective earth (PE) or wiring connection of the IMD is lost.

(ii) For further technical clarification on medical IT systems, refer to IET publication A Guide to Electrical Installations in Medical Locations.

▼**Figure C** Typical theatre layout of medical IT system with insulation monitoring



For each medical IT system, an acoustic and visual alarm system incorporating the following components shall be arranged at a suitable place so that it can be permanently monitored (via audible and visual signals) by the medical staff and, furthermore, is reported to the technical staff:

(g) a green signal lamp (light) to indicate normal operation;
(h) a yellow signal lamp (light) that illuminates when the minimum value set for the insulation resistance is reached. It shall not be possible for this light to be cancelled or disconnected;
(i) an audible alarm that sounds when the minimum value set for the insulation resistance is reached. This audible alarm may be silenced; and
(j) the yellow signal shall go out on removal of the fault and when the normal condition is restored.

Documentation shall be easily readable in the medical location and shall include:

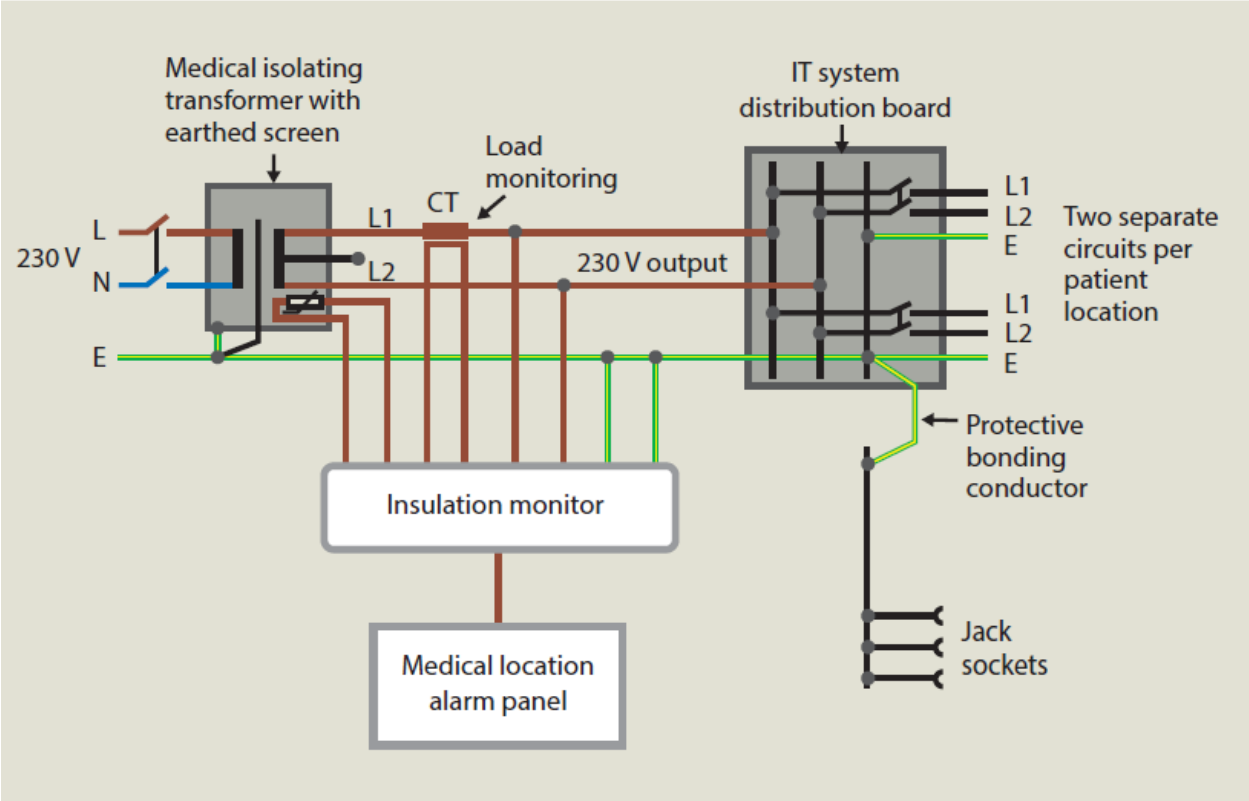
(k) the meaning of each type of signal; and
(l) the procedure to be followed in case of an alarm at first fault.

Notes:

(a) These colours only apply to the visual alarm system associated with the medical IT system. The colour of indicator lights for medical equipment is given in BSEN 60601-1. Care should be taken over the selection of any indicator lights visible within the patient environment to avoid any confusion by medical staff.
(b) A system constructed to the requirements is referred to as a medical IT system.
(c) For illustration of a typical theatre layout refer to Figure B

(d) For illustration of a typical medical IT system arrangement refer to Figure C.

▼ Figure D Typical medical IT system arrangement



Monitoring of overload and high temperature for the IT transformer is required.

Note: This would result in an early alarm to avoid unnecessary tripping of the IT transformer. The alarm is raised when the load current exceeds the rate doutput of the transformer. However, if it is within the specification of the equipment to adjust the set point, then it is desirable that the alarm is raised earlier, say at 10 per cent below the rated output.

In addition to an insulation monitoring device, consideration shall be given to the installation of fault location systems, which localize insulation faults in any part of the medical IT system. The insulation fault location system shall be in accordance with BSEN 61557-9.

9.6 Transformers for IT systems

Transformers shall be in accordance with BS EN 61558-2-15, installed in close proximity to the medical location and with the following additional requirements:

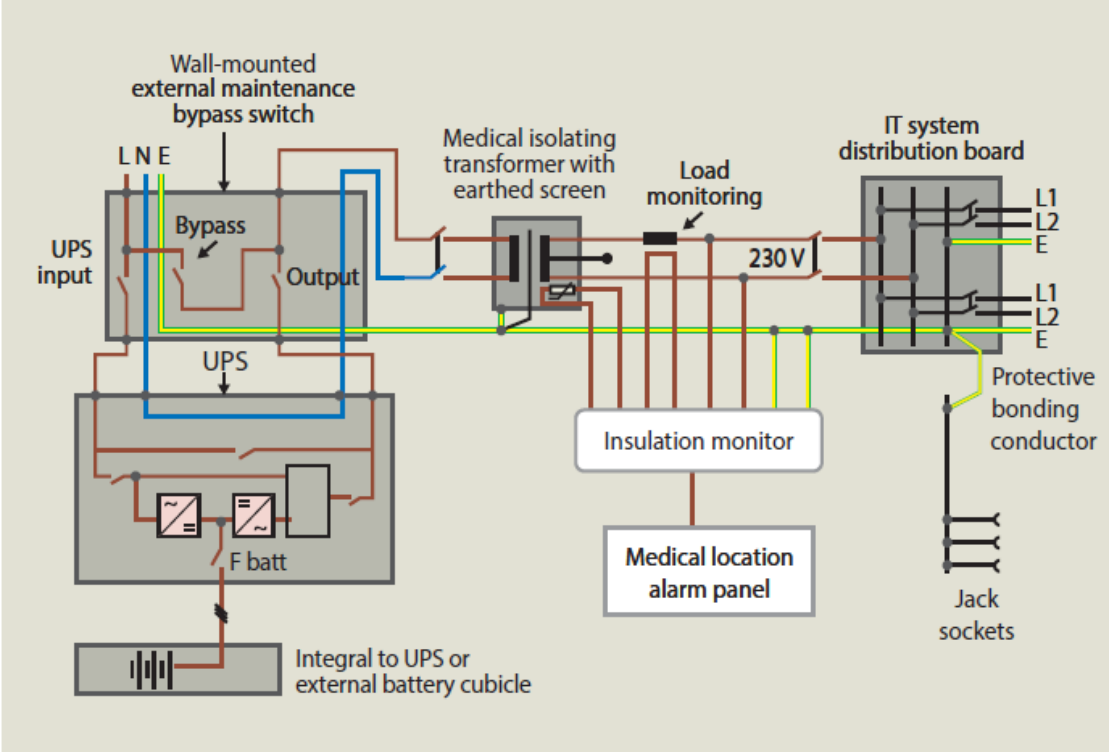
(a) The leakage current of the output winding to earth and the leakage current of the enclosure, when measured in no-load condition and the transformer supplied at rated voltage and rated frequency, shall not exceed 0.5 mA.

(b) At least one single-phase transformer per room or functional group of rooms shall be used to form the IT systems for mobile and fixed equipment, the rated output of which shall be not less than 0.5 kVA and not more than 10 kVA.

Where two or more transformers are needed to supply equipment in one room, they shall not be connected in parallel.
(c) If the supply of three-phase loads via an IT system is also required, a separate three-phase transformer shall be provided for this purpose.

Capacitors shall not be used in transformers for medical IT systems.

▼ Figure E Typical arrangement of a UPS back-up to a medical IT system



9.7 Safety services

A power supply for safety purposes is required which will maintain the supply for continuous operation for a defined period within a pre-set changeover time.

The safety power supply system shall automatically take over if the voltage of one or more incoming live conductors at the main distribution board of the building has dropped for more than 0.5 s and by more than 10 per cent in regard to the nominal voltage.

9.8 Classification of safety services for medical locations

Classification of safety services is listed

▼**Table C** Classification of safety services necessary for medical locations

Classification	Changeover time (s)	Description
No-break	0	Automatic supply available with no break
Very short break	0.15	Automatic supply available within 0.15 s
Short break	0.5	Automatic supply available within 0.5 s
Medium break	15	Automatic supply available within 15 s
Long break	>15	Automatic supply available in more than 15 s

Notes:

(a) Mains-floating UPS sources satisfy the 'No-break' classification requirement. Other types of UPS sources can satisfy the 'Very short break' classification.

(b) Safety services provided for locations having differing classifications should meet that classification which gives the highest security of supply. Refer to C for guidance on the association of classification of safety services with medical locations.

9.9 Inspection and testing

Note: The testing of equipment connected to the electrical installation is outside the scope of this document. For ME equipment refer to BS EN 62353.

9.10 Initial verification

The dates and results of each verification shall be recorded.

The tests specified below under items (a) to (b) shall be carried out, both prior to commissioning and after alteration or repairs and before re-commissioning:

(a) complete functional tests of the insulation monitoring devices (IMDs) as sociated with the medical IT system, including insulation failure, transformer high temperature, overload, discontinuity and the acoustic/visual alarms linked to them;

(b) Measurements of leakage current of the output circuit and of the enclosure of the medical IT transformers in no-load condition and measurements to verify that the resistance of the supplementary equipotential bonding is within the limits stipulated.

10.Other Safety Provisions in Hospitals

#	Provisions	Principal Requirements	Installation Measures
i)	P_0	Duration of touch voltages restricted to a safe limit	TN-S, TT or IT system
ii)	P_1	As P_0 but additionally: Touch voltages in patient environment restricted to a safe limit	Additional to P_0: Supply system with additional requirements for protective earthing, etc.
iii)	P_2	As P_1 but additionally: Resistance between extraneous conductive parts and the protective conductor but bar of the room not exceeding 0.1Ω	Additional to P_1: Supplementary equipotential bonding
iv)	P_3	As P_1 or P_2 but additionally: Potential difference between exposed & extraneous conductive parts and the protective conductor bus bar not exceeding 10 mV in normal condition	As P_1 or P_2: Measurement necessary, corrective action possibly necessary
v)	P_4	As P_1 or P_2. Additional protection against electric shock by limitation of disconnecting time	Additional to P_1 or P_2: Residual current operated protective device
vi)	P_5	Continuity of the mains supply maintained in case of a first insulation fault to earth and currents to earth restricted	Additional to P_1, P_2 or P_3: IT supply system with insulation monitoring
vii)	P_6	Reduction of fault currents and touch voltages in case of a fault in the basic insulation	Additional P_1 or P_2: Medical isolating transformer supplying one individually piece of equipment
viii)	P_7	Prevention of dangerous touch voltages in normal condition and in single fault condition	Additional to P_1 or P_2: Supply with medical safety, extra low voltage

#	Provisions	Principal Requirements	Installation Measures
ix)	*G E*	No interruption of the power supply of the essential circuits of the hospital for more than 15 s	Safety supply system
x)	E_1	No interruption of the power supply of life-supporting equipment for more than 15 s	Special safety supply system
xi)	E_2	No interruption of the power supply of the operating lamp for more than 0.5 s	Special safety supply system for operating lamp
xii)	*A*	Prevention of explosions, fire and electrostatic charges	Measures concerning explosion and fire hazards
xiii)	*I*	No exercise interference from electric and magnetic fields	Layout of building and installation, screening

11. Application of Safety Provisions

#	Medically Used Room	Protective Measures							Safety Supply System			Explosion & Fire	EMI
		P_o/P_1	P_2	P_3	P_4	P_5	P_6	P_7	*GE*	*E1*	*E2*	*A*	*I*
i)	Message room	M	O					O	X				
ii)	Operating wash room	M	X					O	X				
iii)	Ward general	M	O					O	X				
iv)	Delivery room	M	X		X	O		O	X	O	X	O	O
v)	ECG, EEG, EMG room	M	X		X			O	X				X
vi)	Endoscopic room	M	X		X			O	X		O		
vii)	Examination or treatment room	M	O		X	O		O	X		O		
viii)	Labour room	M	X		X	O		O	X				O
ix)	Operating sterilization room	M	O		X			O	X				
x)	Urology room	M	X		X			O	X		O		

#	Medically Used Room	Protective Measures							Safety Supply System			Explosion & Fire	EMI
		P_o/P_1	P_2	P_3	P_4	P_5	P_6	P_7	*GE*	*E1*	*E2*	*A*	*I*
xi)	Radiological diagnostic and therapy room, other than mentioned under Sl No. (xx) and (xxiv)	M	X		X			O	X				
xii)	Hydrotherapy room	M	X		X		O	O	X				
xiii)	Physiotherapy room	M	X		X	O		O	X				
xiv)	Anaesthetic room	M	X	X	X_1	X		O	X	X	X	O	O
xv)	Operating theatre	M	X	X	X_1	X		O	X	X	X	X	X
xvi)	Operating preparation room	M	X	X	X_1	X		O	X	X	X	X	X
xvii)	Operating plaster room	M	X		X_1	X		O	X	X	X	X	X
xviii)	Operating recovery room	M	X	X	X_1	X		O	X	X	X	X	X
xix)	Outpatient operating theatre	M	X		X_1	X		O	X	X	X	X	X

#	Medically Used Room	Protective Measures							Safety Supply System			Explosion & Fire	EMI
		P_0/P_1	P_2	P_3	P_4	P_5	P_6	P_7	GE	E1	E2	A	I
xx)	Heart catheterization room	M	X	X	X_1	X		O	X	X	X		X
xxi)	Intensive care room	M	X	O	X_1	X		O	X	X	X		X
xxii)	Intensive examination room	M	X	O	X_1	X		O	X	O	O		X
xxiii)	Intensive monitoring room	M	X	O	X_1	X		O	X	X	X		X
xiv)	Angiographic examination room	M	X	O	X_1	X		O	X	O	O		O
xxv)	Hemodialysis room	M	X	X	X_1	X			X				
xxvi)	Central monitoring room	M	X	O	X_1	X		O	X				O
M = Mandatory measure, X = Recommended measure, X1 = As X, additionally insulation resistance measurement, O = Additional measure, may be considered desirable.													

12. Medical electrical equipment:

Electrical equipment, provided with not more than one connection to a particular supply mains and intended to diagnose, treat or monitor the patient under medical supervision and which makes physical or electrical contact with the patient, and/or transfers energy to or from the patient, and/or detects such energy transfer to or from the patient.

13. Medical Locations

- group 0
  - medical location where no applied parts are intended to be used
- group 1
  - medical location where applied parts are intended to be used:
  - externally
  - invasively to any part of the body (except group 2)
  - (Disconnection shall be possible without danger to patient. Examination and treatment can be safely interrupted and repeated)
- group 2

medical location where applied parts are intended to be used in applications such as intra cardiac procedures, operating theatres and vital treatment where discontinuity (failure) of the supply can cause danger to life

NOTE An intra cardiac procedure is a procedure whereby an electrical conductor is placed within the heart of a patient or is likely to come into contact with the heart, such conductor being accessible outside the patient's body. In this context, an electrical conductor includes insulated wires such as cardiac pacing electrodes or intra cardiac ECG electrodes, or insulated tubes filled with conducting fluids.

Invasively – relating to a medical procedure in which a part of the body is entered, as by puncture

14. Tests and its sequence

Additional tests for Special location (e.g. medical locations)

- Functional test of insulation monitoring devices of medical IT systems and acoustical/visual alarm systems.
- Measurements to verify that the supplementary equipotential bonding.
- Verification of the integrity of the facilities required with for equipotential bonding.
- Verification of the integrity of the requirements of for safety services.
- Measurements of leakage current of the output circuit and of the enclosure of medical IT transformers in no-load condition:

a) functional testing of changeover devices: 12 months;
b) functional testing of insulation monitoring devices: 12 months;
c) checking, by visual inspection, settings of protective devices: 12 months;
d) measurement verifying the supplementary equipotential bonding: 36 months ;
e) verifying integrity of facilities required for equipotential bonding: 36 months;
f) monthly functional testing of:
– safety services with batteries: 15 min;
– safety services with combustion engines: until rated running temperature is achieved; 12 months for “endurance run”;
– safety services with batteries: capacity test;
– safety services with combustion engines: 60 min;
In all cases at least 50 % to 100 % of the rated power shall be taken over.
g) measurement of leakage currents of IT transformers: 36 months;

h) checking of the tripping of RCDs at *I*ΔN: not less than 12 months.

15.Conclusion-

Methods of implementation of Standard all over India

Implementing IS732 and IS 17512 will reduce accidents in buildings. This implementation is done through following.

i. Awareness creation about IS732and IS 17512
ii. Include recommendation in IS732and IS 17512 in the building classifications by state fire and rescue departments of state government.
iii. Create guides on IS732 , IS 17512 and IS3043 for simplified understanding of these standards
iv. Arrange short term courses on IS732 and IS 17512 to large corporates, state electrical inspectorates, utilities, engineers working in private organizations….. etc. so that they can start using IS732and IS 17512.
v. Create a system for qualifying engineers who can do testing as per IS732and IS 17512
vi. Create a system for qualifying Electrical safety companies who can carryout audits as per IS732and IS 17512.

15.1 Awareness creation about IS732

Majority of engineers working in LV system are not aware of IS732and IS 17512. As a result, IS732 and IS 17512 is not followed for design, erection and testing of an installation

An example to this statement is, IS732 3rd edition recommend different kind of tests to be carried out in an installation during commissioning. Due to unawareness about the standard and its requirement, recommended tests in IS732 3rd edition is not carried out in government and private buildings and industries.

To create awareness about IS732 as a wiring rule, the users shall be informed about this standard and its importance. Following shall be carried out at the earliest to create awareness

a. BIS shall write to CEA to include IS732and IS 17512 in chapter V of CEA (Measures relating to Safety and Electric Supply) Regulations, 2010
b. BIS shall write to trade organisations like IEEMA, CII, FICCI, FSAI, Builders association of India, Architects institute etc to implement IS732and IS 17512 for design, erection and testing of installation up to 1000 VAC and 1500 VDC. BIS request these organisations to arrange seminars on electrical safety based on IS732and IS 17512.
c. BIS shall write to Indian railways, defense services, MES, CPWD, all state government electrical inspectorate and PWD's, large public enterprises such as Coal India, Oil India, IOCL, BPCL, HPCL, ISRO, Large private organisations and engineering companies. BIS request these organisations to arrange seminars on electrical safety based on IS732and IS 17512.

d. Utilities all over India. (also, with explanation from IS3043)
e. A common covering letter as an introduction to IS732, 4th edition and an appeal to users of electricity up to 1000 VAC and 1500 VDC to use IS732 for design, erection and testing of an installation with a conclusion that strict implementation of rules in IS732 will reduce accidents due to electricity can be made and circulated through various organizations to the users.
f. Short video about IS732 and IS 17512 and its contents for circulation in social media.
g. Identify and appoint an agency who is capable of handling technical courses on IS732and IS 17512

15.2 Building classification fire and rescue department.

As per clause 4.3.2.2 of IS732 depending upon the condition of evacuation during emergency, building is classified in four categories. This categorization shall be done by fire and rescue department. BIS shall write to fire and rescue department of state government, inform them about the classification of wiring for buildings depending upon condition of evacuation and request them to ensure the wiring conditions in IS732 and IS 17512 to reduce fire accidents.

15.3 Guides on IS732 and IS 17512

Create simple guides on IS732 and IS 17512 on various rules such as protection from shock, protection from fire and thermal effect, earthing and protective conductor, inspection and testing etc. These guides shall contain pictures and simple explanation of rules in IS732and IS 17512. BIS can appoint private parties to create these guides.

15.4 Technical awareness classes – Short term, medium, and long term

Series of technical awareness classes shall be made with a focus to create BIS listed

1. Safety engineer – who is aware of the basic requirements of IS732and IS 17512 and is able to follow the standards without mis-interpretation. Safety engineer is able to train electricians and shall have knowledge about testing instruments.
2. Safety manager – who is aware of the basic requirements of all BIS safety standard and is able to follow the standards without mis-interpretation. Safety manager is able to train safety engineer and shall have knowledge about testing instruments, analyse the results of testing to find out defects in an installation.
3. Safety companies – Is a company of a firm where a group of safety managers and safety engineers are employed. Safety companies shall have technical skills and knowledge on all BIS standards including product standards and are capable of solving various electrical related issues including safety, failure of electronics etc.

Note: Method adopted by BEE can be followed for enlisting the above specialists.

Different methods can be adopted to create technical awareness. One of the workable models is to conduct medium- and long-term training program through engineering colleges and other

technical universities across India. These university teachers can be educated through webinars and other methods.

15.4.1 Short term course

1 to 2 days technical classes are to create general awareness about IS732 and IS 17512 and to clear misinterpretations from the standard. These classes are to explain basic concepts from the standard and to explain about testing and inspection as per IS732. Engineers from leading public / private organizations shall participate in this program. Special documents shall be prepared to ensure that these participating engineers are able to explain to their electricians and other safety personals in their respective organization about the various requirement of IS732and IS 17512. During the short-term course BIS shall announce the plan of having safety engineer and safety manager so that trainings and webinars can be organized to the interested participants.

15.4.2 Medium term course

4 to 5 days technical classes are to create in depth technical awareness about IS732 and IS 17512 especially on design and testing. Engineers who pass the final test after these training program can be an electrical safety engineer.

15.4.3 Long term course

2 weeks technical classes are to create in depth technical awareness about all safety standards of BIS (IS732, IS3043, NEC, IS/IEC 62305and IS 17512 etc). Only safety engineers are allowed to participate in these programs. These programs are followed by a test. Engineers who pass these tests can become Safety manager.

15.5 Conducting test and enlisting engineers

BIS shall create a system to enlist engineers, safety managers and safety companies. An agency can be Online tests can be conducted (similar to entrance examination by JEE/NEET etc)

APPENDIX - V

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS

Doc. No. : PRTD/AR/**PF:04**	Issue No. : 1	Issue Date 28 Apr 2020	**DECLARATION OF ORIGINAL WORK**

DECLARATION OF ORIGINAL WORK

I, Ritwik Anand, Sc. D (indicate official's Name & Designation),

EmployeeNo 65158 hereby declare that the Action Research Projecttitled

"To study the special requirements of Electrical Installations in Medical Locations" is the original research work done by me. I have not copied from any other Action Research Project or any other work of similar nature and topic done by any person/institution/body either published or yet to be published. Data and information from other sources, used if any, have been with prior permission, wherever required and is duly acknowledged appropriately in the project report submitted by me.

This declaration is made on the 27th day of August 20.21....

27/08/2021

Sign. of Officer with Date

Note: Joint Declaration should be submitted for Projects undertaken jointly