A COMPLIANCE GUIDE TO
ELECTRICAL SAFETY
FOR CE MARKING

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A Compliance Guide to

ELECTRICAL SAFETY

For

CE Marking

With risk analysis as per LVD

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FIRST EDITION

Pune
EMC Publications

A Compliance Guide to
Electrical Safety For CE Marking -With risk analysis as per LVD
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First Print: 2019

Printed in Pune, India
Set in Bookman Old Style.
Published by Madhuri Kathalay.

ISBN 978-93-5351-588-1

MRP Rs 900/-

Made in India

ALSO BY THE AUTHOR

A Practical Approach To Electromagnetic Compatibility- With an Introduction to CE Marking.

Electromagnetic Compatibility – Without Equations.

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To my wife and daughter

And

To my parents who encouraged me to learn

CONTENTS

PREFACE

This book provides a step-by-step approach for equipment safety design and assessment for electrical / electro-mechanical products and machines. It describes the principles of safety and requirements as found in the international IEC and European harmonized standards. It provides ways and means to improve product design so as to ensure reasonable compliance when a product is subject to safety evaluation by a test laboratory. Its goal is to give equipment designers and manufacturers a better understanding of European and international safety considerations, including the safety philosophy. Understanding this safety philosophy and adhering to a few simple rules will help product manufacturers to achieve safety conformity on all products manufactured for worldwide export. The book provides basic design principles for safety of electrical products and machinery that concentrates on component selection and construction techniques. The information is generally applicable to most product types such as information technology equipment (ITE), test and measurement devices, appliances, machinery, and other similar equipment. The design tips concentrate on problematic areas that manufacturers most often encounter during their first safety assessment. The book is general in nature and hence it can never be a substitute for the details and elaboration that are included in a particular safety standard. It is broadly based on the standard EN/IEC 60950 (safety of information technology equipment) and some other standards notably the IEC 61010 (safety requirements for electrical equipment for measurement, control, and laboratory use). It must be noted that the safety requirements of most of the standards are broadly similar. However, including the very specific requirements of all the safety standards (there are hundreds of them) is virtually impossible in a single book. Just to drive home the point, the book gives information about creepage and clearance distances and how to select distances applicable to their product based on the environment, operating voltages, equipment category etc. and design the product accordingly so as to pass the creepage/clearance requirements when the product is actually submitted to a test laboratory. The book cannot and does not give specific creepage and clearance distances prescribed by each and every standard. The reader is therefore encouraged to refer to the actual safety standard for specific safety requirements pertaining to his/her product or product family.

What the book also does not include is information pertaining to evaluation of products for electrical safety. That is quite a different matter altogether as it takes a vast amount of time and effort to become a certified electrical safety test engineer not to mention years of hands-on experience that cannot be gained just by reading a book.

It is sincerely hoped that the guide will prove to be an invaluable aid towards understanding of safety standards and identifying deficiencies in products at the design stage itself and save the manufacturer of the cost that would otherwise be incurred in modifying a frozen design.

Chetan Kathalay
Pune, 2019.

1

CE MARKING

1.1. INTRODUCTION.

CE is the French acronym of "Conformite` Europe`ene". In English it stands for European Conformity i.e. conformity of a product to European laws. It is a mandatory compliance marking printed on all products intended to be placed in the European Union (EU) or more precisely the European Economic Area (EEA) which consists of 28 nations of EU (at the time of writing this book) plus Iceland, Liechtenstein and Norway. The EEA is also referred to as "community market". It should be mentioned here that Turkey is presently not a part of the EU but has implemented all EU laws and as such CE marking is applicable here as well. Again, Switzerland is not a member of the European Union, but for some products it accepts the CE marking based on Mutual Recognition Agreement (see section 1.6). In addition, the CE marking is applicable over some overseas colonies of the EU member countries like Guadeloupe, French Guyana, Martinique, Réunion, Saint-Barthélemy, Saint-Martin, the Azores, Madeira and the Canary Islands. The CE marking consists of the label "CE" placed on the product (or its nameplate) as a visible proof indicating that the product meets all health and safety requirements by conforming to applicable EU directives (laws) prepared by the European Commission. Once a product bears the CE marking, it is free to enter the EU and to move freely within the EU and hence many people consider CE marking as a *passport* to the EU.

1.2. BACKGROUND OF THE EUROPEAN UNION.

The Second World War had caused enormous damage to life and property and had resulted in large scale destruction of most of Europe. After the war, the idea of a unified Europe began to develop in order to maintain peace and tranquillity in the region and to avoid future wars. Furthermore the US and the USSR had become superpowers both militarily and economically. There was also a thought that the European nations, if united, could more effectively face economic challenges posed by these superpowers. The seeds of the European Union (EU) were sown when six countries namely Belgium, France, Italy, Luxemburg, Netherlands and West Germany met in Rome and signed the European Economic Community (EEC) treaty in 1957. Customs duty between these countries was abolished and common policies notable in trade and agriculture were put into place. Further in 1960, four countries namely Iceland, Liechtenstein, Switzerland and Norway formed the European Free Trade Agreement (EFTA) to promote free trade and economic cooperation between these countries. Denmark, Ireland and the United Kingdom joined the European Union on 1st

January 1973, raising the number of member states to nine. By 1986, Greece, Spain and Portugal also joined the union taking the membership to twelve and the Single European Act was signed in the same year. This treaty provided the basis for a six-year programme allowing free flow of goods across EU borders and the concept of "single

1.7. TYPE OF LAWS.

As far as product conformity is concerned, the outcome of the EU institutions are four legislative actions viz. regulations, directives, decisions and opinions. The regulations are directly applicable as law over the entire EU and they do not require approval by individual member states. For example, regulation *756/2008* which gives requirements for accreditation and market surveillance. The directives, on the other hand, are broad legal guidelines prepared by specialists in the commission. Some directives give essential requirements for product conformity, the fulfilment of which leads to CE marking. They are not directly applicable as law over the EU. Member states must modify their laws so as to incorporate a particular directive in their law. This process is called "transposition". For example the directives are incorporated into the law of the UK as "statutory instruments". Decisions can be issued by Council or Commission and are binding only on those parties to whom they are addressed to while opinions have no binding effect but can influence course of future legislation, decisions or judgments given by the court of justice.

1.8. ESSENTIAL REQUIREMENTS OF CE MARKING.

The only requirement for manufacturers marking their products CE is to demonstrate that it complies with the essential requirements (broad guidelines) given in the EU directives. He may follow different methods to meet these requirements (testing products from a third party laboratory to comply with European or "EN" standards being one of them). It is important to note that the manufacturer himself is responsible for designing and manufacturing the product in accordance with essential requirements laid down by the directives, he is also responsible for carrying out conformity assessment in accordance with the procedure(s) laid down by the directive(s) and therefore only he is

EN/IEC 60664-1: Insulation Coordination for Equipment within Low-Voltage Systems

This standard addresses insulation coordination for equipment within low voltage systems and is therefore a very crucial standard. IEC 60664-1 is a basic safety standard and is a guide for technical committees responsible for different equipment in order to rationalize their requirements so that insulation coordination is achieved. Insulation coordination is the mutual correlation of insulation characteristics of electrical equipment taking into account the voltage environments to which the equipment will be subjected to in their normal use. It classifies environment and identifies "pollution degrees" (see section 4.7.8.4), presence of transient peak voltages (called transient over voltages) and also classifies insulation material as per their tracking index (see section 4.7.9.3). The standard also includes methods of electrical testing (like High Voltage (HV) also called Hi-pot) with respect to insulation coordination.

1.12. THE CE MARKING PROCEDURE.

The CE marking process is shown in Fig. 1.3. It starts with the identification of applicable directives. Depending upon its application, its end use or the type of components it incorporates, a product may give rise to different risks and hence more than one directive may be applicable. In case of doubt regarding the applicability of a particular directive it is prudent to download a copy of the directive then to refer the scope of the directive. It must be understood here that it is the responsibility of the manufacturer to ascertain whether or not his product falls under the scope of a particular directive. Once directive(s) have been identified, the manufacturer must follow one of the routes or "conformity assessment modules" prescribed by the directive for his category of equipment.

2

THE LOW VOLTAGE DIRECTIVE

2.1 INTRODUCTION

The directive on "electrical equipment designed for use within certain voltage limits" popularly known as the "low voltage directive" (or LVD in short) is perhaps the oldest directive and has been in force since 1973. It would not be an exaggeration if someone refers to it as "the mother of all directives" –which it is. The directives has been revised many times, the latest revision being the 2016 version of the directive codified as 2014/35/EC published on 26th February 2014 and replaces the old directive 2006/95/EC. The new directive is a "recast" of the older version which means that all major provisions of the older version remain as they are. The new directive has certain requirements to fulfil the new legislative framework namely requirements for market surveillance and those regarding competence of subsidiaries and sub-contracted agencies of notified bodies. Further the roles of manufacturer, importer, authorized representative, distributor and assembler have been clearly defined. The new directive came into force on 20th April 2016. As discussed in section 2.3, the LVD ensures

2.2. CONTENTS OF THE LOW VOLTAGE DIRECTIVE

As with any other directive, the LVD starts with what are called as "recitals" typically beginning with the word "whereas" as is the case with legal document -which LVD is. It is then followed by "articles" which give information regarding a particular aspect of electrical safety. The directive ends with a number of annexures giving details of procedures to be followed for documentation, CE marking, risk analysis etc. Let us take a look at the various articles one by one.

2.3. ARTICLE 1 : SCOPE

This article deals with the subject and scope of the directive and calls for providing high level of protection to person, animals and property and is applicable to all electrical equipment operating between 50 -1000VAC and 75-1500VDC. Products that are outside the scope are given is annexure II of the directive (see section 1.10.2).

2.4. ARTICLE 2 : DEFINITIONS

This article provides definitions of important terms used in the directive. Of importance to Indian manufacturers is the definition of importer who, as we have seen, is any natural or legal person established within the EU (i.e. who is a citizen of one of the European member states) who places electrical equipment from a third country on the European market. In simpler terms, manufacturers outside the EU can make their product available in the EU market through the importer who being a citizen of one of the member states of the EU is liable to pay for damages, in case the product is found to be unsafe. The manufacturer, on the other hand, is defined as any person who designs, assembles, labels and packs a product with a view to place it in the EU market under his own name or trademark (section 1.17.1).

2.14. ARTICLE 12,13 AND 14 : PRESUMPTION OF CONFORMITY

The article 12 states that equipment complying with harmonised EN standards are presumed to comply with the essential requirements of this directive. The new directive has a provision that if no harmonised EN standard exists for a particular product of a product family, then IEC standards or national standard of the European country (in which the product has been manufactured) can also give presumption of conformity.

2.15. ARTICLE 15 : DECLARATION OF CONFORMITY

After complying with the tests and evaluations (as mentioned in the applicable harmonised standards) the manufacturer signs as declaration of conformity. The requirements and contents of the D.O.C are given in Annexure IV of the directive have been explained in section 1.14. A suggested format is given in Fig. 2.2.

2.16. ARTICLE 16,17 : AFFIXING THE CE MARKING

This article tells how CE marking should be affixed on the product. The requirements have been dealt with in section 1.16.

2.17. ARTICLE 18, 19 AND 22 : MARKET SURVEILLANCE AND NON-COMPLIANCE

As seen in the earlier chapter, European authorities carry out market surveillance to weed out non-compliant products. This article says that, if the surveillance authorities establish that a particular product placed in the community market is non-complaint and presents a risk, then the concerned economic operator (importer, authorised representative or distributor) who has placed the product in the community market, is required to bring the product into compliance,

2.25.5 Risk Assessment and rationale for conformity

This section should provide description risk analysis and assessment carried out for the equipment for demonstrating compliance to the LVD. It should also include a list of the standards (harmonised or otherwise) applied in full or in part, explanation (rationale) as to how the hazards have been eliminated. Where standards have not been applied, descriptions of the solutions adopted to satisfy the essential requirements aspects of LVD. The section may also results of design calculations made, examinations carried out, etc. This will prove to surveillance authorities the due-diligence of the manufacturer and his sincere efforts towards designing a safe product. Risk assessment has been discussed in chapter 16.

2.25.6. Description of quality system.

Since the CE marking is based on testing and evaluation of only one representative sample of the product, the quality system of the manufacturer should ensure that all samples coming out of the production line are identical to the sample tested. This section should give a description to prove how the manufacturer's quality system ensures this. One can include a detailed description of the quality system, production processes, quality checks, quality procedures regarding design/component/vendor change, inventory management and so on.

2.25.7. Test reports.

This section should include copies of all test reports both internal and third party which will help to prove that the manufacturer has taken all efforts to make the product compliant with the requirements of the directive. It may be soft copy form.

3

THE CONCEPT OF ELECTRICAL SAFETY

3.1. INTRODUCTION.

The low voltage directive is the primary directive for safety compliance of electrical equipment. When the first version was published way back in 1973, it was a real ground breaker in European standardization and certification because of the numerous EN and IEC standards published thereafter, setting the technical rules for equipment and components. The LVD covers safety of all electrical products that operate at 50 to 1,000 VAC or 75 to 1,500 VDC. It applies to products supplied for both consumer and industrial use and effects consumer protection, health and safety at work. Products covered by the LVD include Information Technology Equipment (EN/IEC 60950), Test and Measurement Devices for Laboratory Use (EN/IEC 61010-1), Audio Video and Similar Apparatus for Household Use (EN/IEC 60065), Household and similar appliances (EN/IEC 60335), and others.

Electrical safety is not limited only to products covered by LVD. According to the machinery directive, machine designers must also be aware of electrical safety since machines pose electrical hazards and

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ELECTRIC SHOCK HAZARD.

4.1 INTRODUCTION

It is a common knowledge that 230V wall-outlet voltages can cause severe shock or death. But rather than the voltage, it the current (which is forced by the voltage) that causes electric shock when it flows through the human body. Having said that, people who know this generally underestimate how little current it takes to electrocute a person. Take the example of a 15W night light which, at a mains voltage of 230V, can draw a current of about 65mA. This, a common man may think, is pretty low to cause any harm –but he does not how wrong he is till he is told that current above 10mA may be enough to cause severe trauma and even death! And that is true. We shall see how.

4.2 SEVERITY OF SHOCK HAZARD

The factors that determine the severity of an electrical hazard and its effect on the human body are voltage, current, resistance,

4.5 SEGREGATION OF CIRCUITS

It is worthwhile to note that only SELV and LCC circuits allow the operator unrestricted access to bare circuit components. TNV-1 circuit allow restricted contact to the operator. On the other hand TNV-2, TNV-3, ELV, hazardous voltage and hazardous energy circuits are considered as dangerous and unsafe and must be protected against operator contact.

Electric shock can occur when there is a breakdown of insulation (i.e. failure of insulation under electric stress when the discharge completely bridges the insulation) between SELV circuits/ accessible parts and parts that carry hazardous voltage. To avoid shock, hazardous voltage circuits and SELV circuits (user touchable) must be properly segregated by using following means :-

- Restricting access
- Isolating (by insulation and/or circuit separation).
- Separating by earthed screens (grounding).
- Using protection components/devices.

Where the above means are not practicable or as an added measure, suitable warning signs should be used to alert the operators and service personnel about hazards. Let us consider the measures one by one.

4.6 RESTRICTING ACCESS

Safety standards such as EN/IEC 60950 call for protection of the operator in operator access area against access (or contact) to bare parts carrying hazardous voltage, ELV circuit, solid functional and basic insulation and wiring for ELV & hazardous voltage. Unrestricted access is permitted to limited current and SELV circuits. The following diagrams illustrate accessibility requirements.

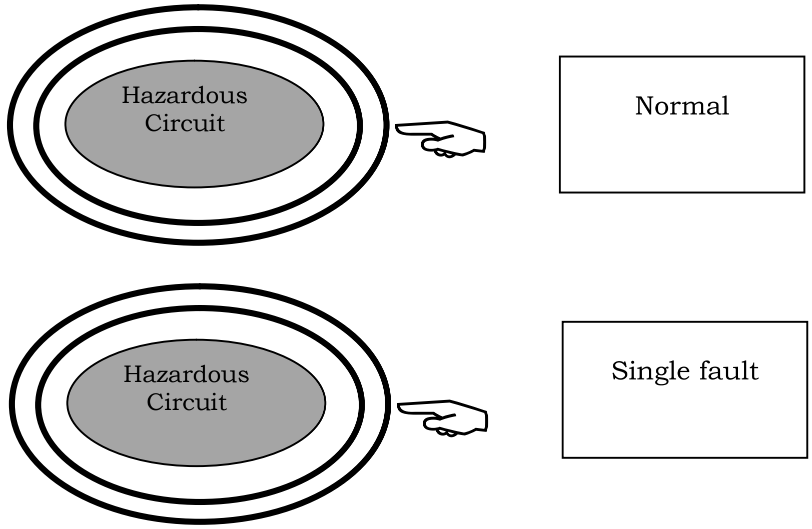

Fig 4.3: Accessibility of hazardous circuits

Hazardous voltage circuits have to be covered so that access is not possible under normal as well as single fault conditions as shown in Fig. 4.3.

As shown in Fig. 4.4, TNV-2 and TNV-3 circuits have to be covered so that access is not possible in normal operating condition.

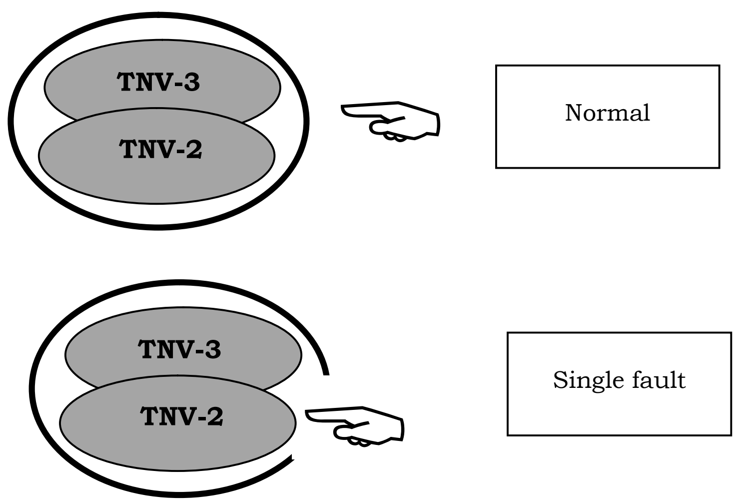

Fig 4.4: Accessibility of TNV-2 and TNV-3 circuits

4.7.2 Levels of protection (LOP)

Safety standards dictate certain levels of protection (LOP) or means of operator protection (MOOP) between various types of circuits that we have discussed in section 4.7.1. The method of protection is one insulation plus another layer of insulation or earth connection or one protection component/device. The Fig. 4.9 shows a general arrangement of insulation requirement in a typical circuit. Internal floating ELV needs to be protected from primary hazardous voltage by one level of protection (i.e. basic insulation). Accessible terminals need to be protected from internal floating ELV by one level of protection. However, if the ELV circuit is grounded then no protection is required for accessible parts since grounding provides one level of protection. Now, accessible terminals need to be protected from internal primary carrying hazardous voltages by two levels of protection. Similarly, internal secondary circuits carrying SELV voltages should be protected from primary hazardous voltage by two levels of protection.

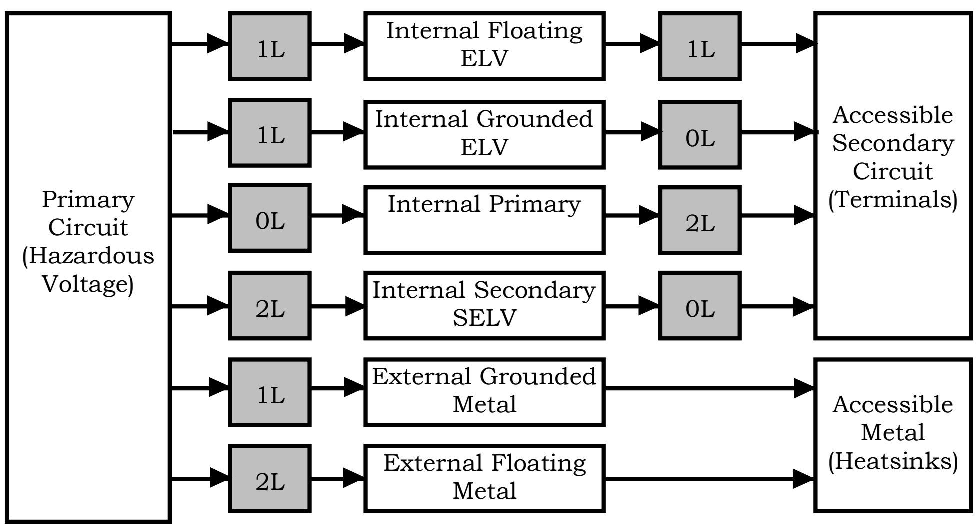

Fig 4.9 : Levels Of Protection

External grounded metal must be protected from primary hazardous voltage by one level of protection (since the ground already primary carries hazardous voltage and the secondary is at SELV. Hence the insulation between primary and secondary has to be double or reinforced. The opto-coupler bridges SELV and hazardous voltage and hence it should also have reinforced insulation. Functional insulation is required between output contacts (which are at SELV) & body and between ground & earth.

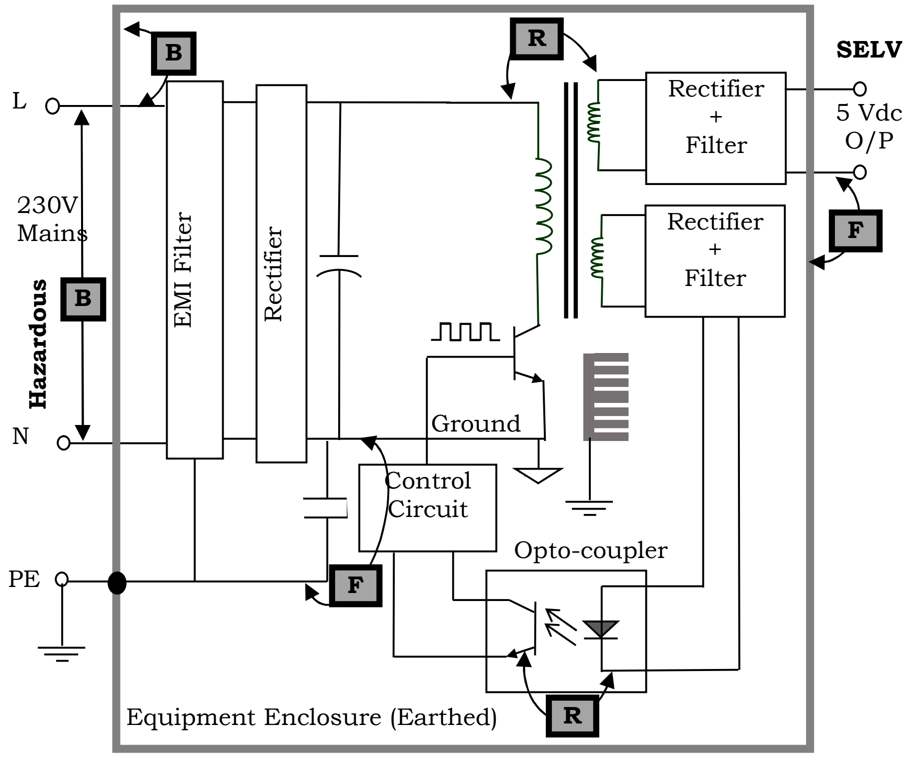

Fig 4.12: Insulation Requirements for SMPS

4.7.5 Tests for insulation

Apart from the insulation requirements which we have seen in previous section, safety standards also specify that the electric strength of the insulating materials used within the equipment should be "adequate" (IEC 60950). Hence the insulation should be subjected to

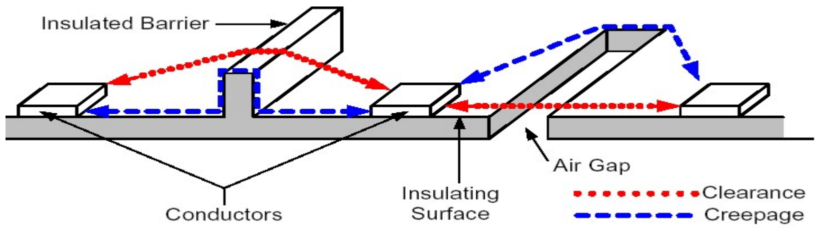

Fig. 4.15: Creepage and clearance

4.7.8.2 Clearance

Clearance (see Fig. 4.15) is defined as the shortest distance through air between two conducting parts. A very good analogy is a flying insect which will go from one point to the other directly through the air. For component leads, clearance distance can be visualised as the "line-of-sight" distance. Clearance is heavily influenced by the quality of the air. Normally 1mm of air gap will breakdown at 3 kV at sea level. At such a high voltage, electrons are stripped of their atoms and become free, causing air to become conductive. The presence of humidity, moisture, conductive particles can cause the breakdown to happen at lower voltages as there are already some free electrons to start with. Another important factor is the altitude. Now this comes as a surprise as one may think what does altitude have to do with insulation breakdown? Well as the altitude increases, the air density decreases and the dielectric properties of air change. The air is no longer a good insulator (until it reaches vacuum) which causes it to breakdown at lower voltages. This is called the Paschen effect and the Paschen's curve describes electric discharge voltage as a function of atmospheric pressure. As shown in the Fig. 4.16, there are four curves. Let us consider an air gap of 10cm. As per curve I it will break down at about 30,000 volts at sea level. At 50,000 feet (approx. altitude at which commercial jets fly) the same 10cm air gap will breakdown at about 6,000 volts (Curve III). So as the operational altitude increases, the missing a non-compliant creepage and clearance distance that may be hard to reach or measure. When in doubt, more precise tools like digital vernier can be used. For measurements on a PCB, small monocle type optical comparators with calibrated scale can be used. Nowadays 3-D product design softwares are used for product design which have the added feature of incorporating creepage and clearance distances in the design.

One more important aspect is taking into consideration small gaps, grooves and ridges on components or PCB that one may encounter during measurement. As a general rule, for pollution degree 2, gaps less than 1mm should be ignored during measurement due to potential build-up of dust within an equipment. As shown in the fig 4.22a, the gap is equal to or more than 1mm and hence should be considered during creepage measurement (shown dotted) i.e. creepage will be more than clearance while as shown in fig 4.22b, the gap is less than 1mm and hence should be ignored during creepage measurement (i.e. creepage will be equal to clearance). Another example may be a "V" shaped groove (Fig 4.22c) or slot where the creepage is not measured to the bottom of the "V" but stops and cuts across the "V" at the 1mm width point.

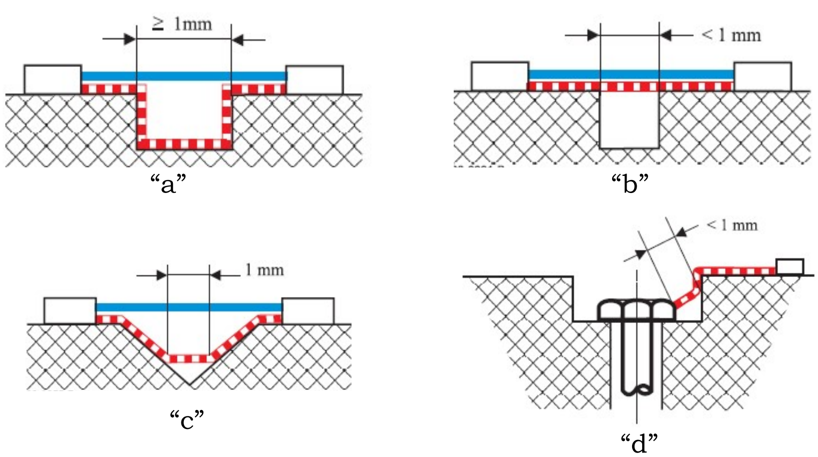

Fig 4.22: Creepage measurement over grooves and slots.

5

ENERGY HAZARDS

5.1 INTRODUCTION

Up till now we have seen hazards due to circuit voltages. But often than not both voltage and current exist in a circuit and they together can cause energy hazards. It must be stressed that energy hazards can exist even in low voltage circuits where the current is high. They can also exist in outputs of high current power supplies. Injury can result in direct bums or burns caused by ejection of molten metal due to short circuits between adjacent poles (which may be caused for example by metal such as ring on finger bridging the supply outputs).

Energy sources can be classified as energy source 1 or ES1, ES2 and ES3 depending upon the available voltage and the available current. The voltage and current are the maximum that can be delivered by the source on any resistive load. The classification is as given in table 5.1 for DC and low frequency AC and in table 5.2 for medium and high frequency ac.

Table 5.1: Energy Source Classification For dc And Low Frequency ac

Energy Source Level		ES1 Limit	ES2 Limit	ES3 Limit
DC	Voltage	≤ 60V	>60≤ 120V	> ES2 Limit
	Current	≤ 2 mA	>2 ≤ 25mA	
AC (up to 1 kHz)	Voltage	≤ ES1 Limit	> ES1 Limit	
	Current	≤ 0.5 mA rms	>0.5mA ≤10mArms	

Table 5.2 : Energy source classification for medium & high freq. AC

Energy Source Level		ES1 Limit	ES2 Limit	ES3 Limit
AC (1 kHz up to 100kHz)	Voltage	≤ ES1 limit Umax = 50 V	≥ ES1 limit < ES2 limit U max = 120 V	> ES2 Limit
	Current	≤ 0.5 mA x f (kHz) Imax = 50mA	≤ 10 mA x 0.5 f (kHz) Imax = 140mA	
AC (above 100kHz)	Voltage	≤ 50V	≤ 120V	
	Current	≤ 50mA	≤140mA	

All values in rms. Table to be seen in conjunction with Fig. 5.1

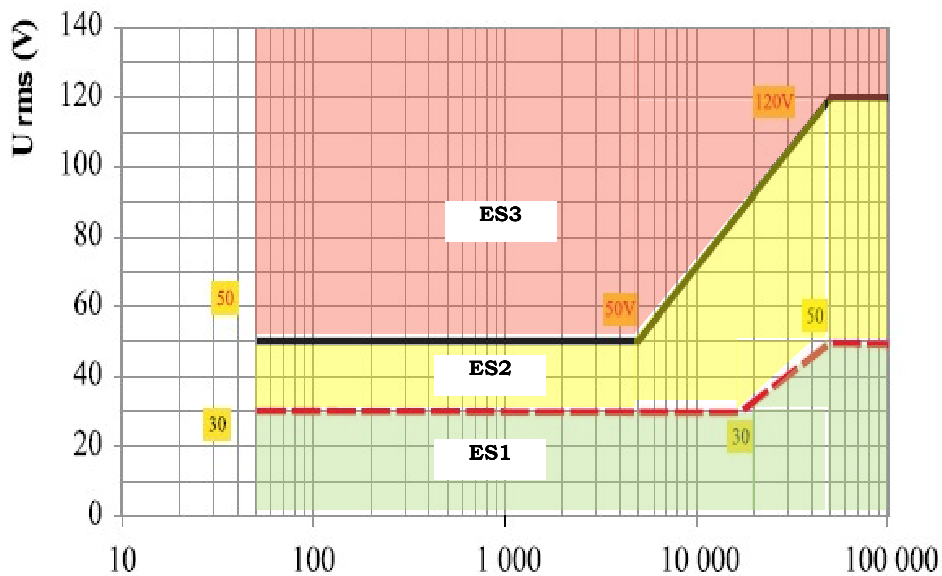

Fig. 5.1: Voltage Limits Depending On Frequency

6

FIRE HAZARDS

6.1 INTRODUCTION

Fire or flammability hazards, as the name suggests, are a result of excessive temperature and possibility of fire. Flammability is defined as "ability of a product or material to burn with a flame under specific conditions". Flammability requirements are intended to minimize the risk of ignition and the spread of flame, both within the product and to the outside by the use of appropriate materials, components and by suitable construction. These can be reduced by reducing the risk of ignition AND minimizing the spread of flame by limiting the temperature of components under normal operating conditions and under single fault conditions or containing the fire.

Keeping the above facts in mind, safety standards (like IEC 60950) accept flammability hazards to have been taken care of if one of the following two methods demonstrate that risk of ignition and spread of flame has been minimised:-

METHOD 1: There is no spread of fire after certain single fault conditions have been simulated (that can cause the spread of fire outside the equipment).

OR

METHOD 2: The sources of ignition within the equipment have been reduced or eliminated, fire is contained within the equipment by using flame retardant materials and using a fire enclosure.

Let us take a look at these one by one

6.2 SIMULATING SINGLE FAULT CONDITIONS

This is the preferred test method for an equipment with "small" number of electronic components as per IEC 60950. The standard however, does not specify how small is "small". Single fault conditions (see section 14.13), especially those related to heating circuits or cooling mechanisms are simulated thereby demonstrating that temperature rise is below specified value (as per thermal class) and that there is no spread of fire.

Conformity with requirements for protection against the spread of fire is checked by placing the equipment on white tissue-paper and covering the equipment with cheesecloth (100% cotton cloth). Upon simulation of single fault condition, molten metal, burning insulation, flaming particles, etc. should not fall and there should be no charring, glowing, or flaming of the tissue paper or cheese cloth.

6.3 ELIMINATING / REDUCING SOURCES OF IGNITION

This is the preferred test method for equipment containing "large" number of electronic components as per IEC 60950.

Potential ignition source is a location where electrical energy can cause ignition. Such sources can be classified as:-

Potential ignition source 1: Location where an arc may occur due to the opening of a conductor or a contact. If the open circuit voltage

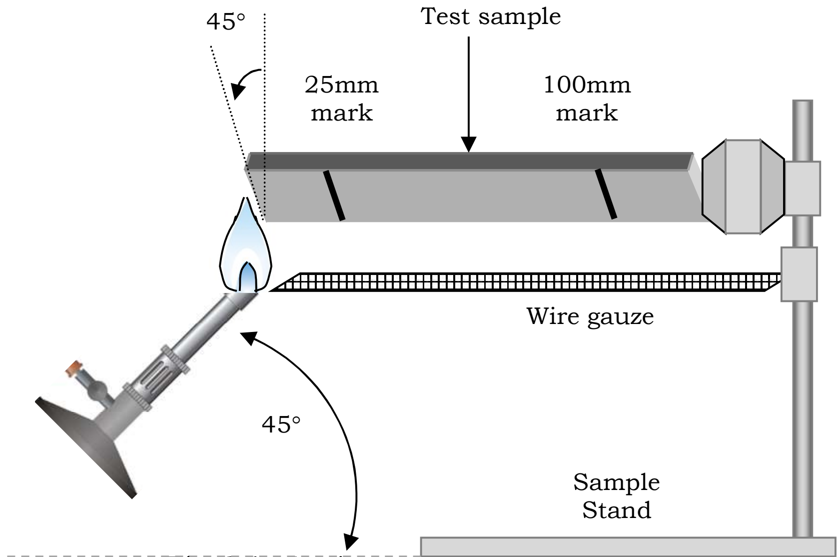

Fig.6.1: Horizontal Burning Test Set-up

The materials are classified as HB, HB40 or HB75 (HB = horizontal burning) in accordance with the criteria given in table 6.1.

It is clear from the above table that, as far as IEC is concerned, HB is the best rating, followed by HB 40 and then HB 75. According to 2013 version of IEC 60695-11-10, HB 75 is likely to be discontinued.

Table 6.1: Horizontal Burning Classification

HB Type	Criteria
HB	The specimen does not burn with a flame after the ignition source is removed. OR The specimen continues to burn with a flame after removal of the ignition source but the flame front does not pass the 100 mm mark; OR If the flame front passes the 100 mm mark :- • it does not have a linear burning rate exceeding 40 mm/min for a thickness of 3,0 mm to 13,0 mm OR • a linear burning rate not exceeding 75 mm/min for a thickness of less than 3,0 mm;

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MECHANICAL & OTHER HAZARDS

7.1 INTRODUCTION

In previous chapter we have seen electrical hazards like shock and fire hazards along with ways and means to comply with them. Apart from electrical (and resultant fire) hazards, safety standards also call for compliance to certain other “non-electrical” hazards that a particular equipment may pose during its normal operation, installation, commissioning, repairs or during movement. In this chapter we will take a look at some other hazards that are addressed by safety standards most notably mechanical, heat, sound, radiation, chemical, material etc. Hazards in each of these categories have the potential to cause injuries or in some extreme cases, even death.

7.2 MECHANICAL HAZARDS

Any electrical equipment should have adequate mechanical strength and it its construction should be such that no hazard is created during routine handling of the equipment. Enclosures, handles, knobs, and the like should have adequate strength to withstand rough handling during normal use and pass the relevant tests as described in the standards. Depending on the product and possible hazards the tests include force tests, impact tests and drop tests.

An equipment during it normal use or under single fault condition may give rise to mechanical hazards which include but not limited to

- Sharp edges which could cause cuts.
- Moving parts that could crush body parts or penetrate the skin.
- Unstable equipment that could fall on a person while in use or while being moved.
- Falling equipment, resulting from breakage of the carrying device (wall mounting bracket or other support part).
- Expelled parts from the equipment.

7.2.1 Cutting Hazard

The edges and comers of enclosures that are easily touched can give rise to cutting hazard. These should be rounded, deburred or smoothened to prevent hazards during normal use. Where sharp edges are needed for functional purposes and access is unavoidable, guarding means should be used to minimise the risk of unintentional contact with such edges. If none of the prevention methods is practical, a clear warning should be reliably affixed (see section 13.2) in a prominent position to warn the user of eminent hazard.

7.2.2 Hazards due to moving parts

Hazardous moving parts should be so arranged or guarded so as to provide adequate protection against personal injury. Protection of the operator is most important, and suitable construction methods should be provided to prevent access to hazardous parts. Permitted methods include locating the moving parts in areas that are not operator-

8
COMPONENT APPROVAL

8.1 INTRODUCTION

Any item that is used in the composition of, or intended to be built into, end products or machines, is called a component. Products on the other hand, are stand-alone equipment that are comprised of components and are ready to use by an operator. With regard to equipment safety, there are two types of safety sensitive components namely "critical" components and "safety" components.

Critical components are components that may influence the safety of a product, such as those that operate at mains supply (120/230/400 Vac) or hazardous voltages (> 50 Vac or 60 Vdc). These components perform functions that protect against electric shock, explosion, mechanical hazards, fire, etc. Examples of critical components are inlets, filters, switches, motors, circuit breakers, opto-couplers, PCBs, power supplies, X capacitors, Y capacitors and transformers. Components that may operate at lower voltages (i.e., 12 or 24 V) and may affect safety are also considered critical components

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EQUIPMENT CLASSIFICATION

9.1 INTRODUCTION

The electric shock classification of equipment determines the extent of insulation needed to protect users and service personnel. Insulation is safer than fusing. As we have seen, insulation is achieved by separating circuits and is required, for example, between user-accessible parts and live parts via insulation layers, thickness, and/or distance (creepage and clearance). As far as safety standards are concerned, equipment are classified according to the operating voltages (including insulation type) or according to mobility.

9.2 CLASSIFICATION ACCORDING TO VOLTAGE

There are three classes of equipment namely Class I, II and III, with Class I and II products generally covered by the Low Voltage directive depending on the type of operating voltage and insulation. Let's us consider these one by one.

9.2.1 Class I equipment

This type of equipment utilizes earth as second means of protection in addition to basic insulation. They are typically mains operated (i.e., 115/230/400 VAC) electrical products such as desktop computers, test and measurement devices, machines, or stationary appliances. They can be easily identified as having a three pin plug (for single phase equipment) where the third pin connects the equipment chassis to utility earth.

Class I equipment must have their chassis connected to electrical earth by an earth conductor. The failure of equipment's basic insulation may cause a metal chassis to become "live" at full mains voltage. To safeguard against electric shock from metal cased electrical equipment, the metal chassis or case or any exposed metal of equipment (other than double-insulated items) must incorporate a protective earthing (PE) conductor connected to the earth pin of an approved three pin plug incorporating an "Earth" terminal. The earth pin is longer than the other two pins so that it is first to make contact when the pin is inserted and the last to break contact when the plug is withdrawn. By connecting to the metal chassis of the equipment, the protective earth wire keeps all this metal at earth potential. What this means is that it is impossible to get an electric shock even when the chassis is connected directly to the live voltage. A fault in the equipment which causes a live conductor to contact the casing will cause a current to flow in the earth conductor. This current should trip either an over current device (fuse or circuit breaker) or a residual current circuit breaker which will cut off the supply of electricity to the equipment.

9.2.2 Class II equipment

Class II equipment are ungrounded and rely solely on second insulation layer (or separation) in addition to basic insulation. Examples include TVs, power tools, portable radios, and other handheld

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RATING AND MARKING LABELS

10.1 INTRODUCTION

Safety standards require every equipment to bear markings and rating labels and in order to properly design these, it is important to know the equipment's actual power requirements. Equipment rating should be decided only after actual measurements as calculating the equipment's input is often unreliable. The equipment's power input under normal operating conditions and with all possible loads applied should be measured at actual. The input is verified by measuring the input current to the product. The product's input power at the desired operating voltage, which is typically 230 VAC (or 400 VAC for three phase) are measured and recorded. The old voltages of 220 to 240 VAC (or 380/415 VAC) may still apply in some countries. It should be noted that 120 VAC, common in the United States, is not generally available in Europe. For ITE, measurements are taken at the desired frequency (50 Hz) and at ±10% for a singular voltage rating (230 VAC) or +6 to -10% for a voltage range (220 to 240 VAC). Because input current varies

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WIRING AND POWER DISCONNECT

11.1 WIRING

Wiring within an equipment is critical to safety and hence wire sizes and insulation must be suitable for their intended use and rating. It should have the proper classification, such as a V-2 flame rating for insulation on internal wiring or <HAR> marked for external fixed power cords.

The cross sectional area of the wires should be adequate for the current they are intended to carry under normal load conditions. All wires used in distribution of primary circuit power should be protected against over-current and short circuit by protective devices of suitable rating. Wires should be protected against mechanical damages and it should be ensured that they do not come in contact with moving parts, burrs, sharp points, cutting edges etc. Non-detachable power chords entering through an opening in a metallic enclosure should be through an inlet bushing or chord guard to prevent abrasion. Chord guards or bushing should be made of insulating material, fixed in a reliable manner (requiring a tool to remove) and should extend beyond the inlet opening by at least five times the chord diameter.

Internal wires should be held in place independent (second or double fixing) of the connection by wire ties or similar methods, to meet single-fault requirement that reduces strain on wire and terminal connections and prevents loosening of terminals. The second fixing should be as close as possible to the initial connection point so that if the wire breaks or comes loose, it will not make contact with metal or live parts. It is assumed that two independent fixings will not come loose. Using proper IEC type terminals as instructed by the terminal manufacturer will reduce any termination problems. Wires are not considered reliably secured to terminals unless there is either an additional fixing provided near the terminal or the terminal has terminators (i.e. ring lugs). For press-on or similar terminators, a double crimp is preferred (e.g. one crimp on the wire and one on the insulation).

Because of the many plug and socket types in Europe, designers often prefer inlets for use with detachable chord-sets instead of fixed cords and plugs. IEC 60320 type inlets (Fig 11.1) are available for up to 15 A input, and IEC 60309 pin and sleeve types are available through 150 A or higher.

IEC 60320 type inlet

IEC 60309 pin and sleeve

Fig. 11.1: Power Inlet.

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CIRCUIT AND THERMAL PROTECTION

12.1 INTRODUCTION

Circuit protection devices, such as fuses, breakers, or fault-interrupters, may be required in case excessive current is drawn as a result of a short circuit, overcurrent, or earth fault. Thermal protection devices limit uncontrolled rise in temperature in case of faults and prevent a fire hazard.

12.2 CIRCUIT PROTECTION

Fuses and circuit breakers are preferred devices for circuit protection. Although several options exist, circuit breakers are normally preferred over fuses. In some of the newer devices several functions are combined into one, thereby reducing the total number of components. An example of this is a combined power switch/ circuit-breaker. The switch/breaker is used as a switch and breaker and senses each line and opens all lines, except the grounded line, simultaneously when a

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WARNINGS AND INSTRUCTIONS

13.1 INTRODUCTION

In order to avoid hazards when operating, installing, maintaining, transporting, or storing equipment, safety information should be provided by the manufacturer in the form of "warning symbols" on the product, along with "instructions" in the product documentation. Maintenance instructions are normally made available only to service personnel. For pluggable equipment intended for user installation, operating and installation instructions should be made available to the user. Further, the instructions should be in a language acceptable to the country in which the equipment is to be installed and used.

Warnings are required for all hazards on any enclosure panel or door that does not clearly show that it contains a hazard in order to notify the operator/user. The service persons must also be warned of any possible hazards such as high voltage or energy, moving parts, high temperature, or laser radiation before they access a compartment.

Additional warning symbols may be required on internal covers and adjacent to hazards within the compartments to protect against accidental or inadvertent contact.

In some cases, a warning may be considered adequate if it is not possible to make hazardous moving parts directly involved in the process completely inaccessible and where the associated hazard is obvious to the operator. In such a case, where fingers, jewellery, clothing, etc. can be drawn into the moving parts, a warning should be provided in a visible and prominent position (see table 13.1). An example of where it may not be possible to guard the hazard is the visible moving parts of a paper cutter where hand-feeding is required. Warnings are only permitted when no other means are possible and should not take the place of a safe design. For example, a moving parts warning is allowed only when the hazard is directly involved in the production process and there are no other possible options i.e., guards, interlocks, stop-switch, sensors etc. Therefore, if a guard or other protection means is possible, it must be employed.

13.2 COMMON WARNINGS AND CAUTIONS

Some of the common warnings and caution instructions are discussed in this section and should be a part of instructions or manual supplied along with the equipment. These are given below. Kindly note that warnings in addition to those given below may be required depending upon the safety standard being referred.

CAUTION !! Double-pole/neutral fusing. Disconnect power before servicing.

CAUTION !! This unit has two power cords. Remove both cords to disconnect power.

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SAFETY TESTING

14.1 INTRODUCTION

Once a product meets all of the applicable design, component, and construction requirements detailed in the previous sections and the relevant safety standards, the electrical safety testing begins. Type tests are performed on a representative test sample or prototype of the equipment in question. The terms “type” and “model” are interchangeable. When a product complies with the component and construction requirements and successful test results are achieved, then all subsequent samples of a given “type” are assumed to comply (e.g., of the same design and identification number [model number]) without testing . The product should be tested at normal operating conditions and the test carried out under the most unfavourable combination of the manufacturer's parameters for supply voltage, frequency, and so on and under full load.

The number of tests will vary from only a few tests, such as for equipment that uses all EU type-approved critical and safety components, to numerous testing for complex equipment using custom or non-approved components and subassemblies. Using non-approved components, where conformity is not verified, may require considerably more testing on the end-product manufacturer's part.

In the sections that follow, we will discuss in detail about the various safety tests prescribed by safety standards. While discussing, an effort has been made to cover the requirements of most safety standards. However, it is always prudent to refer the particular safety standard for specific requirements. Also for machinery, the subsequent sections and the relevant machine safety standards should also be met prior to testing.

14.2 POWER CONSUMPTION.

This test primarily *e*stablishes total power (current) consumed by the product for input rating, circuit protection, and testing.

14.3 INPUT TEST

This test ensures that the equipment draws power as per rating label printed on the equipment or specified in the manual. The equipment is connected to its rated supply voltage while input current is monitored under rated load conditions. The equipment should not draw a current above 110% of rated load.

14.4 VOLTAGE WITHSTAND TEST.

As discussed earlier, a dielectric barrier is commonly used as one of the means of ensuring separation between hazardous circuits and user accessible circuits or surfaces. The voltage withstand test evaluates the ability of a product's insulation to withstand high voltage between circuits. It is also sometimes referred to as hi-pot, HV test or dielectric strength test. The dielectric strength test is a fundamental method of ensuring that a product is safe before it is placed on the even calling for more than one RC network depending upon where the leakage current is being measured (like patient leads). This test is carried out at rated mains voltage or 110% of rated voltage and under normal conditions and single fault conditions (like neutral open and reversed line and neutral). Safety standards provide certain upper limit for leakage current. For Class I hand held products the limit is normally 0.75mA, for class I movable and pluggable products it is 3.5mA , for class III product it is around 0.25 mA. For certain critical products like medical equipment, it may even be lower.

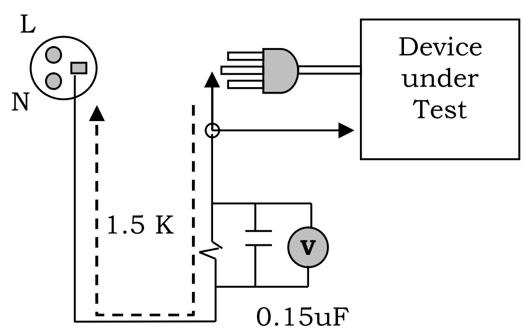

Fig. 14.3: Leakage Current Test Set-up

14.7 GROUND CONTINUITY AND GROUND BOND TEST.

The purpose of a ground continuity test is to verify that all conductive parts of a product that are exposed to user contact are connected to the protective earth (PE). The theory is that if an insulation failure occurs that connects power line voltage to an exposed part and a user then comes into contact with that part, current will flow through the low resistance ground path to the green wire, tripping a circuit breaker or blowing a fuse, rather than flowing through the higher resistance of the user's body. Connecting all exposed conductive parts solidly to PE safely diverts the current away from the person. The lower the ground resistance, the higher is the fault current and quicker the action of protective devices. Ground continuity tests are normally

14.12 MECHANICAL TESTS.

The aim of these tests is that in normal use, equipment must not pose mechanical hazards. The standard EN 60950 gives a good description of the enclosure tests for stability and mechanical hazards and is the basis for this section.

14.12.1 Stability test

The following stability tests are performed to assess the stability of an equipment:-

- An unit should not overbalance when tilted to an angle of 10° from its normal upright position (the doors and drawers are closed during the test).
- Floor-standing units with a mass of over 25 kg should not tip over when a force of up to 20% of its weight, but not more than 250 N, is applied in any direction except upward, not exceeding 2 m from the floor.
- Floor-standing units should not overbalance when an 800 N constant downward force is applied at the maximum moment to any horizontal working surface, or surface for obvious foothold, at a height not exceeding 1 m from the floor (the doors and drawers are closed during the test).

14.12.2 Steady force tests

To assess mechanical strength of external enclosures, these are subjected to a steady force test of 250 N ± 10 N for a period of 5 s. A suitable test tool is used which provides contact over a 30 mm diameter circular plane surface (Fig. 14 .8). The force is applied to the top, bottom and sides of the enclosure.

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SAFETY REQUIREMENTS FOR MACHINERY

15.1 INTRODUCTION

This section addresses additional requirements according to EN/IEC 60204-1 for the electrical safety of industrial machines so as to comply with the essential requirements of the LVD. The IEC/EN 60204-1 is a generic safety standard (type B) used in conjunction with the relevant machine safety standards (type C) which cover machine (mechanical) safety. A machine that complies with IEC/EN 60204-1 is presumed to conform to the requirements of the LVD. The requirements presented in the previous sections are applicable to machines and are for the most part contained in EN/IEC 60204-1 or other associated standards. We will take a look at some of the key electrical safety items that are often overlooked by the beginning machine safety evaluation. EN/IEC 60204-1 does not cover all machine safety requirements for guarding, interlocks, control etc. that are also applicable and listed in the Machinery directive. To ensure the machine's conformity with all the electrical safety requirements, a complete assessment according to EN/IEC 60204-1 and other applicable standards must be performed by

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RISK ASSESSMENT

16.1 INTRODUCTION

Electrical equipment, during its normal operation and use, will always pose a certain amount of risk. The manufacturer of the electrical equipment should endeavour to reduce the risk to such an extent that the residual risk (i.e. the risk remaining after all possible protective measures have been taken) is tolerable (i.e. which is accepted in a given context based on current values of society). The best way the manufacturer can do this is to get his product evaluated to the relevant electrical safety standard. The standardization committee, while preparing the standard, normally takes into consideration almost all the risks that can be posed by the equipment. There are certain documents (like the CENELEC guide 32) that guide the standard making committee regarding risk assessment. In other words risk assessment is ingrained in the basic structure of the standard and compliance to the standard means that the residual risk posed by the equipment is tolerable. Thus compliance to a relevant safety standard will give the manufacturer "presumption of conformity" with the essential requirements of the LVD.

Well, at-least that is what we thought up till now! Then comes the new LVD which makes risk assessment compulsory even if the equipment complies with all the requirements of the relevant product standards. This has left manufacturers confused and often than not there has been a query as to why a separate risk assessment is required when the standards itself are created on the basis of risk assessment and compliance with the standard means that all the possible risks have been addressed and complied with. Not that the risk assessment is new to manufacturers, especially those making measurement, control and laboratory use equipment where the product standard EN 61326-1 has a clause on risk assessment (Clause 17). However, in many a reports, this clause has simply been addressed (or should we say dismissed?) by such statement as "complied with all previous clauses and the equipment posses no risk in addition to these clauses".

While answering the query regarding a separate risk assessment (in addition to compliance to a standard), clarifications from the authorities suggest that even though the standards are made on the basis of risk assessment, a particular product may give rise to certain unforeseeable risks. Again not all products may present the same risks hence the new LVD requires that the conformity assessment procedure requires the manufacturer to carry out a risk assessment of the specific risks posed by the product and to address them in order to comply with all the essential health and safety requirements of the directive. Once these risks have been identified and addressed, the manufacturer can choose to apply the relevant harmonized standards. This seems to be in line with the Machinery directive, which calls for separate mechanical risk assessment in addition to the conformity with relevant harmonized standard.

16.7.1 Risk reduction by inherent design measures.

This is the risk reduction purely based on good engineering practices without resorting to additional components or protective measures per se. Measures include, but not restricted to separation of circuits carrying hazardous voltage, proper ingress protection measures, certified (approved) components, selection of proper and low flammability materials, selection of suitable technology, using SELV, geometrical design of enclosures to avoid injury, limitation of actuating forces, using ergonomic principles to reduce stress and many others.

16.7.2 Risk reduction by technical safety measures.

This is achieved by the application and use of additional safety components (that have no circuit function) which adequately reduce risk for the intended use and are appropriate for the application such as fuses and electrical cut-outs, thermal cut-outs, limit switches to limit movement, proximity switches, warning lamps, guards, fire enclosures, access control devices etc.

16.7.3 Risk reduction by instructions and warnings.

The risks that cannot be reduced even after implementing all possible design and technical measures are called residual risks. For example for our LCD projector we cannot reduce the light intensity below a certain level since the device will become useless or for a drilling machine or a grinding machine, one cannot possibly cover the entire drilling head or grinding tool. These risks can be reduced by providing adequate information the user through appropriate instructions in the product literature and by using relevant warning signs. Instruction to the user should clearly indicate residual risks and the measures to be taken by the user to take care of these risks, about

ANNEXURE 'A'

SAFETY CHECKLIST

Presented here is a suggested safety checklist in order to check all safety precautions before submitting the equipment for safety evaluation. This list is for preliminary safety review only and does not take the place of complete evaluation or test reports. Companies are advised to make their own checklist depending on the standard that is being referred to.

SAFETY AND CRITICAL COMPONENTS

All critical components comply with respective type approval standards (IEC/EN)? (Pl. tick below)

Verified by:-

- ☐ Approval marks
- ☐ Certificates
- ☐ Test reports
- ☐ Other

COMPONENTS CONFORMITY VERIFICATION

- ☐ Certificates and reports available.
- ☐ Approval marks visible on components.
- ☐ Components needing additional IEC confirmation.
- ☐ Transformer
- ☐ Motor,
- ☐ Other.

Checked by:

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