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NEWSLETTER FOR MANUFACTURING COMMUNITY

WORD FOR THE DAY: **Electrical Fires (A review of book "ELECTRICAL FIRES AND FAILURES - A Prevention and Troubleshooting Guide" written by A A Hattangadi)**

At Maintenance Circle, the team strives its best to provide readers with the information that is closer to reality, practical and immediately useful in everyday tasks. So, during this week's expedition, we stumbled upon a book written in most practical manner that even an operator can understand and make use of the knowledge.

Although there are quite a books available covering "theoretical" aspects, this books stands apart in conveying even the fundamentals aspects of electricity and its importance in most practical manner. Electricity is one invisible energy that can cause catastrophe, at the slightest of negligence. Here we have reproduced few pages from third chapter which emphasizes on electrical fires and its importance.

Keeping aside few specific details of Indian Electrical Rules, the contents and concepts presented in this book are relevant throughout the world.

The book contains twenty chapters touching upon day-to-day aspects of electrical (mis)management. It is a book that must be on tables of all shop floor personnel, especially who are involved in maintenance.

Book Title: *ELECTRICAL FIRES AND FAILURES – Prevention and Troubleshooting Guide*
Author: *Mr. A A Hattangadi, Former General Manager, Chittaranjan Locomotive Works*
Publisher: *Tata McGraw-Hill Publishing Company Limited, New Delhi*
Availability: *At most leading book stalls and on popular on-line book shops.*

INTRODUCTION

Fires which originate from defects in electrical equipment are called electrical fires. A few examples of such fires are briefly described below:

- The insulating board which formed the front panel of an electrical equipment cubicle for the control of a 50 H.P. electrical motor got charred between two adjacent terminals. There was a short circuit and a momentary arc. The circuit breaker operated immediately and disconnected the power supply to the defective zone. The motor stopped and there was no fire. Repairs were affected and normal operations were restored within four hours.

- In another incident, a similar failure occurred in an unattended area of a power station. The local protective system failed to operate and the arc continued to flare and the entire front caught fire. The equipment was totally damaged due to single phasing. It took six weeks to obtain the required materials and to repair the cubicle and motor. Generation was restored after 18 hours of shutdown by installing a spare cubicle and motor.

- A parallel clamp which connected a lead-wire to an overhead transmission line overheated and melted. One of the three lines fell to the ground. There was arcing and some *jhuggies (labors)* caught out fire. Three persons were electrocuted. It took six hours to carry out repairs and restore power supply to an industry

- A transformer in an outdoor substation suddenly exploded. Supply to a residential colony was restored after three days by replacing the burnt transformer. Investigation showed the parts of an off-load tap changer inside the transformer had melted. Repairs took several months.

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- A smoothing reactor in a 25KV alternating current electric locomotive caught fire while the train was still far away from any station. The train came to a stop and the fire spreads to the interior of the locomotive was so badly damaged that it had to be written off from further service.

- In a *shamiana*, the temporary wiring was fixed close to the synthetic cloth used for the walls and roof. As the protective system was defective, a short circuit in the wiring led to overheating and continuous arcing. This caused the synthetic material to catch fire. Due to the inflammability of the material and the wind direction, the fire spread very rapidly. In the stampede which followed, there was much loss of life.

There are many more incidents which are reported regularly in the press year after year. However, there are hundreds of other cases of electrical fires which are reported by the press either because they do not involve any loss of life ore because they do not occur in public places. These are incidents which occur in factories, railway installations, power stations, warehouses, and buildings.

The so-called accidental fires are caused by a variety of reasons such as:

- Carelessly thrown lighted matches or cigarette butts
- Careless use of heating appliances like pressing irons and radiant heaters.
- Careless storage and handling of highly inflammable materials
- Overheating, sparking or arcing due to electrical failures.

We shall not discuss the first three of the four types of causes of fire mentioned above. We shall discuss fires of electrical origin starting in electrical equipment due to defects in the design, manufactures installation or maintenance of the equipment.

The effects of electrical fires vary in magnitude from minor burning of an insulating board or an insulated cable to a major disaster involving several hundred facilities and injuries amongst the public, apart from property losses worth crores of rupees. The severity the effects depends on local conditions such as breeze, inflammability of surrounding materials, availability and effectiveness of fire detection and fire fighting systems and the crowd behavior under crisis conditions. All these are, for all practical purposes, beyond the control of the electrical engineer.

The best possible course of action to minimize losses is to attack the problem at its root, i.e., to prevent the fire from starting. It is possible to prevent electrical failures and zero failure performance of electrical equipment is well within our reach. The technology needed for this purpose is already available. The lacuna is only with regard to the training of the electrical artisans, supervisors and engineers. This book provides the course material for the required training.

SCOPE OF THIS CHAPTER

In Chapter 1, it was pointed out that seed-defects in electrical equipment and installations grow into defects and failures and that some failures develop into fires and, perhaps, disaster. In this chapter, it is proposed to discuss four main types of causes of electrical fires, viz.

a) Overloading
b) Insulation failures
c) Pressure contact failures
d) Conductor fractures
e)

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Whereas insulation failures and overloading are more frequent than pressure contact failures and conductor fractures, fires are more likely to be due to the latter two causes. The apparent paradox is explained by the fact that all electrical installations are provided with automatic protective devices which are capable of preventing fire when the fault is either overloading or an insulation failure {See figs 3.3(a) and 3.3(b)}

Unfortunately, there is no such device available for general use to guard against pressure contact failures or conductor fractures.

The prevention of electrical fires requires two fold actions:

- Protection system must be designed, manufactured, installed and maintained correctly.
- Great care must be exercised in designing, manufacturing and installing all components involving pressure contacts and conductors.

The technology involved in both the above lines of action is extremely simple. It is well standardized and quality assurance measures are very practical. Unfortunately, even the few simple rules which must be followed are not fully understood by many people, including some who are responsible for ensuring safety. The main need is for the training of the concerned staff to explain the significance of the apparently trivial requirements which have to be ensured.

The need for a detailed discussion of this subject and the dissemination of information arises out of the following facts:

a) Electricity is an important necessity of modern life. Electrical installations are found in every home, office and factory.

b) Although electrical installations appear totally harmless in their normal state; they can, without warning and at any time of the day or night, release vast quantities of energy into small spaces when they are defective. White hot temperatures are reached in fractions of a second

c) The consequences of fires can sometimes be disastrous, especially when fire detection and control systems are inadequate. This is usually the case. A totally avoidable and simple defect can lead to loss of life, injuries and loss of property, quite out of proportion to the cost of preventing such disaster.

d) In general, a great deal of attention is paid to questions of fire fighting, rescue and restoration aspects not only by investigating agencies, but also y the media. Too little attention is given the root causes of such fires. Investigations and enquires into fires do not usually lead to any real preventive action.

e) There are many misconceptions regarding the causes of electrical fires. If no other causes can be identified, it seems to be the usual reaction ascribe the fire to “an electrical short-circuit in the wiring’ and to leave it at that, as if it is an uncontrollable natural phenomenon.

f) Even if the fire is indeed due to a defect in the electrical installation, a short circuit is the least likely cause. The true cause of fire is more likely to be either a defect in the protective system or a defect in an electrical connector or terminal board.

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g) Since there is a great deal of damage around the true fault centre, it is usually not possible to distinguish between cause and effect when looking at failed or burnt components. Erroneous conclusions may be reached as a result of errors in interpreting the visible evidence in the debris of the fire.

In this chapter, the modes and mechanisms of failures which culminate in fires will be discussed, as also some of the methods that can be adopted to prevent the introduction of seed-defects and the formation of defects which are the root causes of such failures.

We shall also discuss the investigation of electrical fires briefly in this chapter. This is important because, as stated earlier, it is difficult to distinguish cause from effect and special methods have to be adopted to arrive at the true causes of electrical failures which end up as fires.

CAUSES OF ELECTRICAL FIRES

As mentioned previously, there are four types of causes of electrical fires. In order to analyze the problem fully, it is desirable at the outset to distinguish clearly between these four possible failure modes due to different classes of defects in electrical installations.

a) Overloading of electrical equipment results in excessive currents. As the heat developed in the cables is proportional to the square of the current, they get overheated. The insulation on cables is generally made of materials which are damaged easily by excessive temperature. They may therefore lose their insulating properties and lead to short circuits. Since many insulating materials are combustible, they may even catch fire if the temperature rises to their ignition temperature.

b) Defects in or deterioration of electrical insulation may result in short circuits and continuous arcing, followed by ignition of the combustible insulating materials. Electric arc temperatures are extremely high and combustible materials in the vicinity catch fire unless the arc is extinguished within a fraction of a second.

c) Deterioration and failure of pressure contacts between various components in the electrical installation may result in sparking, localized overheating and burning of combustible insulating material. In such cases, there may no arcing initially, but the overheating is sufficient to start a fire. Short circuits and arcing may occur later, but they would not be the original cause of the fire.

d) Fracture of current conducting components due to mechanical stresses or strains may result in local arcing at the point of fracture. Electric arc temperatures are extremely high and combustible materials in the vicinity catch fire.

It would be desirable to clarify the difference between 'sparking' and 'arcing' at this stage.

Sparking is often an early stage in the process or mechanism of failure of pressure contacts. If there is poor contact (for one of several possible reasons) there will certainly be overheating. If the contact is momentarily broken but re-established quickly, there is sparking. This alternate break-make process may continue for hours or even days. It may even stop for a while and restart. Flickering of electric lights is often due to this type of problem. The point at which the intermittent contact is causing sparking can be detected by tracking the source of sound and light in the dead quiet and darkness of night. It is very likely to be found in the main switch-board or meter board or distribution pillar, particularly where aluminum conductors are used.

Arcing occurs when there is a positive gap in the path of the current, either when insulation fails or when a conductor or joint fractures while carrying a current. The arc current literally jumps across an air gap. The air gets ionized and the arc is maintained until the *power* is switched off by a protective device. At such temperatures, the radians heat transfer is often sufficiently high to ignite combustible materials some distance away from the arc.

Overloading of electrical equipment is usually the result of defective system design or unplanned or unauthorized additions to installations. The remedy is obvious. Sometimes, however, overloading of electrical machines may occur due to defects in the driven machinery such as pumps or other machines. The remedy in such cases is to provide adequate protective systems. Electrical fires due to overloading of driven machines are rare because the problem usually gets detected and attended in time.

While all these would, in the ultimate analysis, be due to defects in either design or manufacture or maintenance, a few special features modes may be referred to in this preliminary discussion of the of the subject.

a) Insulation failures are generally due to degradation of the insulation either as a result of normal ageing or as a result of some defect in design, manufacture or maintenance. It is possible to minimize insulation failures resulting from normal ageing by timely preventive replacement of cables; but the cables do not age at every location at the same rate and some failures may occur before the scheduled replacement is accomplished. Very few insulating materials are immune to such degradation, and there is no totally dependable, practical method available to monitor the condition of the insulation continuously. Insulation failures can be minimized but not totally eliminated. Prevention of electrical fires depends, therefore, on protective systems which can detect insulation failures and automatically and instantaneously switch off the power supply to the defective zone, thereby preventing the ignition of insulating materials.

b) Failures of pressure contacts are largely due to the degradation of the mechanical contact pressure due to a number of physical phenomena like thermal expansion/contraction, creep shrinkage, wear, elastic deformation, and vibration. All these can be prevented from causing failures by the proper mechanical stress levels and adequate care during manufacture and maintenance to ensure that essential design criteria are respected.

A very common type of pressure contact failure is seen when aluminum conductors are used with screw is not tightened adequately, the initial contact is bad and there is overheating. On the other hand, if the screw is over tightened, the conductor gets deformed and denied due to the softness of aluminum. The conductor may even fracture within a short time after commissioning. As explained elsewhere, the phenomenon of creep relaxation actually loosen the contact even when he screw is tightened correctly and remains unmoved. One way or another, eventual failure is certain when aluminum conductors are used with screwed terminals.
Failures of aluminum conductors at the terminals can be minimized by the use of clamp-type terminals, in which a clamp-plate is interposed between the screw and the wire. This helps to prevent deformation of the wire initially, but the problem of creep remains. Use of crimped sockets to terminate stranded aluminum conductors is also a practice which helps to prevent damage to the conductors during tightening of the screw. Care must, however, be taken in the selection and use of the crimping tools and sockets.

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Fractures of conductors are generally due to vibration, excessive mechanical stresses and sometimes, due to the use of sub-standard material. All these can be totally prevented by proper design and care during manufacture and maintenance. The likely defects and the precautions are needed to be taken.

The number of types of defect which can lead to failures and fires is very large, but fortunately, every one o them can be prevented by taking few simple precautions during design, manufacture or maintenance.

FIRES DUE TO FAILURE OF INSULATION

In the popular press and even in some technical investigation reports, the cause of fire is often described as “an electrical short circuit. All electrical installations have two or three conductors which are insulated from each other and from earthed structures. The voltage between such conductors is usually the system voltage, e.g. 230 volts, 400 volts etc. If there is any failure of insulation at any point, a short circuit is the result. The causes are excessive current, overheating and arcing at the point of short circuit.

Failure of insulation is quite common and by no means infrequent in an electrical installation. Installation failures can do occur due to a variety of reasons: the insulation may have deteriorated, as all insulating materials are bound to do, due to the normal ageing process. Whereas metals can retain their mechanical properties almost indefinitely, there are few unsuitable for cable insulation. Further, insulating materials are easily damaged due to abrasion, environmental effects, mechanical damage, overheating, and rodent attack. Insulation failures and short circuits occur frequently and regularly in any large installation.

Although electrical insulation failures and short circuits are not unusual and are to be expected to occur at any time without prior notice or warning, fires are not to be considered as the inevitable consequences of short circuits. In fact, every electrical installation is supposed to be provided with a system which prevents fires in spite of insulation failures and short circuits. Such systems come into operation only when there are short circuits; at other times, they remain dormant. In brief, therefore, while short circuits are to be expected, fires are not.

TYPES AND CAUSES OF INSULATION FAILURES

There are three main types of insulation failures

a) Insulation failures die to initial defect
b) Insulation failures due to normal ageing
c) Insulation failures due to external damage

Insulation failures due to Initial Defect

Insulation failure due to initial defect or deficiency in the strength of the insulation may be caused by an error in the design, manufacture or the installation of the equipment. This type of defect can be prevented by taking the following measures.

a) Using material with BIS (Bureau of Indian Standards) certification, and manufactured by reputed manufactures
b) Getting the installation designed and installed by licensed electrical contractors.

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c) Carrying out high voltage (H.V) tests on the installation before energizing it.

All the three measures mentioned are mandatory according to the Indian Electricity Act and Rules.

The reason for carrying out a High Voltage test may be clarified here despite using materials which comply with the Indian Standards and despite getting the work done by licensed or qualified contractors, there is still a small probability of some defect remaining in the installation. To guard against even this small chance, it is a legally mandatory requirement that the installation be subjected to a high voltage test before being energized. In this test, a high voltage which is two to three times the normal operating voltage is applied for one minute between the different main lines and also between the main lines connected together and the earth. The exact value of the test voltage is given in the Electricity Rules.

If there is any defect or weakness in the insulation, a fault will be indicated by the testing equipment. The fault will then have to be located, repaired and then the installation retested.

Once this H.V.test is done satisfactorily, there should be no further work on the installation. If any work of repair, modification or extension is done, the test to be repeated.

If the three precautions mentioned above are taken, the possibility of an insulation failure occurring in service will practically be nil and hence, there will be no fires on new installations.

Insulation Failures Due to Normal Ageing or External Damage

If certain precautions are taken, there is no possibility of any insulation failure or fire in a new installation. However, we have to guard against the effects of time and usage. Firstly, all insulating materials deteriorate in their insulating properties with the passage of time. The rate of deterioration depends on many factors which are beyond measurement or control. Some of these factors are: the electrical loading on the wires, the ambient temperature, the layout and surroundings of the wires, presence of foreign materials, the original quality of the design of the materials.

Therefore, despite the original installation being of the best possible standard, we must be prepared for insulation failures taking place in service after the installations have been in use for some time. This is done by providing what are known as protective systems.

Failures of electrical equipment due to insulation failures need not necessarily culminate in fires. If an automatic protective system is provided to defect the electrical insulation failure and to switch off the power supply instantaneously, there would be only some local damage, but there would be no fire. Such protective systems are indeed available at present. They consist generally, of one or more of the following device:

- Fuses
- Circuit breakers with over current relays

Protective systems are usually provided in all electrical installations. In fact, it is necessary under the law to provide these safety devices. Why then do electrical fires take place? There are two reasons for this:

- Sometimes, the protective systems are not designed or adjusted correctly

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- In some cases, the protective system may have become defective in service and remained in that state due to inadequate maintenance

The absence of or the defective state of a protective system constitutes a seed-defect. This will not lead to any fire immediately, but if and when a short circuit occurs anywhere in the unprotected zone, there is every possibility of continued arcing, overheating and ignition of combustible insulating material. Whether the fire spreads and results in a disaster or not, is now a matter of chance.

THE INDIAN ELECTRICITY ACT AND RULES

Since the provision of adequate protective systems is so vital to the prevention of electrical fires, there are special provisions in the Indian Electricity Act in this regard.

Rule 29 of the Indian Electricity Rules stipulates that electrical installations shall be constructed, installed, protected, worked and maintained in accordance with Indian Standards and Codes of Practice issued by the Indian Standards Institution (now renamed as the Bureau of Indian Standards (BIS)} It further stipulates that the materials and apparatus used shall conform to the relevant specifications of Bureau of Indian Standards where such specifications are laid down.

The National Electrical Code issued by the BIS states in Clause 3.1.3.6 that "The current rating of a fuse shall not exceed the current rating of the *smallest* cable in the circuit protected by the fuse. "Current ratings of various types of cables and wires are given relevant Indian Standards. Violation of this rule and the use of materials and apparatus which do not comply with the Indian standards are probably the most likely causes of electrical fires in tents and *shamianas.*

In another section of the National Electrical Code issued by the BIS, it is stipulated that the electrical installation shall be so arranged that there is no risk of ignition of flammable materials due to high temperature of electric arc. Property shall be protected against damage due to excessive temperature caused by any over currents likely to arise in live conductors. How all this is to be ensured is indicated in Rule 45.

Rule 45 of the Indian Electricity Rules states that "No electrical work including additions, alterations, repairs and adjustments to existing installations shall be carried out upon the premises of or on behalf of any consumer, owner or occupier except by an electrical contractor licensed in this behalf by the State Government and under the direct supervision of a person holding a certificate of competency and by a person holding a permit issued or recognized by the State Government."

Rule 31 of Indian Electricity Rules states that "Every supply line shall be protected by a suitable cutout by its owner." Rule 2 defines the cutout as "any appliance for automatically interrupting the transmission of energy through any conductor when the current rises above a pre-determined amount and shall also include a fusible cutout."

These rules are quoted here merely to emphasize the importance of this subject. This book is actually meant for the guidance of the organizations and the persons licensed or permitted by the government authorities to carry out electrical works in a manner which ensures that there are no fires.

Full text continued in the book……….

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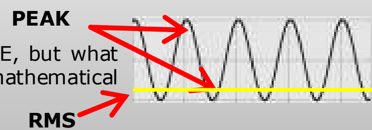
Here is what we should make your day a little more "knowledgeable"

AC - Alternating Current

The electric potential which oscillates between two peak values on opposite site is called an alternating current. This phenomenon occurs due to constant change of polarity between magnets and coil that has relative motion. The highest values reached on either side are called "peak" values. The most ideal alternating current curve is called a SINE CURVE. In mechanical terms, it can be considered similar to a spring which is repeatedly com- pressed and expanded. The number of times it compresses and expands per unit time is called **FREQUENCY**. The highest value it reaches is called **AMPLI-TUDE**. The value displayed on most common digital multi-meters is NOT the PEAK VALUE, but what is known as RMS or **ROOT MEAN SQUARE VALUE**, which is mathematical summation of peak values. For a 215 V AC system, the peak value can be almost 235 to 240 Volts.



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NIKOLA TESLA - *Inventor of AC Generator & Motor*

Nikola Tesla, an Electrical Engineer and a Scientist is known as "Father of Modern World". Tesla's inventions laid the foundation for modern electricity grid, radar, robotics and remote control. He invented "electrical generator" which did not require fuel source. Nikola Tesla invented "Radio "also predating Gugliemo Marconi's patent. His inventions also include turbine that doesn't have blades, florescent lighting, the Tesla coil and alternating (AC) current supply system that included a motor, transformer and 3-phase electricity. Tesla Coil invented in 1891, is still used in radio and television sets and other electronic equipments. In total, Nikola was granted more than one hundred patents and invented countless unpatented inventions

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