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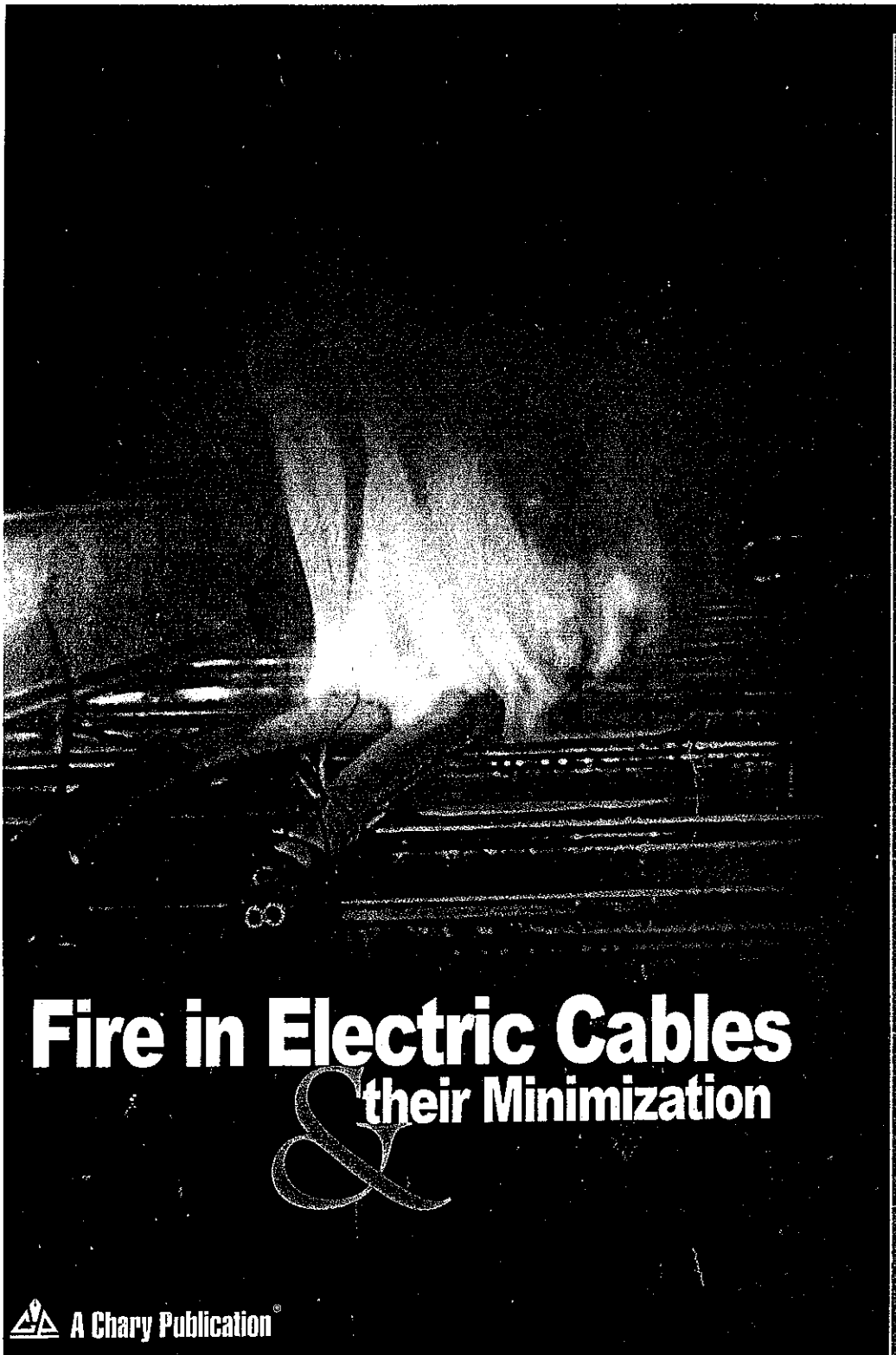

Fire in Electric Cables & their Minimization

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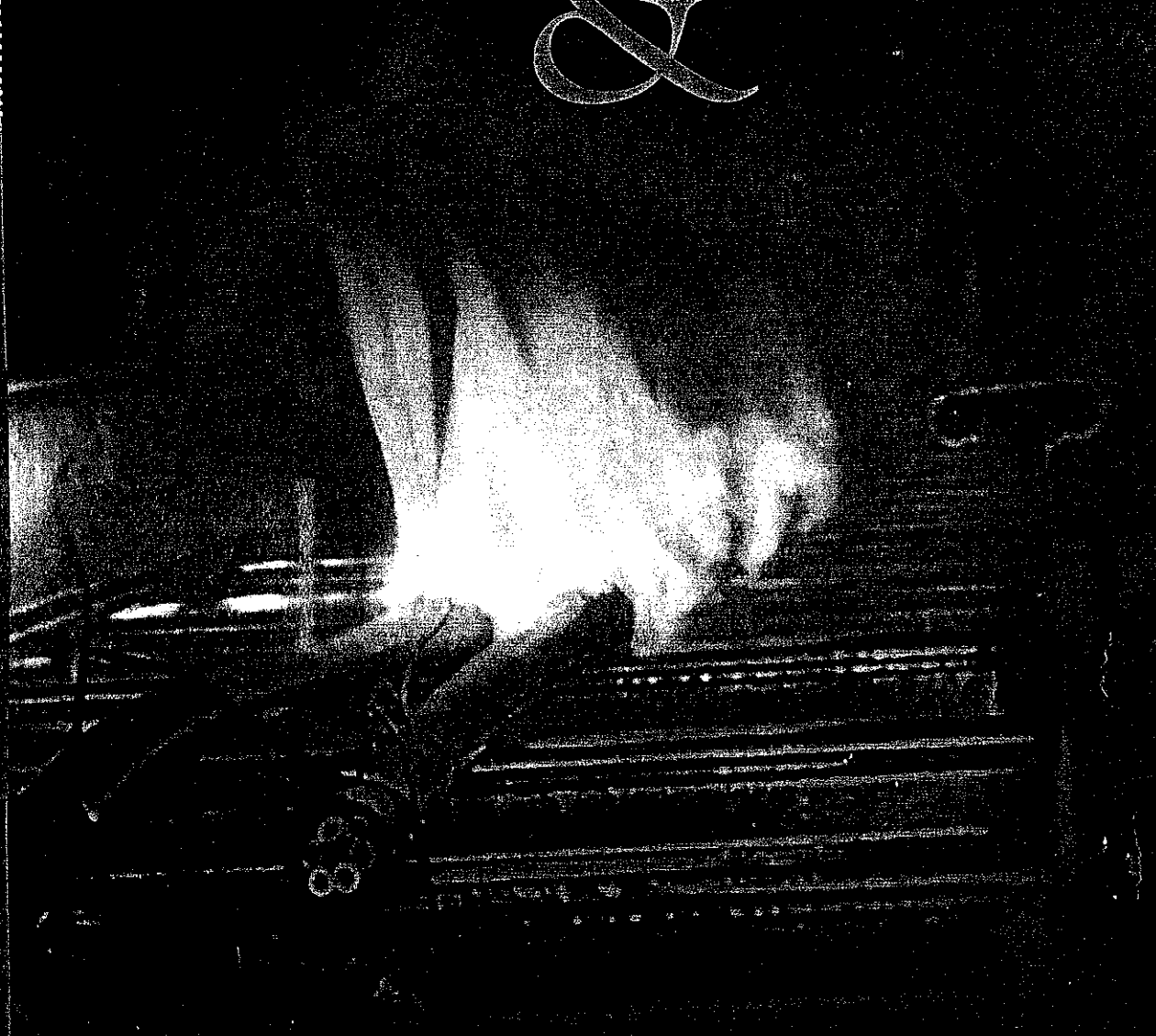
EI Message Board Do not allow usage of frail wires with worn out insulation

Fire in Electric Cables & their Minimization



Major industries such as power plants, fertilizer plants, cement plants, refineries, petrochemical plants are highly prone to fire accidents due to the extensive use of electrical cables. In this article various aspects of fire retardant coatings, smoke suppressants and fire stop systems have been discussed which will help in minimizing the fire hazards.

- Dr. Sunil K. Sharma & Dr. N. K. Saxena

Electrical cables are being extensively used in all major industries due to the fact that the number of gadgets using electricity has increased considerably resulting in considerable increase in power consumption. All the major industries such as power plants, fertilizer plants, cement plants, refineries, petrochemical plants etc. are highly prone to fire accidents mainly because they use electrical cables extensively. Modern production facilities require long runs of power and control cables all over the plant area. These cables are mostly run through underground cable tunnels, trenches, overhead cable trays and ducts. Any fire incidence in their vicinity may result in the initiation of a fire and spread along the cables laid in the trays. PVC occupies a premier position in the field of cable insulation and sheathing on account of its excellent electrical and handling properties. Though not easily ignitable, once it is involved in fire it may burn rapidly along with production of copious amount of toxic smoke. One of the major contributor to spread of fire is the inter-connecting penetration openings in walls and floors. Improperly sealed openings create chimney effect and result in rapid spread of flames and smoke to places remote from the source of initiation. These combustion products make the job of fire fighting all the more difficult and hazardous thus leading to major losses of life and property.

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Fire Research Laboratory at Central Building Research Institute, Roorkee is engaged in minimizing the fire hazards through electrical cable, by research and development in the area of fire retardant coatings, smoke suppressants and fire stop systems.

Electrical Cable

An electrical cable is generally defined as being an insulated electrical conductor. Its sole function is the transfer of electric power. The load to be supplied can vary from a small indicating lamp to a large generator transformer. Any cabling system must meet certain requirements, such as:

- The cable must be able to withstand the voltage to which it will normally be subjected
- A cable must be installed in such a manner that it presents no danger to any person likely to come in contact with it
- The cables must not develop a hazard by induction, or through other means, in other equipment; and
- The type of insulation must suit the type of installation and the environment. The temperature rating of cable must be suited to ambient conditions. Also if the cable is to be installed where it is subject to direct sunlight, resistance to UV becomes a factor. If the cable is to be installed in an area where it is subject to flammable dust or liquid, additional factors must be considered.

The basic components of a cable are conductor and insulation. Copper and aluminium are the materials mostly used as conductors in cables. Copper is a better conductor than aluminium. To achieve the same current flow as a copper conductor, an aluminium conductor would need to have 1.6 times the cross sectional area. Because of the equivalent aluminium conductor requiring a larger cross sectional area than that of copper the size of the cable is larger. The termination of an aluminium conductor requires great care to avoid problems due to the formation of aluminium oxide on the metal surface, which will interfere with the conductivity of the termination. However, aluminium conductors are widely used as they cost less than copper conductors.

The other important component of electrical cable-insulation is influenced by the maximum operating voltage of the cable; and the temperature that the cable has to withstand. This influences the quality and type of the insulation, coverings, sheathings, insulating sleeves on connections and sealing compounds used on the cable.

Typically, a combination of outer sheathing and protection comprising of PVC is provided on 415 volt cables. Mechanical protection can be provided by

placing steel or aluminium wire along the length of the cable between a plastic bedding material wrapped around the insulated cores and the outer sheath. In case of high voltage cable a core screen is also provided. A PVC inner sheath is provided over the copper tape to provide a bedding for the armour wires. This inner sheath also provides a moisture barrier. Finally an outer PVC sheath is applied.

Plastic insulated cables can be made more fire retardant than paper insulated cables and are therefore preferred for power station applications. The preferred insulation for cables used in power stations is of the thermosetting type, i.e. XLPE or EPR. These give a conductor continuous operating temperature of 900°C and a short circuit temperature of 2500°C.

Prevention of Fire Spread Through Cables

In order to prevent spread of fire through cables, opening which are a part of the vertical and/or horizontal segregating elements through which cables or cable trays pass in a building are segregated. It is essential that these are sub divided into smaller zones. This may be done by providing barriers at different intervals and by sealing the openings with the use of fire resistant and gas tight seals i.e. fire stops. Another method to check the fire in electrical cables is application of suitable fire retardant coatings.

To minimize fire losses due to cable fire there are mainly three methods:

- Use of FRLS cables
- Application of Fire retardant coatings
- Sealing of the cable penetrations through walls or floors

These methods can be adopted individually or in combination depending upon the degree of criticality for application and its location.

FRLS Cables

The word FRLS stands for Flame Retardant Low Smoke, another terms to represent the same characteristic is FRSS or Flame Retardant Smoke Suppressant.

Generation of smoke from materials can be reduced either by selecting materials that generate low quantities of smoke or by modifying those that do. Generally, the materials are selected on basis of various useful properties as is the case with PVC for electrical cables. Therefore changing them just because they produce smoke is not always desirable. However, such materials are modified and the smoke suppression characteristic is introduced. This can be achieved either through chemical modification, or by use of additives, or fillers, or even through application of surface coating. The additives used are generally non polymeric compounding ingredients, typically used at levels below 20% of the polymer mass. For PVC the largest class of additives comprises metal or metal based complexes. However, the non metallic additives such as carboxylic acids, aldehydes, alcohols, fluoroborates and sulfur are also known. Fillers are used at greater than 20% of polymer mass and can be classified as of active and inert types. Typical examples of active fillers are aluminium trihydrate, magnesium hydroxide and calcium carbonate. The inert fillers may be silica, asbestos, clay etc.

An effective smoke suppressant may contribute in vapour phase, condensed phase or in both via via different processes e.g. dilution of fuel, modification of pyrolyzates, promotion of char formation or surface insulation etc.

Fire research laboratory at CBRI, Roorkee has developed FRSS complexes and compositions for PVC.

Fire Retardant Coatings

A fire retardant coating needs to have all the attributes of a conventional paint besides the addition characteristic to retard growth and spread of fire. The chemistry of fire retardants centers around six elements i.e. phosphorous, antimony, chlorine, bromine, boron and nitrogen.

Coatings based on formulations that do not support combustion when exposed to intense heat or fire, are called 'flame resisting' or non flammable coatings. They do not provide fuel to the fire and are self extinguishing however; they do not offer much protection under continuous exposure to fire as they loose adhesion and thus expose the substrate to flames. These paints contain antimony oxide, halogenated organic compounds, borates, phosphorous compounds, rubber, silica and silicates etc.

The other type of coatings provides an insulation layer between flame and the substrate. These coatings are known as 'intumescent coating'. They provide substantial protection and markedly reduce the heat penetration through non flammable substrate. A thick layer of cellular carbonaceous material is formed as a result of physical transformation of certain chemical ingredients due to thermal exposure. The coating releases cooling gases which helps in formation of a thick insulating foam. This insulated foam can be toughened to protect the material. These coatings are found to be more effective than the flame resisting/retardant coatings. The intumescent coatings contain organic or inorganic phosphates, amino compounds and polyhydric alcohols. Oil based alkyd binders and resin based epoxy binders are added to hold the constituents together.

Different types of polyols, blowing agents, dehydrating agents and

binders, thickening agents, pigments, and fillers etc. were studied in varying proportions to obtain satisfactory compositions that impart fire retardancy effectively. The specimens of PVC insulated electric cables were coated with developed coatings. They were evaluated using different standard methods for assessing their fire performance.

Intumescent coatings suitable for application on electrical cable have been developed at Fire Research Laboratory, CBRI, Roorkee. The developed coatings were able to withstand fire upto 30 minutes when evaluated as per IEC 331 standard method. These can be used alone or in combination with cable fire stops/ barrier in case where the cable has to be kept operational during fire accidents.

Cable Fire Stop/ Barrier

Insulated cables may be run in one of several forms of a raceway between electrical devices. This may be a pipe, called a conduit, or in one of several varieties of metal or non metallic tubings. Rectangular cross section metal or PVC wire troughs or trunking may be used if many circuits are required. Wiring in exposed area, for example factory floors, may be run in cable trays. Cable galleries/ trenches/ tunnels have continuously running cable for kilometers at end. Fire once initiated can spread rapidly in these galleries and cause havoc. However, spread of fire can be retarded or checked by constructing fire barriers at regular intervals along the length.

Where cables or cable trays must traverse fire resistance rated walls and floors, the openings are required to be fire stopped. Fire stop as the word indicates is a mean of stopping the spread of fire along the cable. It is a specific construction consisting of the materials that fill the openings around penetrating items such as cables, cable trays, ducts and pipes as well as their means of support through the walls or floor to prevent the spread of fire. Presently three types of seal systems are in use. They are:

- Mineral wool panel seal system
- Flexible seal system
- Foam system.

Mineral Wool Panel Seal System

The main components of this system are support frame, infill mineral wool panel, fire seal putty and anchor fasteners. In this type of system, generally a board is provided on one side of the opening. The opening and the space available around cables is than filled with the material. The opening is then closed from the other side using a board. The main problem with this system is that in some locations sufficient working space is not available thereby making it difficult to maintain the quality of the system in the confined space.

Flexible Seal System

The system consists of bags or pillows of fire retardant materials. Earlier these consisted of asbestos cloth bags filled with loose asbestos but due to the ban on use of asbestos these have been replaced by canvas cloth or polyethylene bags filled with loose mineral wool. Sufficient and adequate working space requirement is essential in this case also.

Foam Seal System

This system is based on the use of silicon foam. Foam is produced by mixing two liquid components. When mixed thoroughly in a definite ratio, these components expand and cure to a foamed elastomer at room temperature. Silicon RTV foam is widely used for application in cable fire stops. This system can be used even in confined spaces.

Fire research laboratory at CBRI, Roorkee has also developed a cable fire stop system using indigenously available chemicals. Slurry was prepared of fire retardant chemicals. The slurry was thoroughly mixed and poured into the cavity. Within 5-7 minutes it swells up to five times of its original volume. The fire

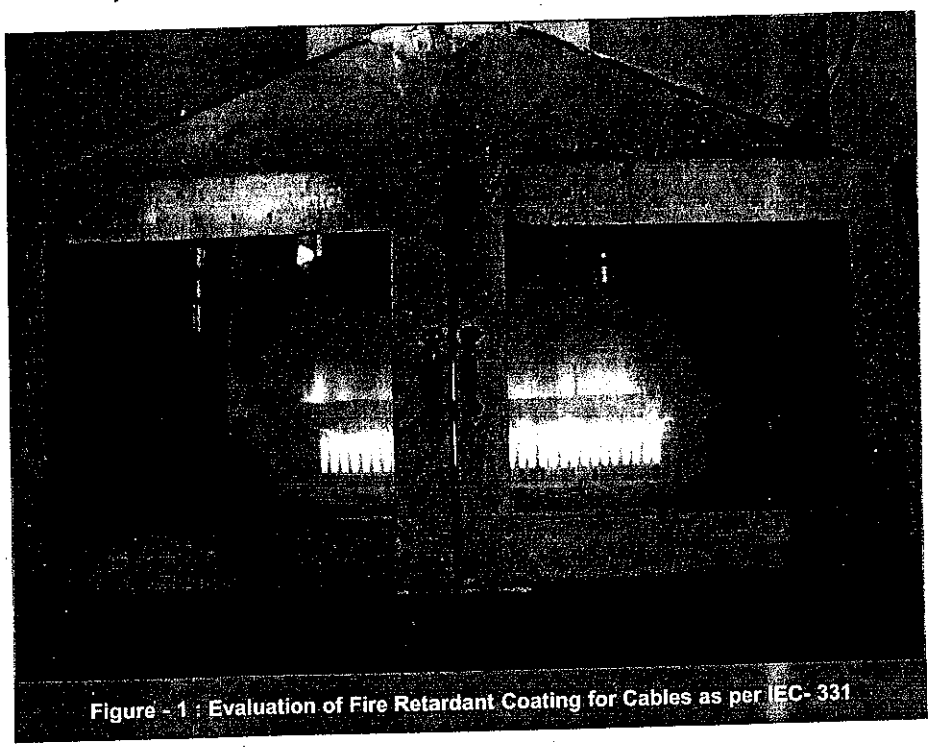

Figure - 1 : Evaluation of Fire Retardant Coating for Cables as per IEC- 331

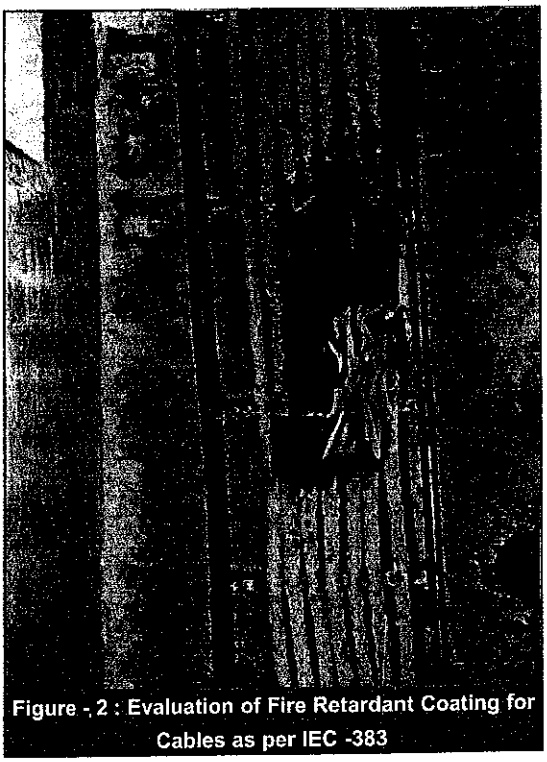

Figure - 2 : Evaluation of Fire Retardant Coating for Cables as per IEC -383

Figure - 3 : Developed Cable Fire Stop under test conditions

performance of this cable fire stop system was evaluated in accordance with various national and international standards and was found quite effective. It has a fire resistance rating upto 4 hrs. as per various international standards.

Fire Performance Evaluation

The various products developed at CBRI were evaluated for their fire performance using various national and international standard methods.

FRSS compositions were used in plasticized PVC and their performance was evaluated in terms of flammability using limiting oxygen index method (as per ASTM D 2863). Specimens are subjected to a flame source inside a chimney through which oxygen-nitrogen mixture is made to flow. The oxygen concentration in the mixture can be increased from 0-100% i.e. pure oxygen. The oxygen index was found to have increased even when small quantities of the FRSS complex were used, thus indicating an increase in fire retardancy of the plasticized PVC. Smoke suppression was also estimated using the above apparatus along with an attachment for smoke measurement using He-Ne laser in a dynamic system. Significant suppress in smoke generation was observed when the specific quantities of FRSS complex and other additives were used. The compositions have been patented.

Fire retardant coatings were evaluated using IEC 331and IEEE 383. In IEC 331 three and a half core aluminium conductor PVC insulated armoured cable specimens were used to determine circuit failure time. Cables were coated with different amount of fire retardant coatings to determine the effect of coating on fire performance. The end of the cable the conductor wires were suitably connected to 440 V, 3 phase supply. A tubol burner was used to ignite the specimen (at 750^0 C) held horizontally. The coated specimen resisted the fire for 30 minutes and no break in electrical circuit was observed.

In IEEE 383 test a bunch of cables was ignited in vertical position with the help of burlap of specified size, soaked in multigrade 20/40 engine oil. The burlap igniter was set on fire and allowed to burn out naturally (for >30 minutes) as shown in Figure 2. There was no spread of flame on cables beyond flame height due to burlap. While the coated samples were found to self extinguish the uncoated cables were severely damaged when tested under identical conditions.

Cable fire stop developed at Fire Research Laboratory, CBRI, Roorkee were evaluated in a floor furnace which was regulated according to standard heating conditions as specified in IS:12458, BS 476, ISO 834, UL 1479, ASTM E-119 etc. It was found to have fire resistance rating of 4 hrs. ■

Sunil K. Sharma

Dr. Sunil K. Sharma, a Ph.D. on Flame Retardant Smoke Suppression of Poly (vinyl chloride). Senior scientist in Fire Research Laboratory, CBRI, Roorkee having more than 30 years of research experience in the areas of fire behaviour, fire retardance and smoke suppression.

N. K. Saxena

Dr. N. K. Saxena, a Ph.D. on Flame Retardant Treatments for Cellulosic Materials. Senior scientist in Fire Research Laboratory, CBRI, Roorkee having more than 30 years of research experience in the areas of fire fire retardance and fire resistance.