भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS

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

1.	**Action Research Project No.**	AR/0051
2.	**Title of Action Research Project**	To study the concept of Fire Survival Cables and prepare a pre-standardization report.
3.	**Name & Designation of Officer**	Shikha Goyal, Scientist- C
4.	**Employee No.**	67695
5.	**Deptt./BO/RO & Place of Posting**	ETD, BIS HQ
6.	**Date of Approval of the Project**	12 June 2020
7.	**Objective of the Project**	1. To study the concept of Fire Survival Cables from leading manufacturers in India. 2. To analyze the applicability of Fire Survival Cables in India. 3. To study the various International/Regional Standards/Reports available on the subject . 4. To identify and explore the possibility of inclusion of additional testing requirements for such cables.
8.	**Report of Action Research Activities**	Please see report enclosed.
9.	**Conclusion & Recommendations**	Please see report enclosed.
10.	**Any other information relevant to the Project**	The project will help in preparation of National Standard on Fire Survival Cables which will enhance the safety of Electrical Installations and as well as, help to reduce the causalities due to fire accidents.

(Shikha Goyal)
Scientist-C, ETD

Sc-F & H (ETD)

Sc-G & DDG (Stdn)

Sc-G & DDG (PRT)

FOREWORD

Electrical cables are the nerves of any electrical system. The Power Cables consist of a huge percentage of capital investment in any electrification project be it domestic or commercial. However, they are the most vulnerable to failures too. Most of the cable failures could be attributed to improper quality leading to short-circuits and thus resulting in fires.

Fire Safety of Cables and Wires

Electrical cables and wires are of significant concern for fire safety in today's buildings and installations:

- If the insulating or jacketing materials in cables catch fire, they can represent a significant quantity of fuel for fire, because of the sheer volume of cables in modern buildings (electrical, telephone, computer connections etc.).
- If cables are not fire safe, then they are highly susceptible to be the cause of fire, making overheating of wires, arcing, short circuits or electrical faults develop into flames of burning insulating material.
- Furthermore, cables often spread fire through a building, as they cross fireproof walls, linking occupied spaces to service areas, ceiling voids and other parts of the building.

Electrical systems are estimated to be the cause of around one fifth of all fires. Cables can contribute significantly not only to the cause of fires, but also to the spread of fire and to heat emission (fire load) , they also can result in:

- Increased smoke emission (sufficient to limit visibility and inhibit escape).
- Increased carbon monoxide production (the most lethal gas in fires).
- Release of irritant gases (depending on the materials used, hydrochloric acid HCl, hydro fluoric acid HF, carbonyl fluoride COF2, and acrolein).

For these reasons, understating the concept and enhancing the fire safety of cables depending on the degree of fire resistance required is crucial.

TABLE OF CONTENTS

1. SCOPE

With the increasing demand for safe buildings, more attention is being paid to the types of cables being installed, and the potential risks involved in the event of fire. Also, the issues of health, safety, and environmental impacts are top priorities for manufacturers as well consumers.

In all fire disasters, fire smoke, heat and toxic fumes are the main obstacles to safe evacuation of a building or area.

Although Indian Standards are available where testing requirements of *Flame-Retardant cables which resist the spread of fire into a new area are defined*.

Fire survival(resistance) cables maintain circuit integrity and continue to work for a specified time under defined conditions. They must be able to must be able to sustain the functioning and circuit integrity for temperatures up to 950°C and for duration of 3 hours along with the ability to sustain hazards such as high temperature, fire, water, and mechanical impacts.

However, no Indian standard exist to check the quality and performance parameters of cables which are able to operate and function for specified period under fire conditions.

The study of cables with respect to maintaining the circuit integrity in conditions of fire will aid in significantly enhancing the safety of buildings and reducing the risks to life and assets in case of an fire. Hence, this pre-standardization report may be utilized to set the basic minimum quality and performance parameters in Indian standard.

2. INTRODUCTION

A power cable is an electrical cable, which is an assembly of one or more insulated electrical conductors, usually held together with an overall sheath. The assembly is used for transmission of electrical power. Power cables may be installed as permanent wiring within buildings, buried in the ground, run overhead, or exposed. Flexible power cables are used for portable devices, mobile tools, and machinery.

Modern power cables come in a variety of sizes, materials, and types, each particularly adapted to its uses. Large single insulated conductors are also sometimes called power cables in the industry.

Cables consist of three major components: conductors, insulation, protective jacket. The makeup of individual cables varies according to application. The construction and material are determined by three main factors:

- Working voltage, determining the thickness of the insulation;
- Current-carrying capacity, determining the cross-sectional size of the conductor(s);
- Environmental conditions such as temperature, water, chemical or sunlight exposure, and mechanical impact, determining the form and composition of the outer cable jacket.

Cables for direct burial or for exposed installations may also include metal armour in the form of wires/stripes spiralled around the cable, or a corrugated tape wrapped around it. The armour may be made of steel or aluminum, and although connected to earth ground is not intended to carry current during normal operation.

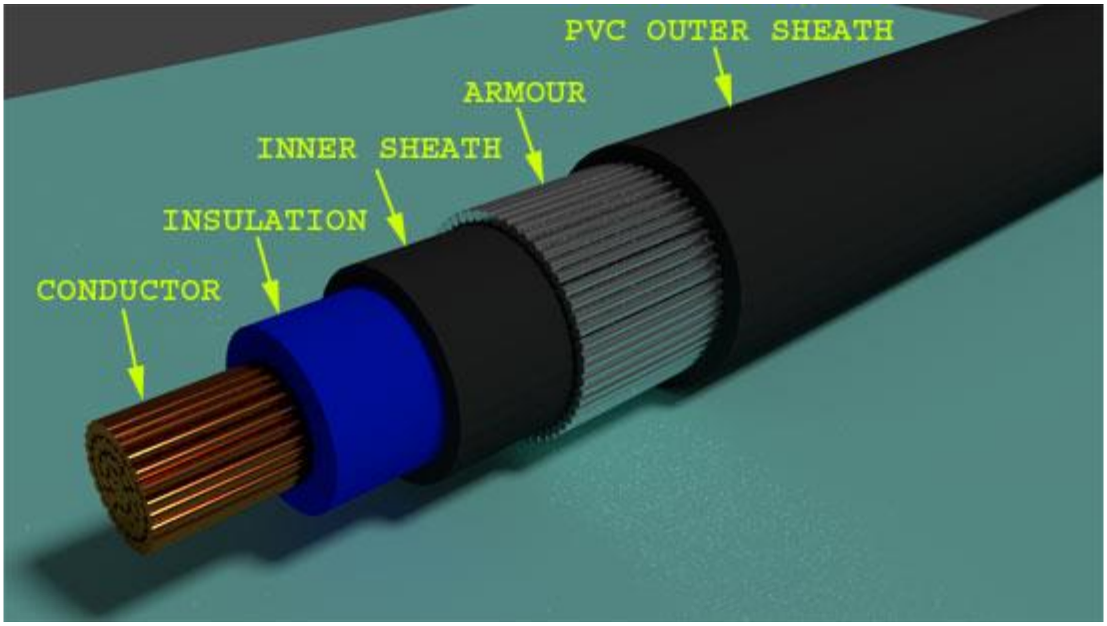
Power cables for fixed installations use stranded copper or aluminum conductors, although small power cables may use solid conductors.

All electrical cables are somewhat flexible, allowing them to be shipped to installation sites wound on reels or drums. Where applications require a cable to be moved repeatedly, such as for portable equipment, more flexible cables called "cords" " are used. Flexible cords contain fine bunched conductors, not solid/stranded core conductors, and have insulation and sheaths to withstand the forces of repeated flexing and abrasion.

The overall assembly may be round or flat. Non-conducting filler strands may be added to the assembly to maintain its shape. Special purpose power cables for overhead or vertical use may have additional elements such as steel structural supports.

Some power cables for outdoor overhead use may have no overall sheath. Other cables may have a plastic or metal sheath enclosing all the conductors. The materials for the sheath will be selected for resistance to water, oil, sunlight, underground conditions, chemical vapours, impact, or high temperatures. In nuclear industry applications the cable may have special requirements for ionizing radiation resistance. Cable materials may be specified not to produce large amounts of smoke if burned. Cables intended for underground use or direct burial in earth will have heavy plastic or metal, most often lead sheaths, or may require special direct-buried construction. When cables must run where exposed to mechanical damage, they may be protected with flexible steel tape or wire armour, which may also be covered by a water-resistant jacket.

Some Cables may also have an inner sheath. It is used for protecting the cable from moistures which would affect the insulation. The inner Cable sheath also provide strengths to withstand the internal pressures of the pressurized cables. The material used for inner sheath should be nonmagnetic material.



The Electrical cable classification can be done on the basis of:

- Material of conductor
- Insulating and sheath material used in their manufacture,
- With/Without Armouring
- Voltage Grade for which they are manufactured.

However, the method of electrical cable classification on the basis of voltage more common, according to which they can be divided into the following categories:

- Low-tension cables — up to 1100 V
- High-tension cables — up to 11000 V
- Super-tension cables — from 22 kV to 33 kV
- Extra high-tension cables — from 33 kV to 66 kV
- Extra super voltage cables — beyond 132 kV

Standardization in the Field of Cables

At National level, Bureau of Indian Standards through its Power Cables Sectional Committee, ETD 09 is responsible for preparation of Indian Standards in this area. The Committee comprises of various stakeholders from Manufacturing Industries, Regulators, Government Bodies, Research Organizations. Academia, Laboratories, End Users, Consumer organizations etc.

At International level, International Electrotechnical Commission (IEC) through its Technical Committee IEC TC 20 is preparing International Standards. India is a P-member on IEC TC 20 and BIS Committee, ETD 09 acts as National Mirror Committee and takes care of country's interest during the formulation of International Standards through comments and voting on the IEC documents. Members of ETD 09 are nominated as experts on IEC committee to put forth Indian point of view by participating in the meeting of the Technical Committee. Presently, Indian Experts have been nominated on IEC TC 20 and its working groups WG 17 and WG 18.

ETD Committee has so far published more than 100 Indian Standards on Power Cables. These standards can be segregated in to the following categories:

- Indian Standards specifying the requirements of various types of power cables. Some of the important power cables standards are:

IS 694	PVC Insulated Sheathed/Unsheathed Cables and cords for working voltages upto and including 1100 V
IS 1554 (Part 1)	PVC Insulated (Heavy Duty) Electric Cables for working voltages upto and including 1100 V
IS 1554 (Part 2)	PVC Insulated (Heavy Duty) Electric Cables for working voltages from 3.3 kV upto and including 11 kV
IS 7098 (Part 1)	XLPE Insulated Thermoplastic Sheathed Cables for working voltages upto and including 1100 V
IS 7098 (Part 2)	XLPE Insulated Thermoplastic Sheathed Cables for working voltages from 3.3 kV to 33 kV
IS 7098 (Part 3)	XLPE Insulated Thermoplastic Sheathed Cables for working voltages from 66 kV to 220 kV
IS 9968	Elastomer Insulated Cables for working voltages upto and including 1100 V
IS 17048	Halogen Free Flame Retardant (HFFR) Cables for working voltages upto and including 1100 V
IS 16246	Elastomer Insulated with Limited Circuit Integrity Cables
IS 14255	Aerial Bunched Cables for working voltages upto and including 1100 V
IS 9857	Welding Cables
IS 5950	Shot Firing Cables

IS 2465	Cables for Motor Vehicles

- Indian Standards specifying the properties of raw materials like conductors (copper/aluminium), Insulation and Sheath materials. Some of the relevant Indian Standards are:

IS 5831	Specification for PVC Insulation and Sheath of Electric Cables
IS 6380	Specification for Elastomer Insulation and Sheath of Electric Cables
IS 8130	Conductors for Insulated Electric Cables and Flexible Cords- Specification

- Indian Standards specifying test methods for various parameters specified in the Power Cables Standards. One of the most important series of standards is:

IS 10810 (Part 1 to 64)	Method of Test for Cable

- Code of Practice/Guidelines Standards

IS 1255	Code of Practice for Installation and Maintenance of Power Cables up to and including 33 kV rating
IS 3961	Recommended current ratings of Cables
IS 10462	Fictitious Calculation Method for Determination of Dimensions and Protective Covering of Cables.
IS 16269	Recommended Short Circuit Ratings of Electric Cables with Rated Voltage from 11 kV to 220 kV

Besides the above published standards, the Indian Standards on the following subjects/areas are in advance stage of formulation:

XLPE Insulated Thermoplastic Sheathed Cables for working voltages above 150 kV upto and including 500 kV

Keeping in view that the safety of an electric installation is largely attributed to the quality of electric cables, the Government of India has brought IS 694 and IS 9968 under mandatory certification through the Electrical Wires, Cables, Electrical Appliances and Protection Devices and Accessories (Quality Control Order), 2003. Other Indian Standards on Electrical Cables are also brought under the ambit of Quality Control Order through Cables (Quality Control Order), 2020.

Indian Standard	Name of Product
IS 1554(Part 1) :1988 **IS 1554(Part 2):1988**	PVC Insulated Heavy Duty Cables
IS 2593 : 1984	Specification for Flexible Cables for Miner's Cap-Lamps
IS 5950 : 1984	Specification for Shot Firing Cables (for use other than in shafts)
IS 7098(Part 1):1988 **IS 7098(Part 2):2011** **IS 7098(Part 3):1993**	Crosslinked Polyethylene Insulated Cables
IS 9857 : 1990	Welding Cables – Specification
IS 9968 (Part 2) : 2002	Specification for Elastomer Insulated Cables Part 2 For Working Voltages form 3.3 kV Up to and Including 33 kV
IS 14494 : 2019	Elastomer Insulated Flexible Cables for Use in Mines – Specification
IS 17048 : 2018	Halogen Free Flame Retardant (HFFR) Cables for Working Voltages Up to and Including 1100 V – Specification

3. RESEARCH METHODOLOGY

The action research entailed the following:

A. To analyze the present scenario to assess the need of FS cables in India.

B. Stakeholder's Consultation -

Interaction with manufacturer associations/industries to understand different types of cables used in the industries through Online Mode.

C. Literature Survey using Desktop –

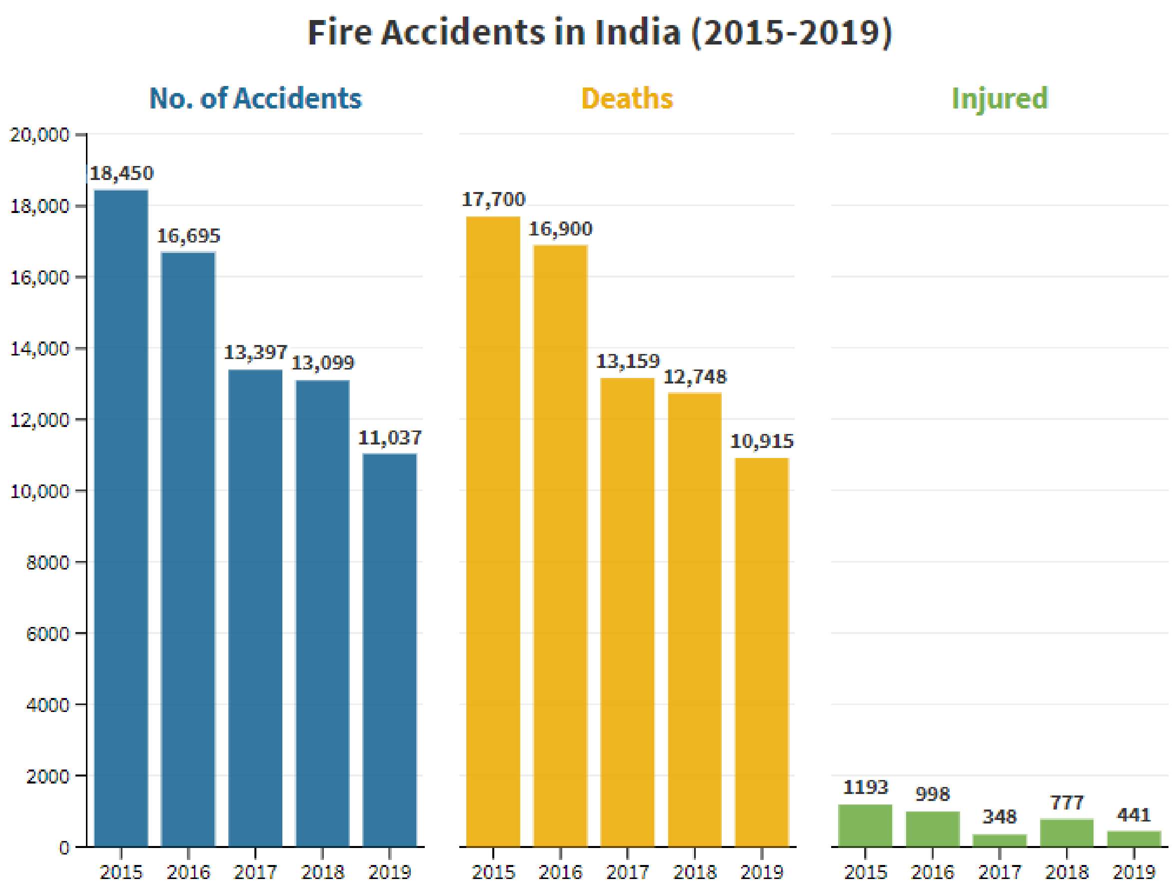
- Study the Concept of Flame Retardant and Fire Survival Cables
- Study of available Indian Standards (with and without Fire Performance Characteristics)
- Study of International Standards.
- Study of procedure of various test methods for verification of Fire Performance Characteristics.

4. PRESENT SCENARIO

A. Accidental Deaths & Suicides in India(ADSI) -2019 report published by National Crime Records Bureau (NCRB) under Ministry of Home Affairs, Government of India

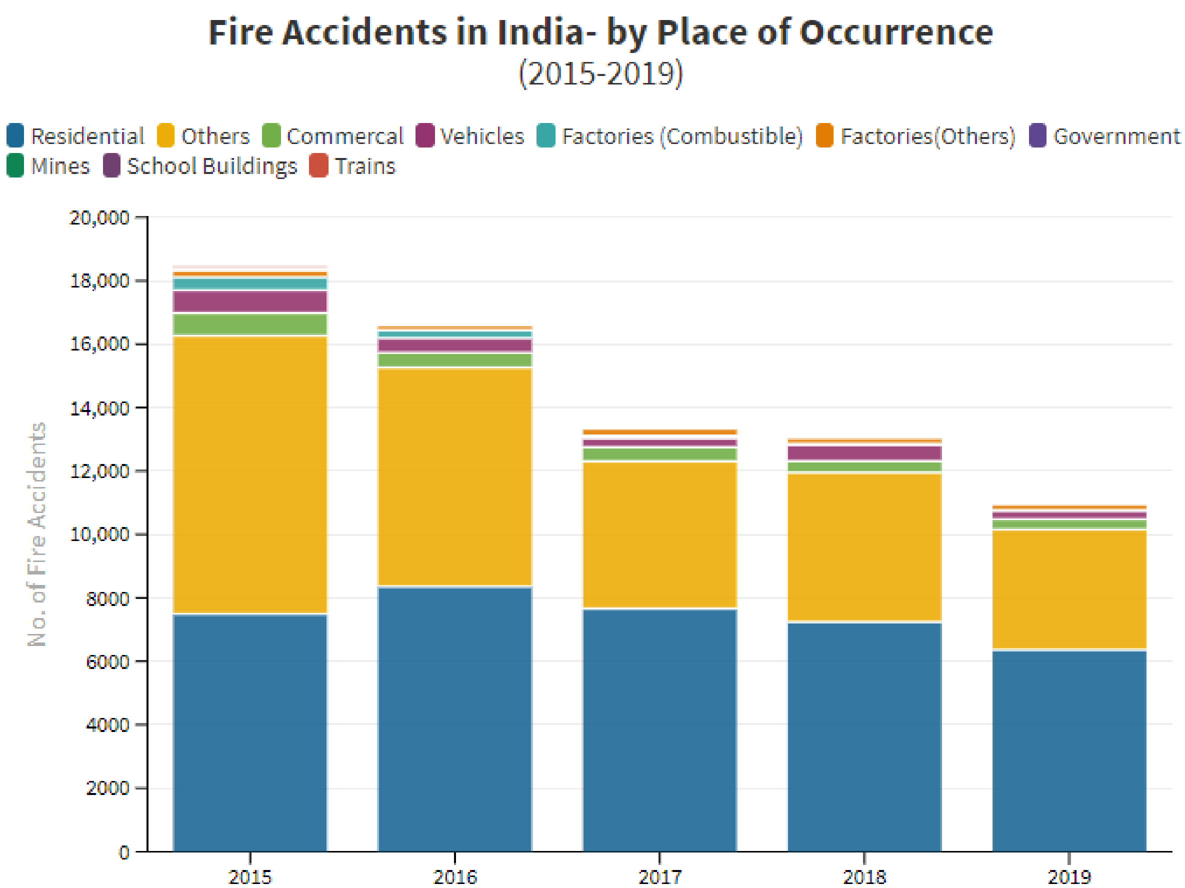
As per **ADSI** -2019 report published by **NCRB**, there were 11,037 fire accidents reported across the country in 2019.

The data over the five-year period (2015-2019) indicates a steady year-on-year decline in the number of fire accidents reported in the country.



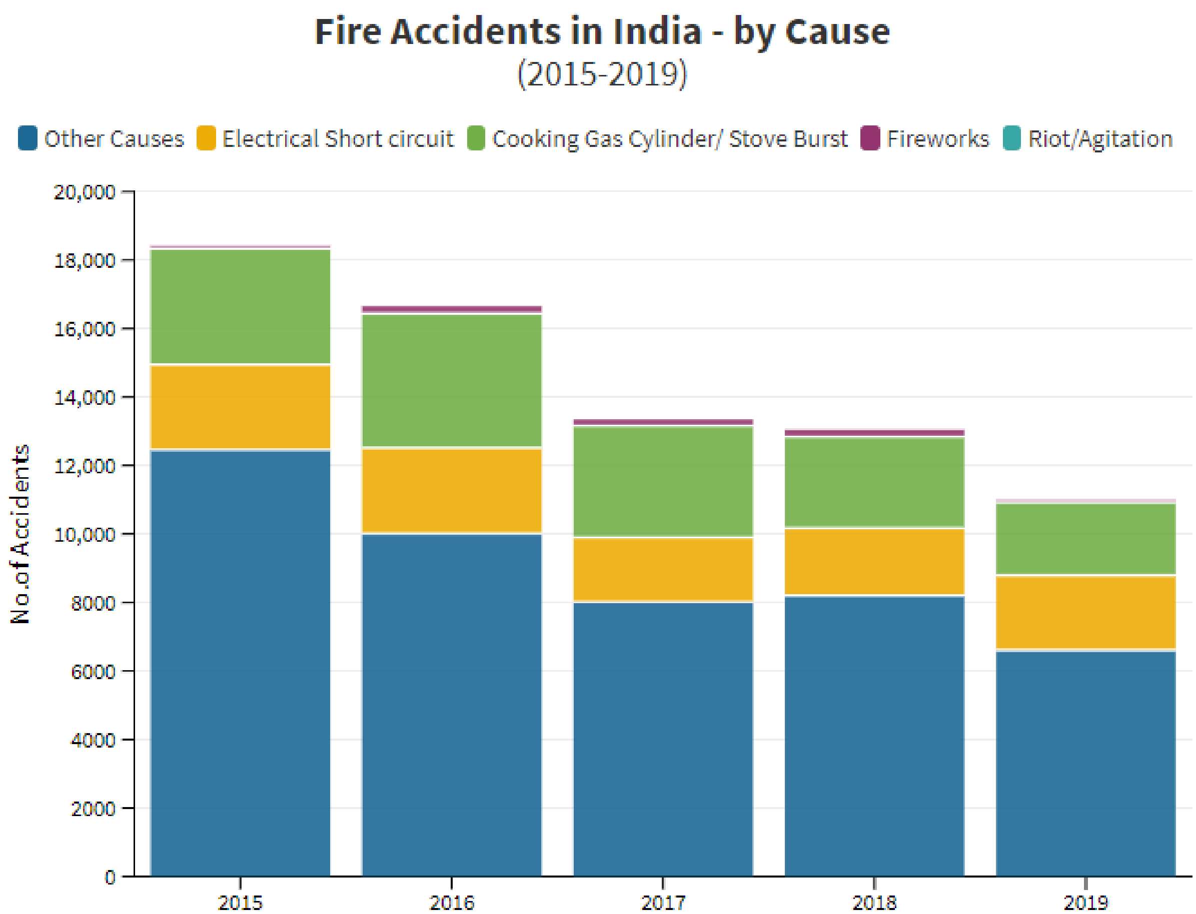
While the decline in the number of accidents due to fire along with deaths and injuries is promising, the significantly higher proportion of deaths compared to injuries is alarming. This higher mortality could indicate challenges with medical & emergency services in dealing with such mishaps, which could have helped reduce the death toll. There could also be other factors such as the severity & nature of the fire accidents for higher mortality.

In 2019, out of the 11,037 Fire Accidents, a total of 6,364 accidents i.e., around 57% occurred in Residential Buildings.



While the number of incidents in the residential buildings has come down over the period of time, their proportion in the overall fire accidents has seen a steady increase year-on-year from around 40% in 2015 to 57.6% in 2019.

For the incidents where the cause has been specified in the ADSI report, the highest number of fire accidents over the years is due to "Cooking Gas Cylinder/ Stove Burst". In 2019, fire accidents due to "Electrical Short Circuit" is marginally higher than the accidents relating to Cylinder/Stove burst. Both these causes account for a significantly higher number of accidents compared to the other causes like "Fireworks" & "Riots/Agitation".



While the number of fire accidents attributed to these two major causes has fallen over the years, the proportion in the overall fire accidents has displayed varying trends. The share of accidents due to "Cooking Gas cylinder/Stove burst" has displayed a fluctuating trend, while that of "Electrical Short Circuit" has consistently increased Year on Year.

Inference : The declining numbers is more noticeable in the case of commercial buildings, wherein the number of reported accidents halved over the five-year period (2015-19), so is the case with the Factories that manufacture Combustible products. However, this improving trend seen in the commercial space is not visible for residential buildings.

The significantly higher number of fire incidents caused due to electrical faults are avoidable provided the regulations are in place and strictly implemented.

B. Global Diseases Burden report published in the BMJ Injury Prevention Journal

As per the report, every fifth fire-related death in the world in 2017 took place in India. Around 9 million fire incidents and 1.2 lakh deaths were recorded across the globe that year.

Of these incidents, India recorded 1.6 million fires and 27,027 deaths, according to a 195-nation analysis by Global Diseases Burden published in The BMJ Injury Prevention journal recently. The Indian deaths were 2.5 times the figures in China, where 10,836 people died in fires in 2017.

India, along with seven countries, including Pakistan, accounted for over half the deaths due to fires. The study said kids under five and adults above 60 are the biggest fire victims — a trend seen in urban India as well.

Inference : The significantly higher number of fire incidents caused due to electrical faults can be avoided/reduced provided the regulations are in place and strictly implemented.

5. STAKEHOLDER'S CONSULTATION

Due to challenge imposed by the COVID-19 restrictions, technical members representing Manufacturers, Industry Associations, Academia, R&D Institutions, Policy Regulators and Laboratories were consulted on various occasions through Video-Conferencing; E-mail correspondences and telephonically.

Discussion Outcomes - A wide spectrum of fire performance is available from the many types of cables on the market. This can range from cables at one extreme which have no enhanced fire properties, which are readily ignitable and burn with ease, to, at the other extreme, fire survival cables.

The choice of cable for a given application depends on the degree of hazard which can be tolerated and the level of performance required. The level of fire performance and the potential hazard resulting from the combustion of a given cable depend on the materials from which the cable is made and the cable construction.

The below table summarizes the different levels of performance that can be achieved by different categories of cables, along with typical areas of application:

Cable Type	Fire Characteristics	Application
Fires Resistant Cable, with (LSHF) materials	• Fire survival • Flame retardant • No acid gas emission • Low smoke emission	For maintaining essential circuits such as emergency lighting and fire alarms, circuits for the safe shutdown of critical processes, etc.
Fires Resistant Cable, with (halogen containing) materials	• Fire survival • Flame retardant	As above, but with increased hazard from smoke and acid gas emission.

(LSHF) Cables and Wires	• Flame retardant • No acid gas emission • Low smoke emission	For installation in areas where smoke and acid gas evolution could pose a hazard to personnel or sensitive equipment, but where circuit integrity is not needed.
PVC or chlorinated polymer	• Flame retardant	Where flame retardancy is desirable, but smoke and acid gas evolution is not considered to pose a serious hazard.
Non-flame retardant (e.g. polyethylene)	• Readily combustible	In situations when fire performance requirements are low and where cable combustion poses little hazard.

Usually, Polyvinyl chloride (PVC) is the most commonly used type of insulation and jacketing materials for power cables.However, in the event of fire, when ordinary or even enhanced flame retardant PVC burns it:

• Emits a dense smoke that will obscure fire exit routes with fumes choking and suffocating people.

• Releases poisonous and hazardous gases due to the presence of halogen element (chlorine) in the PVC compound.

• Causes long term corrosion damage to computer, security/access control equipment, building management systems, lifts and just about anything else with a circuit board.

Clearly, this creates a hazardous situation wherever an accidental fire can occur. The fire may have been extinguished within minutes with no great risk to life but the damage to equipment may be colossal.

6. LITERATURE SURVEY – CONCEPT OF FLAME RETARDANT AND FIRE SURVIVAL CABLES

It is established that smoke and poisonous gases are often a far greater risk to life and property than the fire itself. Low Smoke Halogen Free (LSHF) cables are the safe choice for locations in which there is fire potential and the potential for people to be near that fire.

Flame Retardant Cables

Cables can, depending upon their location, construction and method of installation, affect a fire in a number of different ways. The cables may propagate (spread) flames from one area to another as they quite often form distinct links between separate offices, floors within a building, or even in some cases between buildings themselves.

Flame retardant cables are designed for use in fire situations where the spread of flames along a cable route needs to be retarded. This is achieved through the use of jacketing materials that do not readily burn and will tend to self-extinguish.
Normally, for this type of cables, flame retardant Polyvinyl chloride (PVC) jackets are used, where they tend to have excellent fire performance properties.
The typical application for flame retardant cables with flame retardant PVC outer jacket is in places where *flame retardancy is desirable*, but *smoke and acid gas evolution is not considered to pose a serious hazard to personnel or sensitive equipment.*

Due to relative low cost, flame retardant cables are widely used as fire survival cables.

Fire Resistant (Survival) Cables

The Resistance-to-fire (of a cable) is the term used to describe how long a cable continues to operate in a fire. This may be of primary concern, for instance, in life safety of firefighting installations.
The Resistance-to-Fire performance of cables is indicated in terms of survival time: the times are 15, 20, 90, 120 and 180 minutes of operation in a standardized fire condition.
The best safety and rescue equipment cannot work without secured power supply. If the power supply is adversely affected, the systems themselves will have no power to provide their own critical functions.

Fire resistant cables are designed to *maintain circuit integrity of those vital safety and rescue equipment during the fire*. In addition to maintaining circuit integrity under fire conditions, Fire resistant cables have limited evolution of smoke and corrosive gases when assessed under the fire conditions, thus safeguarding human life and protecting equipment.

Fire resistant cables are intended for applications requiring circuit integrity during a fire, such as;

1. Booster pump systems
2. Sprinkler systems
3. Emergency lighting - speakers
4. Fire and smoke detector systems
5. Rescue elevators
6. Alarm horns
7. Smoke exhaust system for aeration and ventilation.

7. STUDY OF AVAILABLE INDIAN STANDARDS

Keeping in view that the safety of an electric installation is largely attributed to the quality of electric cables, the Government of India has brought IS 694 and IS 9968 under mandatory certification through the Electrical Wires, Cables, Electrical Appliances and Protection Devices and Accessories (Quality Control Order), 2003. Other Indian Standards on Electrical Cables are also brought under the ambit of Quality Control Order through Cables (Quality Control Order), 2020.

S. No.	Indian Standard	Title
1.	IS 694 : 2010	PVC Insulated Sheathed/Unsheathed Cables and cords for working voltages upto and including 1100 V
2.	IS 1554(Part 1) :1988	PVC Insulated (Heavy Duty) Electric Cables for working voltages upto and including 1100 V
3.	IS 1554(Part 2):1988	PVC Insulated (Heavy Duty) Electric Cables for working voltages from 3.3 kV upto and including 11 kV
4.	IS 2593 : 1984	Specification for Flexible Cables for Miner’s Cap-Lamps
5.	IS 5950 : 1984	Specification for Shot Firing Cables (for use other than in shafts)
6.	IS 7098(Part 1):1988	Cross-linked Polyethylene Insulated Thermoplastic Sheathed Cables for working voltages upto and including 1100 V
7.	IS 7098(Part 2):2011	Cross-linked Polyethylene Insulated Thermoplastic Sheathed Cables for working voltages from 3.3 kV to 33 kV
8.	IS 7098(Part 3):1993	Cross-linked Polyethylene Insulated Thermoplastic Sheathed Cables for working voltages from 66 kV to 220 kV
9.	IS 9857 : 1990	Welding Cables – Specification
10.	IS 9968 (Part 1) : 1988	Specification for Elastomer Insulated Cables for working voltages upto and including 1100 V
11.	IS 9968 (Part 2) : 2002	Specification for Elastomer Insulated Cables Part 2 For Working Voltages form 3.3 kV Up to and Including 33 kV
12.	IS 14255 :1995	Aerial Bunched Cable - for working voltages upto and including 1100 V
13.	IS 14494 : 2019	Elastomer Insulated Flexible Cables for Use in Mines – Specification
14.	IS 17048 : 2018	Halogen Free Flame Retardant (HFFR) Cables for Working Voltages Up to and Including 1100 V – Specification

IS → / Tests ↓ Ref : IS 10810(Parts)		694 PVC Insu-lated	1554 Heavy Duty		2593 Miner cap-lamp	5950 Shot Firing	7098 XLPE Insulated			9857 Welding	9968 Elastomer Insulated		14255 ABC	14494 Elastomer - Mines	17048 HFFR
			I	II			I	II	III		I	II			
Annealing test for wires used as conductors (Cu)	1	√	√	√	√	√	√	√	√	√	√	√	-	√	√
Tensile test for aluminium wires	2	√	√	√	-	-	√	√	-	-	√	√	√	-	√
Wrapping test - For aluminium wires	3	√	√	√	-	-	√	√	√	-	√	√	√	-	√
Persulphate test of conductor	4	√	-	-	√	-	-	-	-	-	√	√	-	-	√
Conductor resistance test	**5**	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Thickness of thermoplastic and elastomeric insulation and sheath	**6**	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Tensile strength and elongation at break of thermoplastic and elastomeric insulation and sheath	**7**	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Breaking strength and elongation at break for impregnated paper insulation	**8**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tear resistance for paper insulation	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loss of mass test	10	√	√	√	-	√	√	√	√	-	-	√	-	-	-
Thermal ageing in air	**11**	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Shrinkage test	12	√	√	√	-	√	√	√	√	-	-	√	√	-	-
IS →		**694 PVC Insu-lated**	**1554 Heavy Duty**		**2593 Miner cap-lamp**	**5950 Shot Firing**	**7098 XLPE Insulated**			**9857 Welding**	**9968 Elastomer Insulated**		**14255 ABC**	**14494 Elastomer - Mines**	**17048 HFFR**
Tests ↓ **Ref : IS 10810(Parts)**			**I**	**II**			**I**	**II**	**III**		**I**	**II**			
Ozone resistance test	13	-	-	-	-	-	-	-	-	-	-	**O**	-	√	√
Heat shock test	14	√	√	√	-	√	√	√	√	-	-	√	-	-	-
Hot deformation test	15	√	√	√	-	√	√	√	√	-	--	√	-	-	√
Accelerated ageing test by oxygen pressure method	16	-	-		√	-	-	-	-	-	√	-	-	-	-
Tear resistance test for heavy duty sheath	17	-	-	-	-	-	-	-	-	-	√	√	-	√	-
Bleeding and blooming test	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cold bend test	20	√	**O**	-	-	-	**O**	-	-	-	-	-	-	-	**O**
Cold impact test	21	√	**O**	**O**	-	-	**O**	**O**	**O**	-	-	**O**	-	-	**O**
Vicat softening point	22	-	-		-	-	-	-	-	-	-	-	√	-	-
Melt - Flow index	23	-	-	-	-	-	-	-	-	-	-	-	√	-	-
Water soluble impurities test of insulating paper	24	-	-	-	-	-	-	-	-	-	-	-		-	-
Conductivity of water extract test of insulating paper	25	-	-	-	-	--	-	-	-	-	-	-	-	-	-
PH value of water extract test of insulating paper	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ash content test of insulating paper	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water absorption test (Electrical)	28	-	-	-	-	-	-	-	-	-	√	√	-	√	-

IS → / Tests ↓ Ref : IS 10810(Parts)		694 PVC Insu-lated	1554 Heavy Duty		2593 Miner cap-lamp	5950 Shot Firing	7098 XLPE Insulated			9857 Welding	9968 Elastomer Insulated		14255 ABC	14494 Elastomer - Mines	17048 HFFR
			I	II			I	II	III		I	II			
Environmental stress cracking test	29	-	-	-	-	-	-	-	-	-	-	-	√	-	-
Hot set test	30	-	-	-	-	-	√	√	√	√	√	√	√	√	√
Oil resistance test	31	-	-	-	√	-	-	-	-	√	√	√	-	√	-
Carbon content test for polyethylene (PE sheath)	32	-	-	-	-	-	-	√	√	-	-	-	√	-	-
Water absorption test (Gravimetric)	33	-	-	√	-	-	√	√	-	-	-	-	√	-	-
Measurement of thickness of metallic sheath	34	-	-	-	-	-	-	-	√	-	-	-	-	-	-
Determination of tin in lead alloy for	35	-	-	-	-	-	-	-	--	-	-	-	-	--	-
Dimensions of armouring material	36	-	√	√	-	-	√	√	√	-	-	√	-	√	-
Tensile strength and elongation at break of armouring materials	37	-	√	√	-	-	√	√	√	-	-	√	-	√	-
Torsion test on galvanized steel wires for armouring	38	-	√	√	-	-	√	√	-	-	-	√	-	√	-
Winding test on galvanizedsteel strips for armouring	39	-	√	√	-	-	√	√	-	-	-	√	-	√	-
Uniformity of zinc coating on steel armour	40	-	√	√	-	-	√	√	-	-	-	√	-	√	-
Mass of zinc coating on steel armour	41	-	√	√	-	-	√	√	-	-	-	√	-	√	-

IS → Tests ↓ Ref : IS 10810(Parts)		694 PVC Insu-lated	1554 Heavy Duty		2593 Miner cap-lamp	5950 Shot Firing	7098 XLPE Insulated			9857 Welding	9968 Elastomer Insulated		14255 ABC	14494 Elastomer - Mines	17048 HFFR
			I	II			I	II	III		I	II			
Resistivity test of armour wires and strips and conductance test of armour (Wires strips)	42	-	√	√	-	-	√	√	√	-	-	√	-	√	-
Insulation resistance	43	√	√	√	-	√	√	√	√	√	√	√	√	√	√
Spark test	44	√	-	-	-	-	-	-	-	√	√	-	-	--	√
High voltage test	45	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Partial discharge test	46	-	-	√	-	-	-	√	√	-	-	√		√	-
Impulse test	47	-	-	√	-	-	-	√	-	-	-	√	-	-	-
Dielectric power factor test	48	-	-	√	-	-	-	√	√	-	-	√	-	√	-
Heating cycle test	49	-	-	√	-	-	-	√	-	-	-	√	-	√	-
Bending test	50	-	--	√	-	-	-	√	√	-	-	√	-	√	-
Dripping test	51	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Drainage test	52	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flammability test	53	√	√	√	√	√	√	√	√	√	√	√	-	√	√
Static flexibility test	54	-	-	-	-	-	-	-	-	√	-		-	-	-
Abrasion test	55	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Accelerated ageing test by air pressure method	56	-	-	-	-	-	-	-	-	√	√	√		√	-
Flexing test	57	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxygen index test	58	√	√	√	-	--	√	√	-	-	-	-	-	-	√

IS → / Tests ↓ Ref : IS 10810(Parts)		694 PVC Insu-lated	1554 Heavy Duty		2593 Miner cap-lamp	5950 Shot Firing	7098 XLPE Insulated			9857 Welding	9968 Elastomer Insulated		14255 ABC	14494 Elastomer - Mines	17048 HFFR
			I	II			I	II	III		I	II			
Determination of the amount of halogen acid gas evolved during combustion of polymeric materials taken from cables	59	√	√	√	-	-	√	√	-	-	-	-	-	-	-
Thermal stability of PVC insulation and sheath	60	√	√	√	-	-	√	√	√	-	-	√	-	-	-
Flame retardant test	61	-	√	√	-	-	√	√	-	-	-	-	-	-	√
Flame retardance test for bunched cables	62	-	√	√	-	-	√	√	-		-	-	-	-	---
Measurement of smoke density of electric cables under fire conditions	63	-	-	-	-	-	-	√	-	-	-	-	-	-	√
Measurement of temperature index	64	√	√	-	-	-	√	√	-	-	-	-	-	-	√
Additional Tests		**Y**	**Y**	**Y**	**N**	**Y**	**N**	**N**	**Y**	**N**	**Y**	**N**	**N**	**Y**	**Y**

1. Material Testing of conductors(Copper and Aluminium) - **IS 8130 :2013** - Conductors for insulated electric cables and flexible cords - Specification (Second Revision)
2. Purity of Copper conductor - **IS 191:2007** - Copper -Specification (Fourth Revision)

8. INTERNATIONAL STANDARDS AND PRACTICES

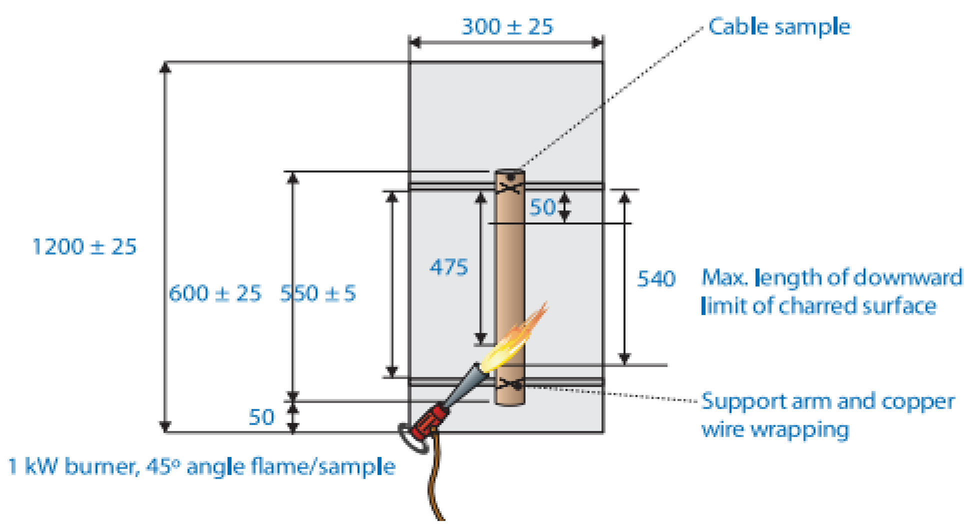
The performance of cables under fire conditions is defined in a number of international standards, the outline of which is as follows:-

A. Flame Propagation Test: (IEC 60332-1)

This test is used to measure the resistance to vertical flame propagation for a single vertical electrical insulated conductor or cable under fire conditions.

A 600 mm long cable sample is suspended vertically in a draught-free enclosure and the lower end is exposed to a gas burner angled at 45 ° to the horizontal. The flame application time is from 1-8 min depending on the cable diameter.

The single insulated conductor or cable shall pass the test if the distance between the lower edge of the top support and the onset of charring is greater than 50 mm. In addition, a failure shall be recorded if charring extends downwards to a point greater than 540 mm from the lower edge of the top support.



Vertical flame propagation test for a single insulated wire or cable (IEC 60332-1)

B. Flame Spread Test: (IEC 60332-3)

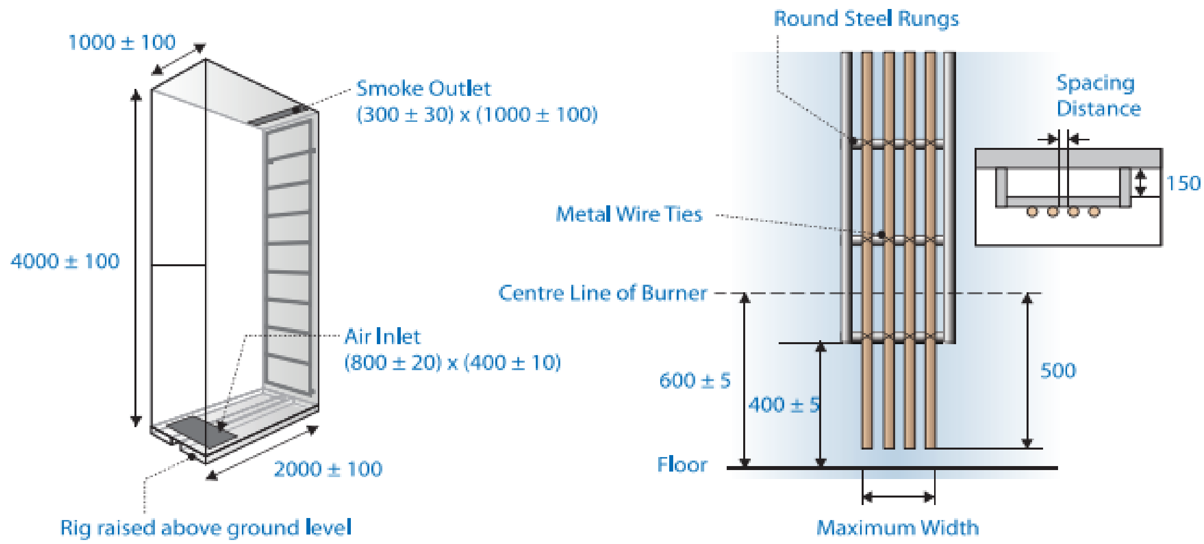
This series of standards covered by parts 3-22, 3-23, 3-24 and 3-25 define the tests used to measure the resistance to vertical flame spread of vertically-mounted bunched wires or cables under fire conditions.

This test attempts to simulate a real installation environment and uses bunched cables, 3.5m long, fixed in a vertical arrangement. The ignition source is a ribbon type propane/air burner with a fuel input of 73.7 MJ/hour. The burner is arranged horizontally at the foot of the ladder to which the cables are fastened and is applied for 20 or 40 minutes, depending on the category.

The test categories are distinguished by test duration, the volume of non-metallic material of the test sample and the method of mounting the sample for the test as follows:

- **IEC 60332-3-22 (Category A):** The number of test pieces required to provide a total volume of 7.0 l/m of nonmetallic material shall be bunched on a ladder exposed to flame for 40 minutes.
- **IEC 60332-3-23 (Category B):** The number of test pieces required to provide a total volume of 3.5 l/m of nonmetallic material shall be bunched on a ladder exposed to flame for 40 minutes.
- **IEC 60332-3-24 (Category C):** The number of test pieces required to provide a total volume of 1.5 l/m of nonmetallic material shall be bunched on a ladder exposed to flame for 20 minutes.
- **IEC 60332-3-25 (Category D):** The number of test pieces required to provide a total volume of 0.5 l/m of nonmetallic material shall be bunched on a ladder exposed to flame for 20 minutes.

The bunched wires or cables shall pass the test if the maximum extent of the charred portion measured on the samples shall not have reached a height exceeding 2.5 m above the bottom edge of the burner.



Vertical flame spread test for vertically-mounted bunched wires or cables (IEC 60332-3)

C. Fire Resistance Test: (IEC 60331, BS 6387)

This test is intended to evaluate cables which are designed as fire survival cables to be used for fire alarm circuits, emergency lighting, and cables for other emergency services. The test establishes whether a cable can maintain electrical circuit integrity for a time up to 3 hours at temperatures ranging from 650 °C up to in excess of 950 °C.

The energized cable (at the rated voltage) is mounted horizontally in a test chamber and is exposed to a gas flame from a ribbon type burner, adjusted to give the appropriate temperature. There are many variations of this test using different conditions and a cable is rated depending on how the cable performs in the various categories. These categories can be summarized as follows:

Resistance to Fire Alone

- **IEC 60331-21**: Cables are subjected to fire at 750 °C for 90 minutes followed by a 15 min cooling period.
- **BS 6387 (Category A):** Cables are subjected to fire at 650 °C for 180 minutes.
- **BS 6387 (Category B):** Cables are subjected to fire at 750 °C for 180 minutes.
- **BS 6387 (Category C):** Cables are subjected to fire at 950 °C for 180 minutes.
- **BS 6387 (Category S**): Cables are subjected to fire at 950 °C for 20 minutes (short duration).'

Resistance to Fire with Water

BS 6387 (Category W): Cables are subjected to fire at 650 °C for 15 minutes, then at 650°C with water spray for further 15 minutes.

Resistance to Fire with Mechanical Shock

- **IEC 60331-31**: Cables are subjected to fire at 830 °C with mechanical shock for 120 minutes.
- **BS 6387 (Category X**): Cables are subjected to fire at 650 °C with mechanical shock for 15 minutes.
- **BS 6387 (Category Y):** Cables are subjected to fire at 750 °C with mechanical shock for 15 minutes.
- **BS 6387 (Category Z):** Cables are subjected to fire at 950 °C with mechanical shock for 15 minutes.

The cable will possess the characteristics for providing circuit integrity so long as during the course of the test; the voltage is maintained i.e. no fuse fails or circuit-breaker is interrupted and a conductor does not rupture, i.e. the lamp is not extinguished.

D. Determination of the Halogen Acid Gas Content

IEC 60754-1 and BS EN 50267-2-1 Standards specify a test for determination of the halogen acid gas other than the hydrofluoric acid evolved during combustion of compound based on halogenated polymers and compounds containing halogenated additives taken from cable constructions.

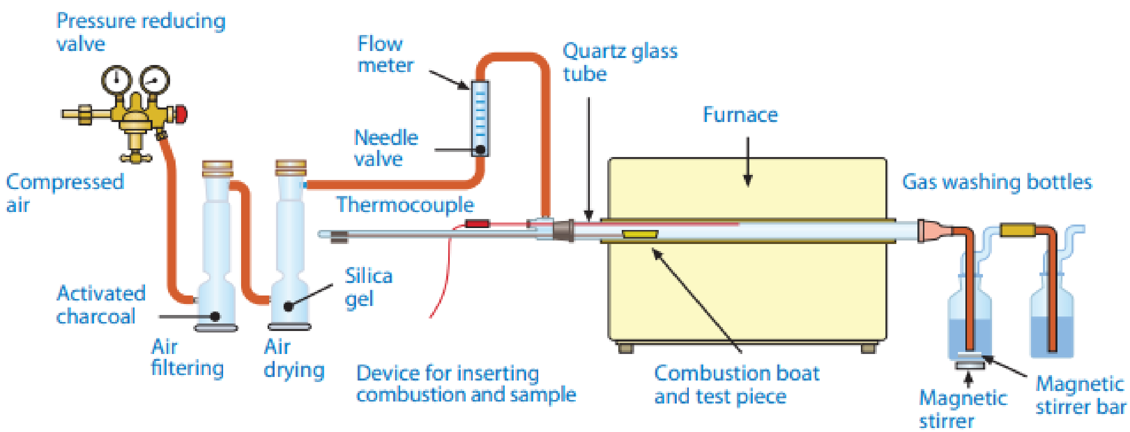
In this test, when the burner is heated to 800 °C, 1g sample is placed inside and the HCL is absorbed into water inside the chamber fed with air flow. The water is then tested with its acidity. If the hydrochloric acid yield is less than 5 mg/g, the cable specimen is categorized as LSHF.

IEC 60754-1 standard cannot be used for measuring the exact HCL yield if the yield is less than 5mg/g. This test cannot determine if the cable is 100% halogen free or not. To determine if the cable specimen is 100% halogen free or not, IEC 60754-2 has to be employed.

E. Determination of Acidity

IEC 60754-2 and BS EN 50267-2-2 Standards specify a test for the determination of degree of acidity of gases evolved during combustion of the cable specimen by measuring its pH and ionic conductivity.

The specimen is deemed to pass this test if the pH value is not less than 4.3 when related to 1 litre of water and the weighted value of conductivity is less than10 µS/mm.



Acid gas emission test apparatus (IEC 60754)

F. Smoke Emission Test: (IEC 61034)

Smoke evolution is another critical performance indicator which needs to be evaluated on a laboratory scale and there are a number of methods used, based either on gravimetric or optical techniques.
IEC 61034 and BS EN 61034 Standards specify a test for determination of smoke density. The 3 meter cube test measures the generation of smoke from electric cables during fire. A light beam emitted from a window is projected across the enclosure to a photocell connected to a recorder at the opposite window. The recorder is adjusted to register from 0% for complete obscuration to 100% luminous transmissions.
A one-meter length of cable is placed in the 3 m3 enclosure, and a fire is then generated within the container and the minimum light transmission is recorded.
The result is expressed as percentage of light transmitted. The specimen is deemed to pass this test if the value is greater than 60%. The higher the light transmittance, the less smoke emitted during a fire.

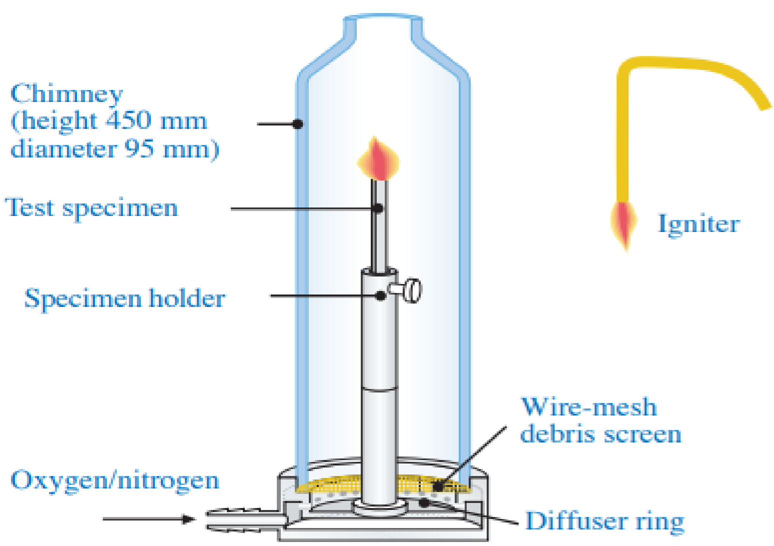
Smoke density 3 m test cube (IEC 61034)

G. Limiting Oxygen Index (LOI): (BS EN ISO 4589, ASTM D 2863)

Oxygen index is perhaps the most widely used indicator of a material's flammability. It is the minimum percentage of oxygen in an oxygen/nitrogen mixture required to support combustion of a given material at room temperature.

BS EN ISO 4589 and ASTM D 2863 Standards Specify methods for the determination the minimum concentration of oxygen, in a mixture with nitrogen, which will support combustion of small vertical test specimens under specified test conditions over a range of temperatures between 25 °C and 150 °C. The results are defined as oxygen index values at the test temperature.

Flame retardant materials require a level of oxygen higher than that normally present in the atmosphere (21%) for burning to be maintained and a material having an oxygen index of 26 or above is considered to be selfextinguishing. In general, the oxygen index of flame retardant PVC jacketed cables ranges from 28% to 32%, and for LSHF cables ranges from 33% to 45%.



Various International Standards on Fire Survival Cables –

COUNTRY	STANDARD	TITLE
INTERNATIONAL	IEC 60331	Tests for electric cables under fire conditions – Circuit integrity
EUROPE	EN 50200	Method of test for resistance to fire of small unprotected small cables for use in emergency circuits
GERMANY	DIN 4102 Part 12 (E30 E60 E90)	Fire behaviour of building materials and elements - Fire resistance of electric cable systems required to maintain circuit integrity - Requirements and testing
UK	BS 6387 (C W Z)	Test method for resistance to fire of cables required to maintain circuit integrity under fire conditions.
FRANCE	NF C 32-070-CR1	Insulated cables and flexible cords for installations - Classification tests on cables and cords with respect to their behaviour to fire.
ITALY	CEI 20-36	Method of test for fire resistance of small cables unprotected for use in emergency circuits
SPAIN	UNE-EN 50362	Method of test for resistance to fire of larger unprotected power and control cables for use in emergency circuits.
USA	UL 2196	Fire Test for Circuit Integrity of Fire-Resistive Power, Instrumentation, Control and Data Cables
CANADA	ULC S139	Standard Method of Fire Test for Evaluation of Integrity of Electrical Cables
AUSTRALIA	AS/NZ 3013	Electrical installations - Classification of the fire and mechanical performance of wiring system elements
SINGAPORE	SS 299-1 (C W Z)	Fire resistant cables - Performance requirements for cables required to maintain circuit integrity under fire conditions

9. RECOMMENDATIONS

A. Based on above information, it is recommended to have an Indian Standard on Fire Survival(Resistance) Cables as they offer following major advantages over other types of cables :

1. Maintain circuit integrity of those vital safety and rescue equipment during the fire.

2. No Emission of Toxic Gases – They eliminate the threat of inhaling toxic gasses which reducing the damage to the human respiratory system.

3. Reduces the Smoke Emission to the Minimum - No releases of dense smoke that impairs visibility of the fire exit routes and hampers rescues operations.

4. Resistant to ignition - It takes much more time than traditional cables to catch a fire, which facilitating the evacuation procedures.

5. Reduces the Flame Propagation - Its excellent flame retardant property prevents the fire from spreading through the place.

B. *Proposed area of Application* - These cables are perfect for applications that require high performance and reliability while offering outstanding safety, so it can be typically used for:

Places which are regularly densely populated	Places with unfamiliar building's layout	Places inhabited by people with limited mobility
• Residential Complex • Hotel • Schools & Universities • Commercial Offices	• Shopping Malls • Public Buildings • Airport Terminals • Cinemas & Theatre	• Care Homes • Foster Homes • Retirement Homes • Hospitals & Clinics

C. *Proposed Materials and Tests* – The following materials and tests is proposed on the basis of study of Indian Standards on Power cables at Page – 20 and study of international standards on fire performance characteristics of cables at Page - 26:

Material/Item	**Justification**	**Test (as per IS 10810 *for property Evaluation*)**
Conductor - **Copper**	As *the cable must be able to sustain functioning and circuit integrity at 950°C , Copper with the higher melting Point of 1085°C provides an added advantage.*	• Conductor Resistance Test • Annealing Test (for copper)
Insulation & Sheath – **Cross-linked Polyethylene and Halogen Free Flame Retardant**	*Low Smoke Halogen Free (LSHF) cables are the safe choice for locations in which there is fire potential and the potential for people to be near that fire.*	• Thickness Test • Insulation Resistance • Tensile Strength & Elongation • Ageing in Air Oven • Shrinkage Test • Oxygen Index and Temperature index • Smoke Density • Assessment of Halogen
Other Tests	*To demonstrate satisfactory performance characteristics to meet the intended application.*	• High Voltage Test • Flammability Test • Circuit Integrity Test as per IEC 60331

10. REFERENCES

1. Accidental Deaths & Suicides in India(ADSI) -2019 report published by National Crime Records Bureau (NCRB).

2. Global Diseases Burden report published in the BMJ Injury Prevention Journal, 2017.

3. Evolutions for testing fire rated cables and alignment with real fire scenarios by By Richard Hosier. April 2014.

4. IEEMA Journal. Cables. Volume 7. Issue 1. September 2015.

APPENDIX - V

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS

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

DECLARATION OF ORIGINAL WORK

I, SHIKHA GOYAL, Sc-C (indicate official's Name & Designation),

EmployeeNo 67695 hereby declare that the Action Research Projecttitled "To study the concept of fire-Survival Cables and prepare a Pre-standardization Report" is the original research work done by me. I have not copied from any other Action Research Project or any other work of similar nature and topic done by any person/institution/body either published or yet to be published. Data and information from other sources, used if any, have been with prior permission, wherever required and is duly acknowledged appropriately in the project report submitted by me.

This declaration is made on the 27th day of August 2021

Shikha Goyal 27/08/2021

Sign. of Officer with Date

Note: Joint Declaration should be submitted for Projects undertaken jointly