

**2-DAY CONFERENCE ON
“FIRE PROTECTION SYSTEMS IN
INDUSTRIES, HOSPITALS, BUILDINGS AND
POWER SECTOR”**

**AT FEDERATION OF GUJARAT INDUSTRIES (FGI),
GOTRI-SEVASI ROAD, VADODARA**

15 & 16 OCT 2024

PROCEEDINGS



**JOINTLY ORGANIZED BY
THE SOCIETY OF POWER ENGINEERS (I)
VADODARA CHAPTER &
CENTRAL BOARD OF IRRIGATION AND
POWER, NEW DELHI**



**The Society of Power Engineers (India)
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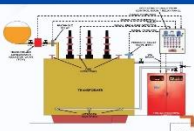
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INDEX

Sr. No.	Description	Author/s	Page No.
1	Fire in Industrial, Commercial and Residential Installations due to electricity.	Er. Ram Pravesh Sharma	1
2	Fire in Floating Roof Tank Due to Lightning Strike.	Er. KK Roy	8
3	Enhancing Fire Protection Strategies in Lignite Open-Cast Mines.	Mr. Sumankumar A. Goswami Mr. Rahul Kumar	13
4	Legal Provisions in CEA Regulations for Fire Prevention & Protection in Electrical Power	Er. BN. Raval Er. PA Shah	18
5	Hydrogen Safety in Industry	Shri LR Patel	23
6	Fire Safety in Building & Hospitals	Shri Rajesh B Shirke	29
7	Fire-Survival Cables: An Essential Aspect for Fire & Safety	Shri Bharat Sehgal	41
8	General Safety & Fire Safety in The Extra High Voltage Substation - Assessment, Construction Practices & Recommendations	Er. Ishan Desai Er. SM Takalkar Er. (Ms) Binal Modi	46
9	Electric Fire and Explosion Hazard Prevention for Power Transformer	Er. (Ms) Binal Modi Er. Ishan Desai Er. PA Shah	53
10	Enhancing Electrical Fire Safety in an Industrial Facility: A Case Study	Er. (Ms) Hetal Prajapati Er. Parth Bhatwadekar	59
11	Change Your Safety Attitude	Shri AB Chaudhry	61
12	Power Transformers Fire – Root Cause Analysis	Er. (Dr.) AJ Chavda Er. YV Joshi	64
13	Fire Safety and Prevention in Substation Equipment: Focus on Instrument Transformers	Er. GV Akre	72
14	Causes and Mitigating Measures of Rising Fire Incidents in Hospitals - Ways to Prevent Fire Accidents in Hospitals	Er. Gaurang Bhavsar	79
15	The Advantages of Nasa Fire Technology Limited's Solutions Over Traditional Fire Extinguishers	Shri Pratik Trivedi	82
16	Tactical Ventilation for Mitigating Fire Hazard	Er. SS Mishra	85
17	Lessons Learnt from Electrical Fire Incidences	Er. Hemendra Raval	88
18	Condensed Aerosol Systems - Basic Design Considerations	Er. Krishnan	92
19	Provisions under National Building Code for Safety of Buildings	Er. (Dr) Rital Gajjar Er. (Ms) Binal Modi	94
20	Prevention of Transformer Explosion Fire – A Report of Satisfactory Service Experience	Er. SK Shelgaonkar Er. Amit Jaiman	99

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FIRE IN INDUSTRIAL, COMMERCIAL AND RESIDENTIAL INSTALLATIONS DUE TO ELECTRICITY

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Synopsis: *The reason for fire due to electricity in Industrial, commercial and residential installations happens due to improper design & engineering, inappropriate procurement of equipment and material from vendors. Installation, commissioning and maintenance not as per prescribed procedure and by competent person. Proper and updated documentation and record keeping of all stages is biggest problem. Now a days outsourcing of different services for controlling time and cost is creating trouble in running the installations continuously and safely due to substandard agency and lack of co-ordination among them.*

As mentioned in synopsis, topic will cover one by one the stages from design to maintenance and record keeping. Only causes of electric fire and its minimization shall be discussed. The basic purpose of this presentation is to eliminate or minimize the risk of ignition from electrical energy sources.

Fire detection, communication and firefighting shall not be discussed here.

1. Design: During this stage, based on the load list, equipment rating, plot plan & layout, hazardous area classification (HAC), applicable latest national and international standards, recommended practices and statutory requirement, system shall be designed. All basic calculations like short circuit, arc flash, equipment rating, earthing, lightning etc. shall be done. Based on this short circuit rating at each busbar of various voltage rating shall be fixed. Based on load and equipment rating and its location, single line diagram with protection system is

prepared. Earthing & Lightning system shall be designed.

For plants and commercial complexes where hazardous gas, liquid, dust and fiber is processed, plot plan & elevation drawing shall be classified and marked as per standards as zone 0, 1, 2, 20, 21 & 22 based on presence of hazardous gases, vapour, dust and fiber. Plants may be oil & gas, petrochemical, paint, biogas, sewage treatment, warehouses, where hazardous material is stored and handled.

For hazardous area classification and drawing preparation in most of the organization it is believed to be the work of Electrical discipline and at some places Piping. But this is not correct. Often, area classification assessment studies default to the responsibility of Electrical Engineers, without considering the fact that the assessment process itself has nothing to do with the discipline of electrical engineering. Assessing a process facility for HAC is completely dependent on the actual process conditions. Process pressures, temperatures, flowrates and stream compositions are essential elements used to define a hazardous classified location.

Since for this a lot of basic data is required from process (chemical) department. Like PFD, MSDS (material safety data sheet), materials of construction, piping and instrumentation diagrams (P&IDs), relief system designs and design bases, ventilation system designs, material and energy balances, safety shutdown systems and electrical classifications. Electrical classification was, and still is, legally considered an integral part of required process safety

information. Electrical & Instrument discipline role is only selection of suitable equipment and material for the hazardous area.

Area Classification:

As per IEC / IS the specified area is classified as Zone 0, 1, 2 & 20, 21 & 22 depending on the presence of the gas vapour, dust and fibre as defined (ref. standards IS-5572 & IEC 60079-10). For defining the area, standards define the horizontal & vertical distances from the sources of hazards & density of gas. Like for heavier than air gases 8 m above and 16 m horizontally from the source in all direction for normal release & 32 M horizontally (but for extended 16M Vertically only 0.63 m) for large release shall be classified as zone 1 or 2 depending on the presence of gas. But all trenches & trapped area shall be zone 1. Area adjoining Zone 1 shall be considered as zone 2. For details ref. standards.

Exclusions:

Following is excluded from the scope of this classification & selection. For this purpose, separate standards are applicable.

- i) Underground Mining application, Gas group I (Methane)
- ii) Processing & manufacturing of explosive.
- iii) Catastrophic failure (rupturing of vessel or pipe)
- iv) Ignition source other than those associated with electric Apparatus
- v) Toxic risk due to combustible material.

Definition & Terms used in HAC:

Hazardous Area: An area in which an Explosive Gas atmosphere is present, or likely to be present, in quantities so as to require special precautions for the construction, installation and use of Electrical Apparatus.

Explosive Gas Atmosphere: A mixture with air under normal atmospheric condition, of Flammable material in the form of gas, vapor or mist in which after ignition combustion

spreads throughout the unconsumed mixture.

Flammable Material: For classification, it includes:

Petroleum having Flash point below 65°C or any flammable gas or vapor in a concentration capable of ignition.

Petroleum or any flammable liquid having flash point above 65°C, likely to be refined, blended, handled, or stored at or above its Area means 3 D Area

Normal atmosphere means 20°C and one atm pressure.

Flammable liquid that has flash point below 93°C & vapor pressure not exceeding 2.81 kg/M² are classified as Class A, B & C

Class A: Having flash point below 23°C.

Class B: Having flash point below 65°C.

Class C: Having flash point above 65 °C & below 93°C (Solvent to Heavy fuel oil)

Flash point: Temperature at which liquid gives so much vapour that this vapour when mixed with air, turn an ignitable mixture and gives a momentary flash on application of a small pilot flame under specified condition of test

Ignition temperature: The lowest temp at which ignition occurs in a mixture of explosive gas and air when the method of testing ignition temperatures specified in relevant IS is followed.

Adequate Ventilation: At which concentration is 1/4th of lowest flammability.

LEL: Lower explosive limit, concentration of flammable gas, vapor or mist in air, below which an explosive gas atmosphere will not be formed.

UEL: Upper Explosive limit, the concentration of gas, vapor, mist in air, above **which an explosive gas atmosphere will not be formed.**

MSEG: Minimum experimental safe gap.

Maximum gap of the joint between two parts gas or vapor in air.

Maximum gap of the joint between two parts of the inter chamber of a test apparatus which, when the internal gas mixture is ignited under the specified condition, prevent ignition of external gas mixture by flame propagation through a 25mm long joint for all concentration of tested gas or vapor in air.

MIC: Minimum ignition current

Statutory Requirements:

These are Statutory requirement to be complied by parties. They are required for safety of the personnel. Statutory requirement are acts, rules and regulations formulated by Central Government. State Government have acts in line with Central Government at local level

Electricity act 2003 & NEC 2023. These are the statutory requirement for India.

For classifying the area and selection of equipment following information is required.

Details are given in Appendix 1,2,3 & 4. A comparison of the same as per IEC/IS & NEC is also given as Appendix -5

1. Zone / Division identification. Appendix -1
2. Gas group identification. Appendix -2
3. Temperature class identification. Appendix-3
4. Comparison of above as per IEC / IS & NEC Appendix-4

2. Engineering: Based on design, engineering shall be developed. Required size and type of equipment and material shall be estimated. Protection system shall be designed accordingly.

Layout drawing shall be prepared.

Equipment in classified area is selected as follows as per IS:5571

- a) No Electrical Equipment should be placed in Zone 0 area. Where not practicable, intrinsically safe apparatus should be used. (Exia & Exib)
- b) Following type of equipment shall be used in Zone 1 area:

- I. Intrinsically safe (Exia & Exib)
- II. Flameproof (Exd.)
- III. Pressurised (Exp)
- IV. Sand filled (Exq)
- V. Oil immersed (Exo)
- VI. Incapsulated (Exm)
- VII. Or any other apparatus as may be especially certified or assessed for Zone-1 area.

Following type of equipment shall be selected for Zone area 2

- I. Intrinsically safe (Exia & Exib)
- II. Flameproof (Exd.)
- III. Pressurised (Exp)
- IV. Sand filled (Exq)
- V. Oil immersed (Exo)
- VI. Incapsulated (Exm)
- VII. Increased Safety (Exe)
- VIII. Non Sparking (Exn)

While selecting the equipment Temperature & gas grouping shall be considered. Separate standards for different equipment should be referred. Also, standards are available for different type of equipment like Exi, Exd, Exe, Exn etc, which should be referred for details for equipment construction, testing, certifying & approving.

Static electric and earthing system shall be designed as required.

3. Procurement: Based on engineering, specification shall be prepared for each equipment and material. Vendor list shall be prepared separately for each type of equipment as per area classification. For equipment, required type test certificate of competent authority should be asked and verified thoroughly. Shop test of equipment shall be done and all drawing and documents should be well documented.

Testing of Equipment:

For testing, certifying & approving of all the referred equipment, all over the world test lab, certifying & approving agencies have been

recognised. Only papers of these authorities should be followed. Reference for those is available hereunder:

National and international testing and approving authority:

1. CIMFR (Central Institute for Mining & fuel Research, formerly known as CMRI) Located at Dhanbad, Jharkhand. This institute is dedicated to test equipment for hazardous area.
2. ERTL (Electronic regional test Laboratory), located at Kolkata, New Delhi, Mumbai & Thiruvananthapuram
3. PESO Petroleum Explosive Safety Organization, earlier CCOE (Chief Controller of Explosive, Nagpur)
4. DGMS (Director General Mines safety, Dhanbad)
5. DGFASLI (Director General of Factory Services & Labour Institute, Mumbai)
6. UL (USA)
7. CSA (CANADA)
8. CESEESI (ITALY)
9. GOST (RUSSIA)
10. BASEEFA & SCS (UK)
11. PTB & DVS (GERMANY)

4. Installation: During installation equipment should be installed as per vendor's instruction by competent person. Before commissioning testing should be done and all record should be preserved. As built drawing should be available and it should be updated if there is any revision in main drawing.

5. Maintenance: During maintenance, appropriate procedure should be followed for opening and closing the equipment by appropriate tools. Records should be maintained. Updated as built drawing should be available for any change in basic drawing.

List of important standards & recommended practices:

- IS-3043: Earthing
- IS-2903: Lightning protection
- IS-5571: Selection of electrical

equipment for hazardous area.

- IS- 7689: Static electricity
- RP- 110: Static Electricity
- 113 – Area classification for hydro-carbon process
 - 173: Fire prevention and protection for electrical installation
 - 180: Lightning Protection
- NFPA 780: Lightning Protection
- NFPA 70 : National Electric Code (NEC) (NEC Article 500)
- NFPA 77: Static Electricity
- API RP 2003: Protection against static Electricity, lightning and stray current.
- API RP 500: Hazardous Area Classification.
- IEEE 142: Grounding of Industrial Plant (Green Book)
- IS 5572 For Classification of Hazardous Area
- IS 2148 Flame Proof Enclosure of Electrical Equipment.
- IS 6381 Construction & Testing of Electrical Apparatus with type of Protection 'e'
- IS 5780 Specification for Intrinsically Safe Electrical Apparatus & Circuits
- IS 8241 Methods of Marking for Identifying Electrical Equipment in Explosive Area.
- IS 8224 Specification for Electric Lighting Fitting for Explosive Area
- IS 8289 Electric Equipment with type of protection 'n'
- API RP 540 (Electrical installations in petroleum processing plants).
- NFPA 496 (Standard for purged and pressurized enclosures for electrical equipment)
- NFPA 497 [Recommended practice for the classification of flammable liquids, gases or vapors and of hazardous (classified) locations for electrical installations in chemical process areas).

- IEC
- API (US)
- ATEX Directive (for Europe)
- Installation, connection, protection & maintenance of all the equipment should be done as per the guideline of the IS 13408 Part I, II, III Code of selection, Installation & Maintenance of Electrical apparatus for use in Explosive Atmosphere

6. Commercial advantages:

Generally, all companies take insurance against fire. For this insurance companies review all drawings and documents. Based on this they decide annual premium. If installation has been designed, engineered, installed and maintained as per required standards and mandatory requirements, then premium will be less otherwise more as per their guideline.

7. Takeaways of above:

For lightning, static electricity and protection against ignition, all the requirements mentioned by standards are, as per the knowledge available as of today. This requirement keeps on changing as technology changes. Even with the best of protections provided, fire happens. Some due to human error and some due to system failure and natural phenomena. Most of the tank farm fire happens due to noncompliance of safety norms. Therefore, due care should be taken during design & upkeeping of plant.

It is observed that big industrial units take help of reputed engineering consultancy organisation, hence system design, procurement, installation and maintenance are satisfactory. But the approach of medium and small industrial units is not satisfactory, since the hired engineering consultants may not be aware about equipment suitable for hazardous area. Biggest problem is procurement of suitable material for

hazardous area. Most of the vendor for such material are small scale or medium scale with insufficient facility as well as required documentation. Mostly their type test certificates are outdated due to revision of relevant standards. Also, competent person is not available to verify such documents.

Things are more complicated, when equipment for hazardous are sourced from foreign countries and relevant documents are not available. Especially, where electrical & Instrument document are part of package. Cost cutting and outsourcing of different services are taken. In such cases control and co-ordination is a problem.

Sometime design, procurement and construction is outsourced separately, without any co-ordination between agencies. Therefore, any change in lay out or equipment after design is not implemented or implemented wrongly.

In such cases appointment of PMC (Project Management Consultant) is necessary.

In case of commercial and residential installation this problem is more acute, since major planning is done by Architect, who does not provide sufficient and suitable space for electrical equipment. Electrical job is outsourced to non-competent sub-contractor. Cable & wire selection and laying is not as per good engineering practice. Circuit protection is not as required. All outsourced agencies are not upto the mark. Hence most of the fire takes place, due to heating in cable duct, wire and due to short circuit or earth fault.

In bigger plants due to EPC contract for execution co-ordination is poor. Equipment is sourced from different countries. With their symbols, certificates etc, hence more confusion is faced at all levels.

In plants small equipment like junction box, push button stations, switch sockets etc are sources from small vendors, where quality

is doubtful. Most of the fire takes place due to such equipment.

Sometime after fire, enquiry is set up for investigation, but nothing concrete comes out, because relevant actual information, data and document is not available to investigating agency.

In view of above, awareness among stakeholders is more important. More training should be given to concerned personnel. Experienced person of specific field should be employed. But in present, environment of frequent changing of job, it is difficult. Things were better prior to 1990, before liberalisation of Indian market, especially to bigger organisations.

Appendix

1. Zones: Hazardous area is classified in Zones based upon the frequency of the Appearance and the duration of an explosive gas atmosphere. This is classified as:

Zone 0: Gas is present continuously or is present for a long period (more than 1000 hours in a year)

Zone 1: An area in which explosive gas is likely to occur in normal operation (10 to 1000 hrs. in a year).

Zone 2: An area in which an explosive gas atmosphere is not likely to occur in normal operation, and if it does occur, it will exist for a short period only (less than 10 hours in a year)

Zone 20, 21 & 22: like 0, 1 & 2 but for Dust & Fiber

Zone & Division:

Gas & Vapor/ Dust / Fiber / Class I, II & III

Zone 0 & 1 of IEC is Division 1 of NEC & Zone 2 of IEC is Division 2 of NEC

Gas Grouping

As per IEC / IS, Gas is grouped as Group I, Group IIA, IIB & IIC. Group I is Methane, IIA is Propane & similar hydrocarbons, IIB is Ethylene & similar hydrocarbons and Group IIC is Acetylene & Hydrogen.

As per API RP 500 & NEC all gases & vapour are defined as class I, Dust class II & Fibre Class III. Again, gases are classified in Group as Group A - Acetylene, Group B - Hydrogen, Group C - Ethylene & Group D - Methane.

Zone 0 & I of IEC is Division 1 of NEC & Zone 2 of IEC is Division 2 of NEC

3 Temperature class:

As per IEC/ Indian standard maximum surface temperature is classified as temperature class & is as follows:

T1	450°C.
T2	300 °C
T3	200°C
T4	135°C
T5	100°C
T6	85°C

4. Comparison of above as per IEC/IS & NEC

As per NEC

Gas/Vapor (CLASS I)

Dust (Class II)

Fibers (Class III)

As per IEC

Gas & Vapor (Zones 0, 1, or 2)

Dust (Zones 20, 21, or 22)

As per NEC

Division 1 – Under normal operation / continuously / for long periods

Division 2 – Rarely or under abnormal circumstances such as a leak condition.

As per IEC

A. Continuously or most of the time during normal operation:

For Gas / Vapor this would be Zone 0.

B. Rarely under normal operation:

For Gas Vapor this would be Zone 1.

For Dust this would be Zone 21.

C. Not likely under normal operation (leak condition):

For Gas / Vapor this would be Zone 2.

For Dust this would be Zone 22.

As per NEC Gas grouping

Group A – Acetylene

Group B – Hydrogen

Group C – Ethylene

Group D – Propane

Group E – Metal dusts (e.g. Magnesium, Aluminum, Titanium etc.)

Group F – Carbon-based (e.g. coal and charcoal)

Group G – Nonconductive dusts (e.g. Flour, wood / saw dust, plastic dust)

As per IEC

Gas Grouping:

IIC – Acetylene & Hydrogen

IIB+H₂ – Hydrogen

IIB – Ethylene

IIA – Propane

Solids:

IIC – Conductive dusts (e.g. Magnesium, Titanium)

IIB – Nonconductive dusts (e.g. Flour, wood / saw dust, plastic dust)

Température Class Comparaison

Temperature °C	IEC	NEC
85	T6	T6
100	T5	T5
120	T4	T4A
135	T4	T4
160	T3	T3C
165	T3	T3B
180	T3	T3A
200	T3	T3
215	T2	T2D
230	T2	T2C
260	T2	T2B
280	T2	T2A
300	T2	T2
450	T1	T1

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FIRE IN FLOATING ROOF TANK DUE TO LIGHTNING STRIKE

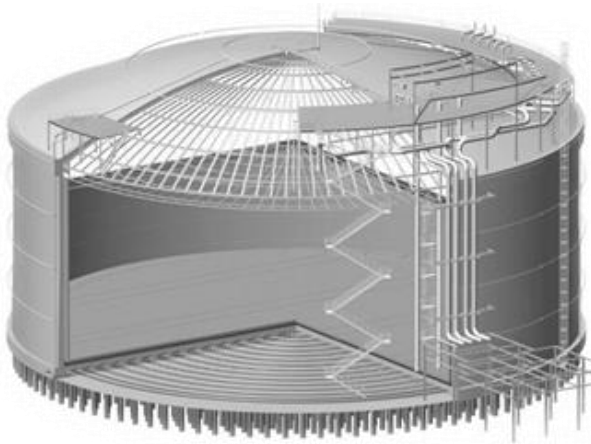
Er. KK Roy

Chief Consultant

KSR International Consultants & Engineers, Vadodara

1.0 Type of Petroleum Storage Tanks

Petroleum production and refining, petrochemical and chemical manufacture, bulk storage and transfer activities, and other businesses that consume or produce liquids and vapours are all sectors that use storage tanks.



The most common types of storage tanks used to store liquids are as follows:

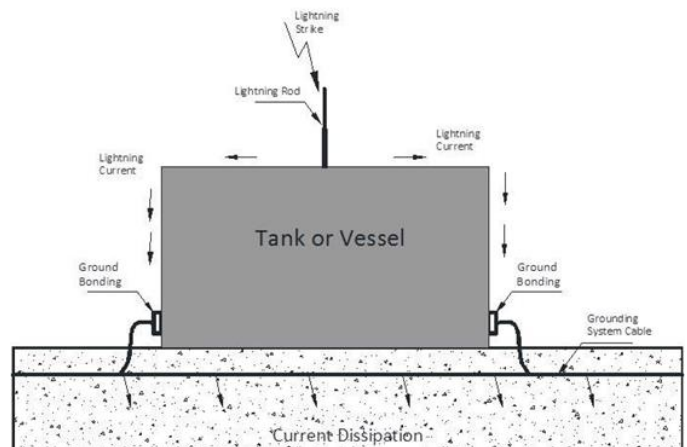
- a. **Fixed-roof tanks**
- b. **External floating roof tanks**
- c. **Internal floating roof tanks**
- d. **Domed external floating roof tanks**
- e. **Horizontal tanks**
- f. **Variable vapour space tanks**
- g. **LNG (Liquefied Natural Gas) tanks**

2.0 Direct Lightning Strike on Oil Storage Tank

Lightning strikes are characterized by very high stroke currents arriving in a very brief amount of time. An average lightning strike delivers about 30,000 amps of electricity to ground within a few milliseconds. This current will flow across the surface of the earth until the cell between the thundercloud and earth is neutralized. The current will flow in all directions, although the amount will vary in proportion to the paths of lowest impedance.

2.1 Fixed Roof Tank

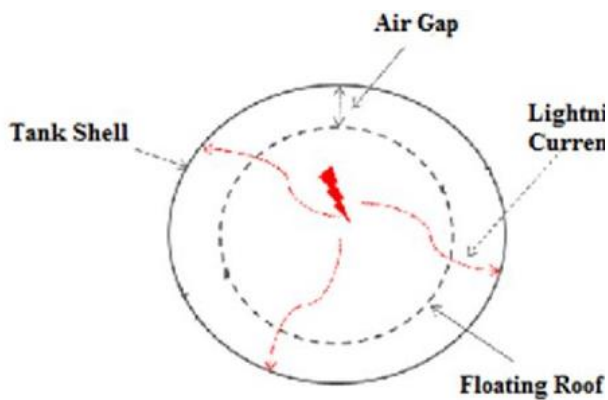
The construction of Oil Storage tank is fully welded and there is no lose gap in the tank from Roof, Shell & Bottom hence connecting the bottom of the tank directly to earth will discharge all the high current at high potential to the earth through Earth Pit. In fixed Roof Tank the flow of Lightning Current goes to Earth through as elaborated in the Figure below:



2.2 Floating Roof Tank (FRT)

The construction of floating roof tank is that the roof is in contact with the liquid surface. It is attached to the sides of the tank with rollers. A seal between the moving roof and the tank wall prevents process vapors from leaking into the space above the roof. As liquid is added, the roof moves up; as liquid is removed, the roof moves down. At no time is there a vapor space directly above the liquid. Hence there is no need to vent the tank when it is being filled and there is no need to add inert gas when it is being emptied.

Air Gap can be seen between Roof & Shell of the Tank as elaborated in following Figure:



The Air Gap between Roof & Shell can be clearly seen in following Tank internal photos:



3.0 Fire in Floating Roof Tank (FRT) due to Lightning strike

The mostly likely strike location on an FRT is the top of the rim or the gauge pole. However, lightning may endanger an FRT if a stroke terminates on

- (1) **the roof,**
- (2) **the shell,**
- (3) **anything attached to the roof or shell, such as the gauge pole, or**
- (4) **a structure or the earth near the FRT.**



If lightning terminates on any of these locations, a portion of the total lightning current will flow across the roof-shell interface. If lightning should terminate on the tank shell sizable currents will flow across the roof-shell interface. If lightning terminates in the vicinity of an FRT, either to the earth or to a structure, smaller currents will flow across the roof-shell interface. In either case, lightning-related currents will flow across the roof-shell interface. If the impedance between the roof and shell is high, arcing will occur across the seal interface.

3.1. Recommendations for Lightning Safety in Line with API-RP545

Following are three key recommendations to improve the lightning safety of petroleum storage tanks with external floating roofs, as follows:

- I. Install *submerged* shunts between the roof and shell every 10 feet (3 metres) around the roof perimeter. The shunts should be submerged by one foot (0.3 metre) or more, and if existing above-seal shunts are present, they should be removed.
- II. Electrically insulate all seal assembly components (including springs, scissor assemblies, seal membranes, etc.), and all gauge and guide poles, from the tank roof. The insulation level should be *one kilovolt* or more.
- III. Install bypass conductors between the roof and shell no more than every 30 metres (100 feet) around tank circumference. These bypass conductors should be as short as possible and evenly spaced around the roof perimeter. They should have a maximum end-to-end resistance of 0.03 Ohms and be of the minimum length necessary to permit full movement of the floating roof.

3.1.1. This can be further elaborated as below:

- i. **Submerged Shunts:** Shunts are used for the conduction of the fast and intermediate duration components of the lightning stroke current. The arcing occurs between the shunt and shell during all lightning events. If the shunt is submerged, then theoretically the arcing will occur where no air/oxygen is present, and ignition will be avoided. Providing submerged shunts on new tanks will require substantial design changes. On existing tanks, the changeover from above-seal to submerged shunts will be very costly and will require major overhauls. In addition, because they are submerged, these shunts will be extremely difficult to inspect and maintain.
- ii. **Insulation of Seal Components and Poles:** Insulating these components will encourage lightning currents to travel through preferential paths (shunts and bypass conductors) rather than arcing between the roof and shell. However, it is doubtful if the recommended insulation level of *one kilovolt* will be sufficient to cause the desired outcome. As with No. 1 above, substantial design changes and costly field modifications will be required to implement this recommendation, with attendant inspection and maintenance issues.
- iii. **Bypass conductors:** Bypass conductors are used for the conduction of the intermediate and long duration components of the lightning stroke current. One of the observations from testing was that the fast component of the lightning stroke did not ignite flammable vapours, and that it was the long component of the lightning stroke that caused ignition. With

conventional, above-seal shunts, the sustained arc at the shunts lasted long enough to ignite flammable vapours. Because bypass conductors will provide a positive bond between the roof and shell, the bypass conductors will present a lower impedance connection between the roof and shell, as compared to the shunts. Therefore, the long component of the lightning current will be diverted away from the shunts and through the bypass conductors. The installation of bypass conductors is relatively easy and inexpensive, on both existing and new tanks. And because they are external, bypass conductors are easy to inspect and maintain.

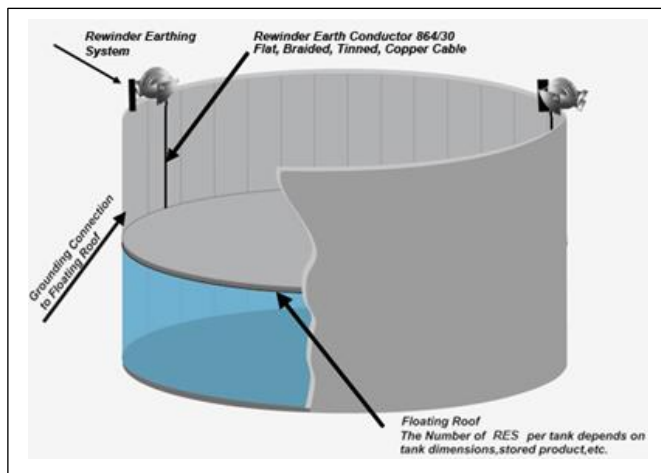
3.1.2 Types of Bypass Conductors

In response to these requirements, the marketplace has provided tank owners with a choice between two different types of bypass conductors:

- *a conventional fixed length, stranded conductor or*
- *a retractable conductor wound on a spring-tensioned reel.*

The ideal bond between the FRT roof and shell would have a low impedance across a wide range of frequencies. The ideal bond would also be easy to install on new tanks and to retrofit onto existing tanks. The ideal bond would also be easy to inspect and test, and to replace if necessary.





Retractable Grounding Assembly (RGA) on Floating Roof Tank

The conductor on the RGA is spring-tensioned, meaning that it automatically retracts on the reel when it is not under tension. Therefore, the conductor is always as short as possible, regardless of the position of the roof. In other words, the RGA is always “*of the minimum length.*”

In addition, the conductor on RGA is constructed of braided copper strands. Copper is 40 times more conductive than stainless steel, which is used by some other types of bypass conductors. Stainless steel bypass conductors will not meet the 0.03 Ohm requirement of API RP 545.

CASE STUDY – FIRE OF FLOATING ROOF TANKS DUE TO LIGHTNING STRIKE

1. INTRODUCTION:

There was an incident of Floating Roof Tank fire at one of the major coastal crude oil terminal installations in western India.

The terminal consists of 18 no. of crude oil tanks, with related pumping facilities, pipelines & firefighting facilities. Each tank is 79 Mtrs in dia & 18 mtrs shell height. All tanks are double deck floating roof tanks with primary & secondary seals. Shunts are provided above the secondary seal for electrical conductivity of lightning current across the floating roof & inner surface of shell at regular intervals of about 3 mtrs.

2. THE INCIDENT:

There was heavy lightning, thunderstorm & rains in the region, and as eyewitnesses blast sound & fire was noticed in the southern region of rim seal of one of the tank during early hours of the day. This was followed by rim seal fire in the south-east region of same tank, about 20 to 25 mtrs. away from first location. Out of the two locations involved in fire, one location was found almost in trajectory of one of the ‘lightning arrestors’ installed on the tank shell top where the effect of lightning fire was most severe. Liquid level in the tank was 15.94 mtrs. at the time of fire, against the safe filling height of 16 Mtrs. Thus, floating roof was almost up to maximum height. Flame height was noticed to be about 5 to 10 ft. above the tank. Fire was extinguished by foam application through foam pourers by Fire & Safety staff, by fire tenders of company and nearby mutual aid partners.

3. LIGHTNING STRIKES ON THE TANK

3.1. The source of ignition was lightning which coupled with the presence of hydrocarbon vapour in the flammability range resulted in the rim seal fire and explosion. Roofs of both the tanks were at highest elevation as the tanks were almost full during the lightning strikes. The hazards from lightning tend to be worse when the tank roof is high (Refer API/EI research report on Verification of lightning protection requirements for above ground hydrocarbon storage tanks -first edition 2009) as the lightning strike will easily jump from shell to roof, creating severe sparks at shunts which are not tightly pressing against the shell. Typical Lightning Strike when the roof is at high elevation is shown as Figure below:

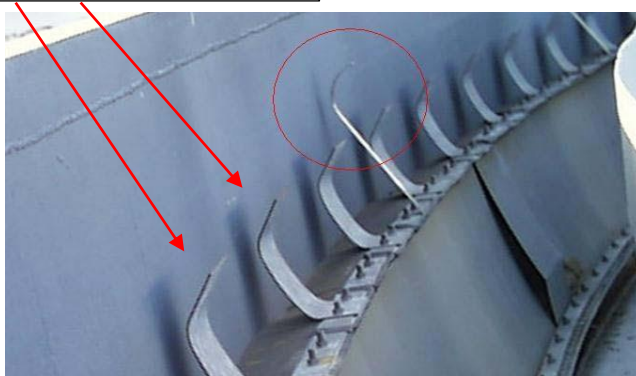
3.2. Although shunts are provided to **facilitate** electric continuity between the floating roof & the shell, one of the main reasons for poor contact between the shell and the shunt is the mechanical imperfection

High Intensity



of the tank shell such as ovality distortion – out of roundness of the shell. Also gaps between secondary seal and the tank shell will allow

Gaps in Shunts & Shell



In case of the affected tanks (SS- 004 & SS- 001) gaps which were existing between the secondary seal & shell surface emitted enough vapours to get ignited because of shunt generated sparks.

3.3. Maintenance & Inspection for these tanks were carried out about ten years. It is obvious that the affected tanks had considerable vapour accumulation between primary and secondary seal due to escape of vapour from the deteriorated primary seal. This coupled with release of vapour from secondary seal from its gap at the affected locations provided easy source of hydrocarbon to catch fire from lightning strikes.

4. ROOT CAUSE OF THE INCIDENT:

The root cause of incident is the lightning-initiated rim seal fire on account of spark generation at gaps between the shunt & the shell igniting vapours which escaped from the gaps prevailing between secondary seal & the tank shell.

About the Author



Er. Krishna Kumar Roy is Electrical Engineer graduated from University of Mysore having 42 years of experience. His areas of expertise include Design

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ENHANCING FIRE PROTECTION STRATEGIES IN LIGNITE OPEN-CAST MINES

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ABSTRACT--Mining has played a pivotal role in India's economic development and industrialization. The country, rich in mineral resources, has a diverse range of minerals, including coal, iron ore, bauxite, and limestone, which are crucial for various industries. In modern times, the mining sector has been a cornerstone of India's economic growth, contributing significantly to the country's GDP and employment. The sector encompasses a wide range of activities, from the extraction of metals and minerals to their processing and commercialization. In India, mining methods vary widely depending on the type of mineral resource and its geological characteristics. The primary methods include open-cast mining, underground mining, and mountaintop removal. Open-cast mining, or surface mining, is commonly used for minerals like coal, bauxite, and iron ore, where the ore body is close to the surface. This method involves stripping away overburden to access the mineral deposit, making it cost-effective but often leading to significant land and environmental impacts. Underground mining, on the other hand, is employed for deeper deposits and involves creating tunnels or shafts to access the ore, such as in the extraction of gold and certain types of coal. This method is more complex and costly but reduces surface disruption.

1.0 INTRODUCTION

Lignite open cast mining in Gujarat, primarily concentrated in the Kutchh and Saurashtra regions, plays a crucial role in meeting the state's energy demands. This method of mining, which involves removing overburden to access lignite deposits near the surface, is characterized by its

large-scale operations and relatively lower production costs compared to underground mining. Open cast mining facilitates efficient extraction of lignite, which is used predominantly in thermal power stations to generate electricity. While this approach supports the state's growing energy needs and contributes to economic development, it also raises environmental and social concerns, such as land degradation and impacts on local communities. Efforts are underway to mitigate these issues through improved mining practices and reclamation projects, aiming to balance resource utilization with environmental sustainability.

Fire protection is essential in lignite open-cast mining due to the inherent flammability of lignite, which is prone to spontaneous combustion because of its high moisture content and porous nature. The mining process, involving heavy machinery and equipment that generate heat and friction, further elevates the risk of ignition. Additionally, the dust generated during mining operations can be highly combustible, posing additional fire hazards. Without effective fire protection measures, the risk of uncontrolled fires increases, which can lead to significant environmental damage, including air pollution and soil degradation, as well as posing severe safety risks to workers. Moreover, fires can cause substantial economic losses through damage to equipment and disruption of operations. Implementing robust fire protection strategies is crucial to manage these risks, safeguard the environment, ensure the safety of personnel, and

minimize financial impacts, thus maintaining the overall efficiency and sustainability of lignite mining operations.

2. CAUSES OF FIRE IN LIGNITE OPENCAST MINES

Fires in lignite open-cast mines can be triggered by several factors, each contributing to the high risk of combustion associated with lignite extraction. Key causes include:

- **Spontaneous Combustion:** Lignite's high moisture content and porous structure make it susceptible to spontaneous combustion. This occurs when lignite is exposed to air and starts to oxidize, generating heat that can eventually ignite the material.



Spontaneous heating in Lignite stock yard.

- **Heat and Friction from Machinery:** The heavy machinery used in open-cast mining, such as excavators, trucks, and crushers, can generate significant heat and friction. If this heat encounters dust or small particles of lignite, it can trigger a fire.
- **Dust Accumulation:** Mining operations produce large amounts of dust, which can be highly flammable. Dust accumulation on equipment and surfaces can increase the likelihood of fires if it becomes ignited by heat sources or sparks.
- **Electrical Failures:** Faulty wiring or equipment malfunctions in electrical systems used in mining operations can produce sparks or overheating, leading to potential fire outbreaks in the presence of

flammable dust or lignite.

- **Improper Storage and Handling:** Inadequate storage practices, such as piling lignite in large heaps without proper ventilation, can create conditions conducive to spontaneous combustion. Similarly, improper handling of materials can expose them to conditions that increase fire risk.
- **Exposure to Extreme Weather:** High temperatures and dry conditions can exacerbate the risk of fire, particularly if they lead to the drying out of lignite piles and increase their flammability.
- **Human Error:** Accidental causes, such as improper disposal of flammable materials or the use of open flames near combustible materials, can also lead to fires in mining operations.

Addressing these causes requires a combination of effective fire prevention measures, rigorous monitoring, and prompt response strategies to manage and mitigate fire risks in lignite open-cast mines.

3. FIRE PROTECTION MEASURES

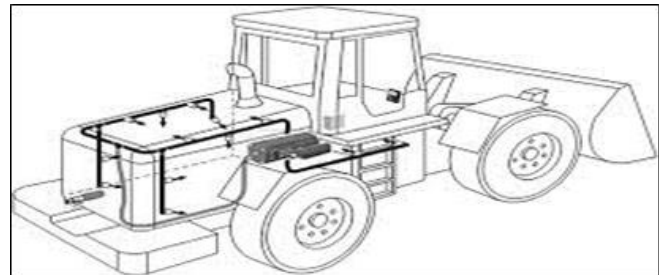
Fire prevention in lignite open-cast mines involves a comprehensive approach to minimize the risk of ignition and control potential fire hazards. Key measures include:

- **Regular Monitoring and Maintenance:** Implementing routine inspections and maintenance of machinery, electrical systems, and infrastructure helps identify and address potential fire hazards. This includes checking for overheating components and ensuring that equipment is in good working order.
- **Dust Control:** Effective dust management is crucial in reducing fire risks. This can be achieved through regular watering of roads and stockpiles, using dust suppressants, and maintaining proper ventilation systems to keep dust levels under control.

- **Temperature Monitoring:** Installing temperature sensors in areas prone to spontaneous combustion, such as lignite stockpiles, allows for early detection of heat build-up. Automated systems can alert personnel to take corrective actions before temperatures reach dangerous levels.
- **Proper Storage Practices:** Lignite should be stored in well-ventilated areas with proper spacing to minimize the risk of spontaneous combustion. Piles should be regularly turned or managed to ensure even distribution of air and prevent heat accumulation.
- **Firebreaks and Barriers:** Establishing firebreaks and barriers around high-risk areas helps contain and prevent the spread of fires. These physical measures can limit the spread of fire to other parts of the mining site.
- **Fire Suppression Systems:** Installing fire suppression systems, such as sprinklers and fire extinguishers, in key areas of the mining operation ensures quick response to any fire incidents. These systems should be regularly tested and maintained.
- **Employee Training:** Training workers in fire prevention and response procedures is essential. Personnel should be aware of the risks, know how to handle equipment safely, and be familiar with emergency protocols.
- **Emergency Response Plans:** Developing and regularly updating comprehensive emergency response plans ensures that all potential fire scenarios are addressed. These plans should include evacuation procedures, communication protocols, and coordination with local fire services.
- **Preventive Measures for Spontaneous Combustion:** Techniques such as regular

monitoring of temperature and moisture content in lignite piles can help manage the risk of spontaneous combustion. Implementing cooling systems or controlled burning can also be effective in some cases.

- **Use of Fire-Resistant Materials:** Where possible, employing fire-resistant materials in the construction of infrastructure and equipment can help reduce the risk of fire spreading.



Fire suppression system in machinery used in lignite mining

By adopting these fire prevention measures, lignite open-cast mines can significantly reduce the risk of fires, ensuring safer and more efficient mining operations while protecting the environment and personnel.

4. DEVICES USED AGAINST FIRE IN LIGNITE OPENCAST MINES

In the lignite industry, where the risk of fire is significant due to the flammable nature of lignite and the conditions of mining operations, various devices and systems are employed to quench and manage fires. Key devices used for fire suppression and control include:

- **Fire Extinguishers:** Portable fire extinguishers are essential for immediate response to small fires. Types include:
 - **Water Extinguishers:** Effective for fires involving solid materials like lignite.
 - **Foam Extinguishers:** Foam type fire extinguishers containing aluminum sulfate, sodium bicarbonate, and perfluoro hexanoic acid are useful for

cooling and smothering fires involving flammable solids and liquids.

- Dry Chemical Extinguishers: Versatile and effective for various



Fire extinguishers used in Lignite mining.

- Fire Sprinkler Systems: Automated fire sprinkler systems are installed in key areas, such as processing facilities and storage areas. They activate when heat is detected, releasing water or fire suppressants to control or extinguish fires.
- Fire Hose Reels and Hydrants: Installed throughout the mining site, fire hose reels and hydrants provide a ready supply of water for manual firefighting efforts. These are crucial for larger fires and areas where rapid access to water is needed.
- Fire Suppression Systems:
 - Water Mist Systems: These systems generate fine water droplets that can effectively cool and suppress fires with minimal water usage. They are particularly useful in confined or sensitive areas.
 - Foam Systems: Fixed foam systems can be deployed in areas prone to large fires, providing a blanket of foam to smother and cool the fire.
- Temperature and Smoke Detection Systems: These systems include heat detectors and smoke alarms that provide.

early warning of potential fire hazards. They are often integrated with automatic fire suppression systems to trigger responses before fires escalate.

- Fire Blankets: Fire-resistant blankets can be used to smother small fires or provide protection to workers in emergency situations.
- Firewater Tanks and Reservoirs: Large storage tanks or reservoirs are used to ensure a reliable and ample supply of water for firefighting. These are strategically located across the mining site.
- Dust Suppression Systems: While primarily used to control dust, these systems also help reduce fire risk by keeping dust levels manageable and preventing dust accumulation that could contribute to fire hazards.
- Emergency Shutdown Systems: Automated systems that can quickly shut down equipment or processes in the event of a fire, reducing the risk of fire spreading and allowing for controlled responses.
- Fire Resistant Barriers: Used to create firebreaks and barriers around high-risk areas to prevent the spread of fires and protect critical infrastructure.

5. CASE STUDY

On June 13, 2017, at 2:07 PM IST, a fire destroyed several lakh tonnes of lignite stored at NLC India Limited's mine in Neyveli, Cuddalore district, Tamil Nadu. According to NLC India officials, the lignite was mined from miniature mine I A and was intended to supply fuel to a private power plant in Omangalam near Neyveli township. Despite precautionary measures, the lignite caught fire due to intense heat on Monday afternoon. Fortunately, there were no casualties or significant property damage. An NLC India Limited official explained that lignite generally

has an incubation period of 45 days for storage. The miniature mine I A was established to supply fuel to the Omangalam private power plant under a fuel supply agreement. However, the private firm failed to transport the lignite, leading to its accumulation in the mine. Lignite can ignite spontaneously in intense heat, and despite using water sprinklers to keep the fuel wet, the fire broke out.

6. CONCLUSION

Fire protection in lignite open-cast mining is a critical component of safe and efficient operations. By understanding the causes of fires and implementing comprehensive protection measures, mining operations can significantly reduce fire risks. From excavation of lignite to its processing should be not cross the time limit of incubation period. Continued innovation and adherence to best practices will further enhance fire safety and contribute to the overall sustainability of the lignite industry.

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- b. Worked as assistant professor in mining at Kalinga University, Raipur.
- c. Served as organizing committee member in national conference on "Recent innovations in engineering and technology" at Kalinga University, Raipur.

LEGAL PROVISIONS IN CEA REGULATIONS FOR FIRE PREVENTION & PROTECTION IN ELECTRICAL POWER

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1.0 INTRODUCTION

1.1 Many Fires in High Rise Buildings, Malls, Hospitals and Public Places occur due to Electrical Short Circuit. The Central Electricity Authority – CEA has framed various guidelines to contain and mitigate the fire due to electrical short circuit.

1.2 The following Acts, Guidelines and Rules framed by Government of India and CEA are in vogue these days.

- Measures relating to safety and electrical supply CEA Regulation 2010
- The amendments incorporated in 2016 and 2018
- Indian Electricity Act, 1910
- Electricity Act, 2003
- The Central Electricity Authority Regulations (CEAR) has been enforced from 24th September 2010 by replacing Indian Electricity Rules 1956.

2.0 CEA REGULATIONS

2.1 General: The CEA Regulations 2010/2023 are measures relating to Safety and Electricity Supply. CEA Regulations, 2010 have been covered in ten chapters. These Chapters are applicable for general safety requirements and cover the general rules applicable to all classes of electrical installation, low and medium voltage installations supply, high and extra high voltage installations. It also provides the provision of rules applicable to overhead lines and underground cables, mines and oilfields. These regulations are applicable to overhead lines and underground cables,

lines and underground cables, mines and oilfields. These regulations are applicable to different Industries, Commercial Establishment and Utilities. There are 136 Regulations in CEAR 2023. However, important regulations which relate to Fire Safety are discussed in this presentation.

2.2 Regulation No. 3 – Designated

Person: This relates to designating person(s) to operate and carry out the work on electrical lines and apparatus. This regulation helps in proper operation by qualified, trained and experienced personnel in Electrical System. Thus, the chances of Electrical Fire and damage to the electrical equipment can be avoided or minimized.

2.3 Regulation No. 4 - Inspection of Record of Designated Person:

This provision indicates the qualification, experience and training received by the Designated Personnel should be kept on record by the employer and the Electrical Inspectorate shall have access to them on demand.



2.4 Regulation No. 5 – Designated an Electrical Safety Officer (Amendment 2016):

Employer shall nominate one of the Engineers as Electrical Safety Officer. He must have Degree in Electrical Engineering with experience of 5 years or Diploma with experience of 10 years in O & M of Electrical Installations.



2.5 Regulation No. 6 - Chartered Electrical Safety Engineer for self-certification (amendment 2018): The state government shall authorize Chartered Electrical Safety Engineer. His main function is to verify the appointment of Licensed Electrical contractor for the execution of the work. This regulation will prove effective and will be able to enforce various Electrical Safety and Fire Safety.

2.6 Regulation No. 14 - General safety requirements, pertaining to construction, installation, protection, operation and maintenance of electric supply lines apparatus: All electric supply lines and apparatus shall be as per prevailing Standards, Codes, Guidelines, etc. as issued by the State and Central Government. This will ensure safety of General Public, Utility, Property and Industrial /Construction workers.

2.7 Regulation No. 18 - Earthed terminal on consumer's premises: The supplier shall provide and maintain on the consumers premises Earth Terminal. The consumer shall take all reasonable precautions to prevent mechanical damages to the earthed

terminal and its lead belonging to supplier. This will provide proper earthing at the consumer end. The difference between transformer neutral and the earth terminal will be eliminated to a greater extent. This will ensure electrical as well as fire safety.



2.8 Regulation No. 20 - Danger Notices: The owner of every installation of voltage exceeding 250V shall affix permanently in a conspicuous position a danger notice in Hindi or English and the local language with a sign of skull and bones of a design as per standards (IS - 2551). This will caution the General Public regarding danger of the Electrical shock and fire.



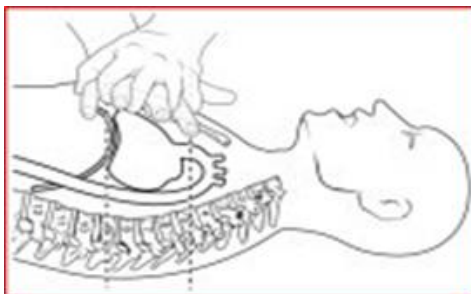
2.9 Regulation No. 24 - Distinction of different circuits: The owner of every generating station, substation, junction-box or pillar in which there are any circuits or apparatus, shall ensure by

means of indication of a permanent nature that the respective circuits are readily distinguishable from one another. This will avoid accident or mal operation.

2.10 Regulation No. 27 - Provisions applicable to protection equipment: Following may be ensured:

1. Fire buckets filled with clean dry sand
2. The fire extinguishers shall be tested for satisfactory operation. Testing shall be at least once a year and record of such tests shall be maintained
3. First-aid boxes or cupboards conspicuously marked and equipped with contents shall be provided and maintained. Such FA Box should be kept in charge of responsible persons who are trained in first-aid treatment and one of such persons shall be available during working hours.
4. Two or more gas masks shall be provided conspicuously and installed and maintained at accessible places 5 MW and above (PS) and 5 MVA and above (SS) for use in the event of fire or smoke.

2.11 Regulation No. 30 - Display of instructions for resuscitation of persons suffering from electric shock: Instructions, in English or Hindi and the **local language** for the resuscitation of persons suffering from electric shock, shall be affixed by the Employer. This will provide immediate recovery action against electric shock. This will reduce the risk of fatal accident.



2.12 Regulation No. 34 - Installation and Testing of Generating Units: Generating units / Transformer required to be inspected by Electrical Inspector before commissioning the Unit. This provision is mandatory to safeguard the Equipment and operating staff against electric shock and fire.

2.13 Regulation No. 36 - Leakage on consumer's premises: There shall not be any leakage of Electric Current in the system of a consumer which is injurious the use of electricity by the supplier or by other persons, or which is likely to cause danger. The EI is authorized to issue written notice to rectify the installation.



2.14 Regulation No. 39 - Conditions applicable to installations: Every switchboard shall comply with the following:

- a. A clear space of not less than one meter in front of the switchboard.
- b. At the back of the switchboard, shall be more than 75 centimeter.
- c. The inflammable materials including gases and chemicals are produced, handled or stored shall be away from the electrical installations, equipment and apparatus.

Above regulation is very important for the safety of consumer, control room operator and the equipment.

2.15 Regulation No. 42 - Connection with

Earth: The equipment used for regulating or controlling energy shall be earthed by the owner by two separate and distinct connection with earth. Record of earth test to be maintained by supplier/ owner (earth test shall not be more than 1 Ohm). This will safeguard electrical installation and equipment during abnormal condition. In many cases the improper connection of electrical equipment to the earth results in to damage to the equipment / apparatus and injury to people around it due to spelling, blasting and leakages.



2.16 Regulation No. 44 - Residual Current

Device: The electrical installation, shall be controlled by a residual current device to disconnect the supply during abnormal condition. This will safeguard the installation during fault.

2.17 Regulation No. 50 - Connection with Earth.

- i. All apparatus shall be protected against lightning and apparatus shall also be protected against switching over voltage. Further,
- ii. All non-current carrying metal parts associated with HV / EHV installation shall be effectively earthed to a grounding system
- iii. Neutral point of every generator & transformer shall be earthed by connecting it to the earthing system.
- iv. Earthing system shall be tested for its

resistance to earth on a dry day during dry season not less than once a year and records of such tests shall be maintained and produced before the Electrical Inspector.

This will safeguard the equipment, apparatus and avoid any abnormality. This is also for electrical fire safety.

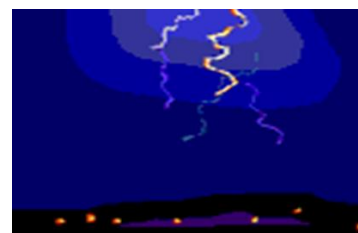
2.18 Regulation No. 66 - Transporting and storing of material near overhead

lines: Current carrying material shall neither be stored nor transported in the vicinity of any bare overhead conductors or lines. This will avoid the electrical hazard. There are large numbers of cases where inflammable materials stored near or below the electrical lines have resulted into electric fire.



2.19 Regulation No. 77 - Protection against Lightning:

Outdoor electrical installation exposed to lightning shall have arrangement of diverting electrical surges to the earth due to lightning. This will avoid injuries due to lightning stroke to human being and loss of property / materials. There are different ways and means to protect the electrical equipment against lightning strikes. This will include transmission lines and substations.



2.20 Regulation No. 79 - Laying of Cables:

The underground power cable shall be laid voltage level up to 33kV (1M) and above 33kV (1.2M). This is for safety of general public and utility / industrial personnel. In addition to electrical safety, it also prevents electrical fire.

3.0 CONCLUSION:

- ✓ The Acts, Rules, Guidelines, etc. are consolidated and prepare Regulations for Power Sector as well as Industries.
- ✓ The purpose of the Regulations is to ensure Safety of Human Being/ Animal and Property.
- ✓ Appointment the Qualified and Experience Electrical Engineer and / or Safety Officer results into reduction of accidents and causality.
- ✓ Regulations shall be followed and aware about its amendment.

About the Authors



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He provides the holistic solutions regarding:

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2. Electrical Energy Audit
3. Energy Management and Auditing
4. Electricity bill analysis
5. Walk through services
6. Power trading consultancy
7. Third party inspection
8. Demand side management

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Energy Solutions

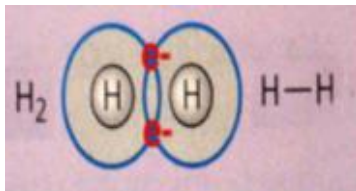
HYDROGEN SAFETY IN INDUSTRY

Er. LR Patel

Retd. Safety Officer, GSECL and Safety Consultant

1.0 INTRODUCTION:

Hydrogen is present in our atmosphere, in



water, in several chemical compounds and in almost every organic molecule.

Hydrogen is involved in the petrochemical, fertilizers, clean processes, and energy sectors. Thus, hydrogen is attracting large interest of several groups from governments to companies as it offers ways to decarbonize a lot of sectors, especially those that have been proved to be difficult to meaningfully reduce emissions.

Hydrogen (H_2) has the potential to play a key role in connecting different infrastructure layers in a low- or zero-carbon economy. Looking beyond its conventional applications as an industry feedstock in refining and fertilizer production, it is increasingly being heralded as a way to unlock the potential of renewable energy. In simple terms, surplus solar and wind energy can be converted to hydrogen and then to electricity on demand. Or it can be used to power zero-emissions fuel-cell cars and advance electro mobility.

Hydrogen is the lightest and most abundant element in the universe. At standard temperature and pressure conditions, hydrogen is colourless, odourless, tasteless, nontoxic, non-acid, non-metallic diatomic gas, which is in principle physiologically not dangerous. The energy density of hydrogen is very high; 1 kg of hydrogen contains approximately 2.5 times more energy than 1 kg of natural gas. One of the most important characteristics is its low density which makes it necessary for any practical applications to either compress the hydrogen or liquefy it.

Hydrogen can be considered an ideal gas over a wide range of temperatures (not too low) and pressures (not too high, up to 10 MPa). At some point, however, like any other substance that is sufficiently cooled or compressed, hydrogen will act like a real gas.

Hydrogen is classified as non-toxic and non-acid, non-carcinogenic, being a simple asphyxiate with no threshold limit value (TLV) or LD50 (lethal dose 50%) value. But it is highly flammable/explosive substance.

1.1 H_2 as a Renewable Fuel

One of the most important promises for hydrogen use is in energy and energy conversion/storage since it can change the fuel uses all over the world and start a greener and more sustainable approach. Hydrogen combustion can easily be achieved, with a high energy per unit mass (kJ kg^{-1}), around $141.10 \text{ kJ kg}^{-1}$, which is almost 3 times higher than for fossil fuels, such as gasoline and methane.

1.2 H_2 as a critical feedstock for chemical Industry

It is important for oil refining, fertilizer production, power fuel cell with no emissions, transportation by light/heavy duty vehicles, trains, planes and ships.

1.3 National Green Hydrogen Mission of India

India has set its sight on becoming energy independent by 2047 and achieving Net Zero by 2070. To achieve this target, increasing renewable energy use across all economic spheres is central to India's Energy Transition. Green Hydrogen is considered a promising alternative for enabling this transition. Hydrogen can be utilized for long-duration storage of renewable energy, replacement of fossil fuels in industry, clean transportation, and

potentially also for decentralized power generation, aviation, and marine transport. **Hydrogen is important for the future because it can be a versatile, clean, and abundant energy carrier.**

The National Green Hydrogen Mission was approved by the Union Cabinet on 4 January 2022, with the intended objectives as follows:

- To make India a leading producer and supplier of Green Hydrogen in the world. The Mission targets setting up of at least 5 MMT (Million Metric Tonne) per annum of green hydrogen capacity with an associated renewable energy capacity of about 125 GW by 2030.
- Making India a leading producer and supplier of Green Hydrogen in the world.
- Creation of export opportunities for Green Hydrogen and its derivatives.
- Reduction in dependence on imported fossil fuels and feedstock.
- Mission are expected to reduce the green hydrogen production cost to \$1.5 per kg by 2030 (at present normally @ \$ 3.2 per kg)
- Development of indigenous manufacturing capabilities.
- Attracting investment and business opportunities for the industry.
- Creating opportunities for employment and economic development.
- Supporting R&D projects.

2.0 How it's produced and application:

Depending on the nature of the method of its extraction, hydrogen is categorised into three categories, namely, Grey, Blue and Green.

- **Grey Hydrogen:** It is produced via coal or lignite gasification (black or brown), or via a process called steam methane (grey). These tend to be mostly carbon-intensive processes.

- **Blue Hydrogen:** It is produced via natural gas or coal gasification combined with carbon capture storage (CCS) or carbon capture use (CCU) technologies to reduce carbon emissions.
- **Green Hydrogen:** It is produced using electrolysis of water with electricity generated by renewable energy. The carbon intensity ultimately depends on the carbon neutrality of the source of electricity (i.e., the more renewable energy there is in the electricity fuel mix, the "greener" the hydrogen produced).

Production	Hydrogen	Utilization
• Coal-Gas • Bio mass • Solar • Hydro	• as a energy carrier	• Transport • Power Generation • Energy storage • Fertilizer /Chemical • Heating

2.1 Industrial use of Hydrogen:

Hydrogen can be used for the following:

- Petroleum refining
- Glass purification
- Semiconductor manufacturing
- Aerospace application
- Fertilizer production
- Welding- gas cutting, heat treatment process
- Pharmaceuticals
- **Power plant- Generator cooling, Co-fuel with gas/coal, Gas turbine**
- Hydrogenation of vegetable oil
- Steel industry

2.2 How it is produced by electrolysis which is most acceptable method

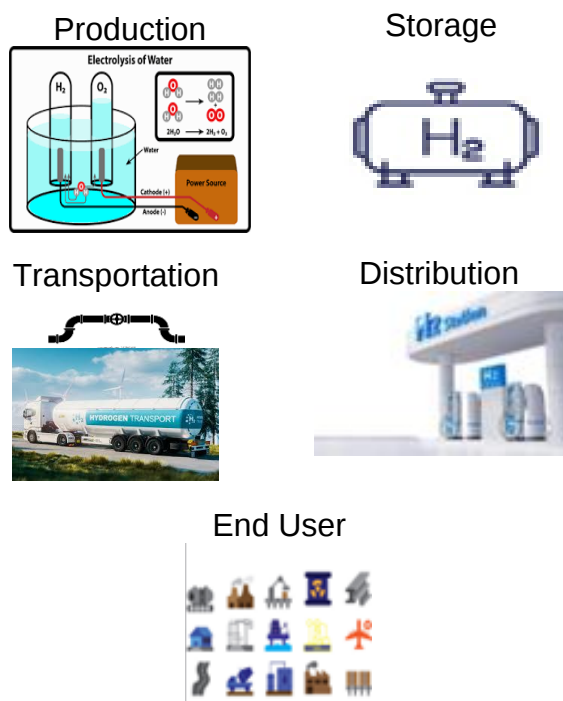
Electrolysis works much like a battery in reverse: Rather than generating electricity, it uses electrical current to split water into hydrogen and oxygen. The reactions that generate hydrogen and oxygen gas take place on different electrodes using

different precious metal catalysts.

The important input source of electricity generated by renewable methods like solar, wind or hydro.

3.0 Is Hydrogen safe?

This is a common question like electricity and other danger chemicals, it can be made safe by understanding its property / behaviour and application of required safety measures. From generation to storage- transportation and finally at end use level of Hydrogen, there must be zero deviation /gap with safety requirements. A small hole in ship can be proved a disastrous situation. Though, it is not so difficult to understand the likely potential accidental hazards of the Hydrogen. **Safety required at each stage/level:**



3.1 Legal framework:

Following statutory provisions are available to make system safe in operation at all stages of Hydrogen.

A: Factory Inspectorate: Factory Act-1948, MSHIC (Manufacture, Storage and Import of Hazardous Chemicals), (Safety report, On site emergency Plan, Safety audit, Risk assessment, Testing,

monitoring, Fire/explosive aspects, Hazardous classification area).

B: PESO: Gas cylinder rules, Petroleum /Explosive rules, Static and Mobile Pressure vessels.

C: OISD, National Electrical Code & BIS: relevant standards.

D: International standard: NFPA, ASME.

4.0 Hydrogen- safety

4.1 Common Causes of past accident

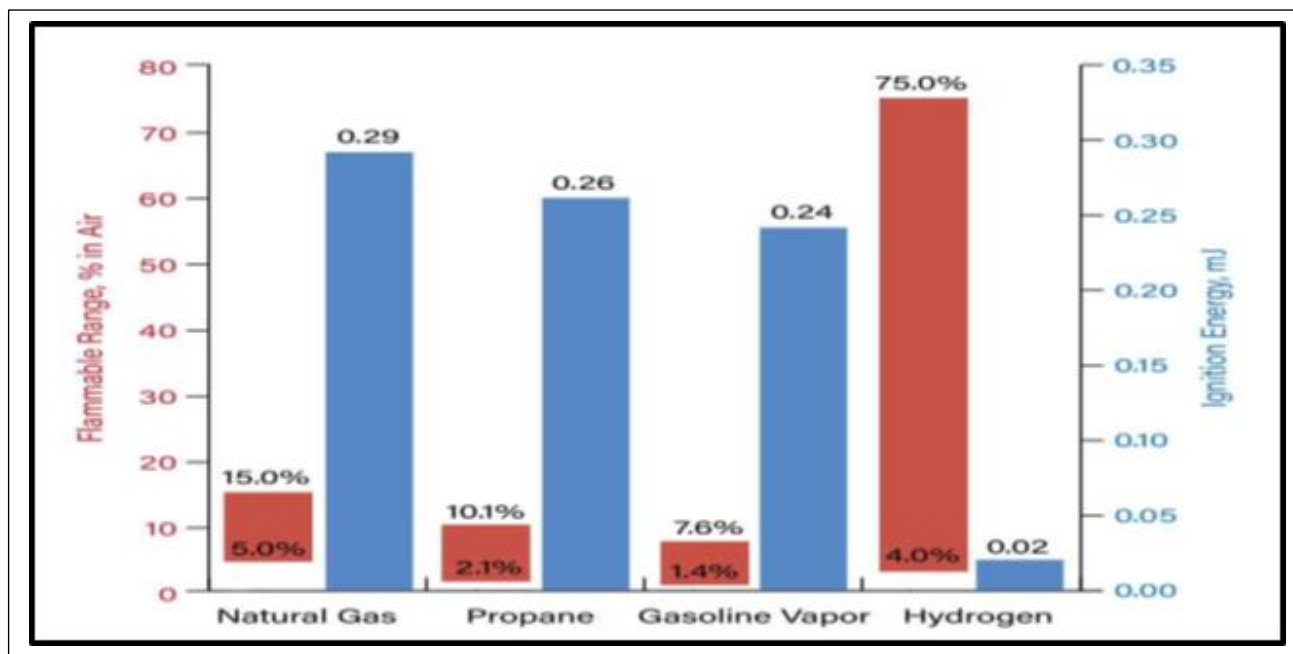
- Poor design /Poor maintenance/ Mechanical failure/ Corrosion attack
- Undetected leaks /Hydrogen-oxygen off-gassing explosions.
- Inadequate inert gas purging/Vent and exhaust system incident.
- Loss of control on pressure/ Piping and pressure vessel ruptures.
- Embattlement of storage tank at low temperature.
- BLEVE –small leak to huge cloud mixture and ignited.
- Damaged by nearby system.
- Human failure (lack of knowledge, training, absence of mock drill).

4.2 Hazards of Hydrogen

- Liquid Hydrogen (LH_2): Cryogenic burns (frostbite) may result from contact with extremely cold liquids or cold vessel surfaces.
- Exposure to large, liquefied hydrogen spills may result in hypothermia.
- Hydrogen Embrittlement- process by which a metal becomes brittle and develops small cracks.
- Highly inflammable / explosive which required a small ignition energy to make fire/explosion.
- Storage hazards- low temp in tank, high pressure in cylinder.

4.3 Important Property and features

- It is small molecules that migrate.



quickly through openings and many polymeric materials.

- Hydrogen has the highest energy content per unit mass of all fuels - higher heating value is 141.9 MJ/kg, almost three times higher than gasoline.
- Less dense than air – easily diffuse
- Easy for fire / explosion due to Low ignition energy requires for fire/explosion (0.016 mJ) & Wide flammability range in air 4 to 75%.
- H₂ flame is invisible /white in colour which difficult to detect.

4.4 Important safety measures to mitigate the risk

1. Understand the process safety aspects for design of the system (HAZOP).
2. Conduct HIRA (Hazard Identification and Risk Analysis) of the system from initial to time to time. Review their control measures for any near miss.
3. Provide gas detector & flame detector at production, storage, transfer and end use level.
4. Keep the area well-ventilated to avoid flammable mixture.

5. Avoid electrical installation nearby facility. If required, comply with IS 5571/5572 (Electrical installation for hazardous area: (Zone 0, 1, 2))
6. Keep minimum inventory and adequate distance with others. Safety distances for GH₂ and LH₂ with regard to design and operation are compiled by OSHA provisions.
7. Avoid contact with air directly in process. Use inert gas N₂ or CO₂ for purging or blanketing.
8. Use soap solution to detect leak from pipe joints/pressure points / gas cylinder.
9. Train the employees and contractors for safe handling of hydrogen including emergency management.
10. All ignition sources such as open flames, electrical equipment, or heating equipment should be eliminated.
11. Ensure protection against static charge /mechanical spark which easily arises in hydrogen system and most of the cause of hydrogen cylinder fire.

12. Adopt work permit system with all control measures during maintenance work.
13. Provide ABC /DCP type of fire extinguisher. Provide water sprinkler to make cool/ extinguish the fire.
14. Hydrogen plant to be located at isolation area. Solid barricading /barrier to be provided at fixed installation.
15. Mechanical integrity to be ensured & complied with ASME code.

Hydrogen transport by Gas Cylinder



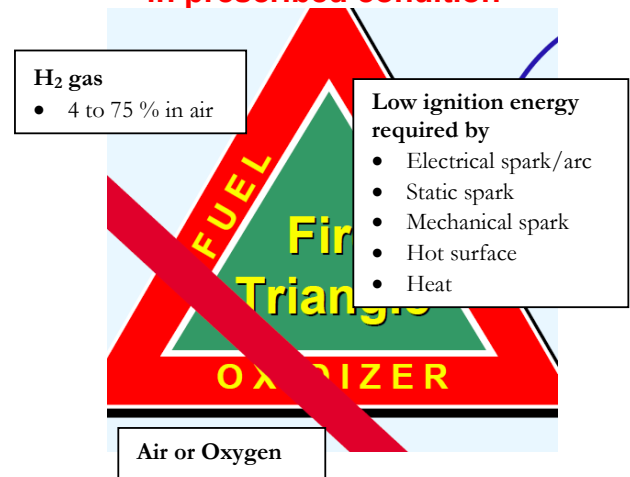
Hydrogen transport by Tube- vessels



Hydrogen gas detector provided above stored hydrogen cylinders storage area, no electrical fittings, well ventilation area & water sprinkler



Fire can be initiated by three elements in prescribed condition



Cold burns by low temp LH₂



H₂ tank leak from tank



Conclusions:

Hydrogen will become game changer for world economy in near future. When the production cost become competitive with affordable and acceptable technology at every stage i.e. production, storage, transportation Hydrogen become essential commodity like electricity. It will also reduce carbon footprint drastically as we have faced today. Despite its dangerous property of highly flammable, safety measures will make it safer energy carrier than all others.

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FIRE SAFETY IN BUILDING & HOSPITALS

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SYNOPSIS: The safety in general and the safety against Fire is assuming very big importance as the country is on front foot in development.

There is not a single day when there is no news of Fire in different parts of the country. Fire Safety is a very big topic, but some important aspects of Building fire safety are covered in this presentation. This includes structural elements of fire safety and non-Structural Elements of fire safety. The fire safety in hospital is very important because if fire occurs, it is difficult to evacuate the patients in a short time. There are provisions in National Building Code for all the buildings in general and hospitals in particular.

The presentation below covers most of the safety requirements in building and various suggestions to avoid loss of life.

1.0 STRUCTURAL ELEMENTS OF FIRE SAFETY

The structural elements refer to the provisions of space and escape mechanism in building structure. These are described below:

A. Open Spaces

1. The width of the access road shall be a minimum of 6M.
2. A turning radius of 9M shall be provided for fire tender movement.
3. The covering slab of storage/static water tank shall be able to withstand the total vehicular load of 45 tones equally divided as a four-point load (if slab forms a part of path/driveway)
4. The Set back area shall be a minimum 4.5M.
5. The roads shall not be terminated in dead ends.

B. Basements

1. Each basement shall be separately ventilated.
2. Each vent shall have a cross-sectional area (aggregate) not less than 2.5% of the floor area spread evenly round the perimeter of the basement.
3. A system of air inlets and smoke outlets shall be provided & clearly marked as "AIR INLET" & "SMOKE OUTLET".
4. Clear headroom of minimum 2.4M shall be provided for the entire basement.
5. The access to the basement shall be separate from the main and alternative staircase providing access and exit from higher floor. Where the staircase continues, in the case of building served by more than one staircase, the same shall be of enclosed type serving as a Fire Separation between the basement and higher floors.
6. The staircase of the basement shall be of enclosed type having fire resistance not less than 02hrs & shall be situated at the periphery of the basement to be entered at ground level from the open air and in such a position that smoke from any fire in the basement shall not obstruct any exit serving the ground & upper stores of the building. The staircase shall communicate with the basement through a lobby provided with fire resisting, self-closing doors of 02hr resistance. Additional stair shall be provided if travel distance does not meet specification given in Table 22 of the NBC.
7. For multistoried basements, one intake duct may serve all basement levels, but

each level & basement compartment shall have a separate smoke outlet duct or ducts. The ducts shall have the same fire resistance rating as the compartment itself.

8. Mechanical extractors for smoke venting system from lower basement levels shall also be provided. The actuation of the system shall be incorporated with the detection and sprinkler systems. The performance of the system shall be superior than standard units.
9. Mechanical extractor shall have an interlocking arrangement, so that extractor shall continue to operate and supply fans shall stop automatically with the actuation of fire detection system.
10. Mechanical extractor shall be designed to permit 30 air changes per hour in case of a fire emergency.
11. Mechanical extractor shall have an alternate source of electricity supply.
12. No cut outs to upper floors shall be permitted in the basement.
13. All floors shall be compartmented by a separation wall with 2hrs fire rating, such that each compartment shall have a surface area are not exceeding 750 Sq. M. Floors which are fitted with sprinkler system may have their surface areas increased by 50%. In long building fire separation wall shall be at distance not exceeding 40M.
Smoke extraction system to be provided for all escape passages and corridors for air-conditioned buildings.
14. Lift/Elevators shall not normally communicate with basement; if, however, Lifts are in communication, the lift lobby of the basement shall be pressurized. A positive pressure between 25 & 30 Pascal (Pa), shall be maintained in the lobby & a positive pressure of 50 Pa shall be maintained in

the lobby & a positive pressure of 50 Pa shall be maintained in the Lift shaft. The mechanism for pressurization shall act automatically with the Fire Alarm. Provision shall be made to operate the system manually as well. The Lift car door shall have a Fire resistance rating equal to the Fire resistance of lift enclosure. The material used for interior finishing shall conform to class-1 materials.

C. Means of Escape/Egress

1. The exit in healthcare facilities should be limited to doors leading directly outside the building, internal staircase and smoke proof enclosures, ramps, horizontal exits, external exit and exit passage.
2. Exits shall be so arranged that they may be reached without passing through another occupied unit.

D. Internal Staircase

1. A staircase shall not be arranged around a Lift shaft.
2. Hollow combustible construction shall not be permitted.
3. The construction material shall have 2hrs. fire resistance.
4. Minimum width of stairs shall be 2mts.
5. Width of the tread shall not be less than 300mts..
6. The height of the riser shall not be less than 150 mm and the number of stairs per flight shall not exceed 15.
7. Handrail shall be provided at a height of 1000mm, which is to be measured from the base of the middle of the treads to the top of the handrails.
8. Minimum head room in a passage under the landing of a staircase and under the staircase shall be 2.2mtrs.
9. The staircase shall be continuous from ground floor to the terrace and the exit door at the ground level shall open directly to the open spaces or a large lobby.

10. Fire/Smoke check doors shall be provided for a minimum of 2hrs fire resistance rating.
11. Lift opening and any other opening shall not be permitted.
12. No electrical shaft and panel, AC duct or gas pipelines, etc. shall pass through or open onto the staircase.
13. No combustible material shall be used for decoration/wall paneling in the staircases.

E. Protected Staircase

1. The staircase shall be enclosed by walls having 2hrs fire resistance.
2. Protected staircase shall be pressurized. Under no circumstance shall they be connected to a corridor, lobby and staircase which is unpressurized.
3. In emergency condition 50 Pascals
4. The pressurization system shall be interconnected with the automatic / manual fire alarm system for actuation.

F. Horizontal Exits

1. Width of the horizontal exit shall be same as the exit doorways.
2. A horizontal exit shall be equipped with at least one fire/smoke door of minimum 2hrs fire resistance of self-closing type. Further they shall have direct access to the fire escape staircase for evacuation.
3. A refuge area of 15 Sq. M or an area equivalent to 0.3 Sq. M per person for the number of occupants in two consecutive floors, whichever is more, shall be provided on the periphery of the floor or preferably on an open-air cantilever projection with at least one side protected with suitable railing/guards with a height not less than 1M.
4. Doors shall always be accessible from both sides.
5. A horizontal exit involving a corridor 8ft

or more in width serving as a means of egress from both sides of the doorway shall have the opening protected by a pair of swinging doors arranged to swing in the opposite direction from each other.

6. An approved vision panel is required in each horizontal exit. Center mullions are prohibited.

G. Exit Doors

1. Width of the doors shall be minimum 2M and other requirements of the door shall comply with the NBC.
2. Where door locking arrangements are provided, provision shall be made for the rapid removal of patients by such reliable means as remote control of locks or the keys of all locks made readily available to staff who are in constant attendance.
3. Doors in fire resistant wall shall be so installed that they may be normally kept in open position but shall close automatically. Corridor doors opening into the smoke barrier shall be not less than 2000mm in width. Provision shall be made for double swing single/double leaf type doors.

H. Corridors and Passageways

1. The minimum width and the height of corridors and passageways shall be 2.4M. The exit corridor and passageways shall have width not less than the aggregate required width of Exit doorways leading from them in the direction of travel to the exterior. Corridors shall be adequately ventilated.

I. Compartmentation

1. In building or sections occupied by bedridden patients where the floor area is over 280 Sq. M., facilities shall move patients in hospital beds to the other side of a smoke barrier from any part of such a building or section not directly

served by approved horizontal exits from the floor of a building to outside.

2. Any section of the building more than 500Sq.M shall be suitably compartmented with fire resistance of not less than 2hrs.
3. Every store used by inpatients for sleeping or treatment shall be divided into not less than two smoke compartments.
4. Every store having an occupant load 50 or more persons, regardless of use, shall be divided into two smoke compartments.
5. The size of each smoke compartment shall not exceed 500 Sq M.

J. Service Shafts/Ducts

1. Serviceshafts/ducts shall be enclosed by walls with 2hr and doors with 1hr fire resistance rating. All such ducts/shafts shall be properly shielded and facilities shall be available to control fires along these shafts/ducts at all levels.
2. Refuge chutes shall have opening at least 1M above the roof level for venting purpose and they shall have an enclosure wall of noncombustible material with fire resistance rating of 2hrs. They shall not be located within the staircase enclosure or service shaft and be as far away from the exit as possible.
3. The inspection panels and doors of air conditioning shafts shall be well fitted, with a fire resistance rating of 1 hr.

2.0 NONSTRUCTURAL ELEMENTS OF FIRE SAFETY

Lighting is the most important in nonstructural element of fire safety. It is described below:

A. Emergency and Escape Lighting

- c. Emergency lighting shall be powered from a source independent of the normal lighting system

1. Emergency lighting shall provide adequate illumination along escape routes to allow the safe movement of persons towards and through the exits.
2. The horizontal luminance at floor level on the center line of an escape route shall be not less than 10 lux. Additionally, for escape route that are up to 2mtrs in width, 50% of the route with shall be lit to a minimum of 5 lux.
3. The luminaries shall be mounted as low as possible but at least 2mtrs above the floor level.
4. Emergency lighting shall be designed to ensure that a fault or failure in any open luminaries does not further reduce the effectiveness of the system.
5. Emergency lighting luminaries and their fitting shall be of nonflammable type.
6. The emergency lighting system shall be capable of continuous operation for a minimum of 1 and half hour (90 minutes).

3.0 PROVISIONS OF NBC RELATED TO FIRE SAFETY IN HOSPITALS

- a. The common path of travel shall be 30m. The maximum dead end of corridor distance shall not exceed 6 m.
- a. Principle of progressive horizontal evacuation is of paramount consideration for hospital patients particularly those lacking self- preservation. This calls for moving occupants from a fire affected area to an adjoining area at the same level through a fire-resistant wall, to protect them from the immediate dangers of fire and smoke (see Fig. 14).
- b. Progressive horizontal evacuation operates on the basis of evacuation from compartment to compartment and on use of adjacent compartments as temporary means of refuge. All compartments shall be divided with self-closing

- (door closers) fire doors with electromagnetic hold open. A coordinator shall be provided to sequence the closing of double leaf in case of emergency.
- d. Doors in fire resistant walls shall be so installed that these may normally be kept in open position but will close automatically. Corridor door openings shall be not less than 2.0 m in width of double swing double leaf type door. A coordinator shall be provided as above, for closing of double leaf in case of emergency.
 - e. Exits and other features for penal and mental institutions, and custodial institutions shall be the same as specified for hospitals [see 6.3.2 (g)], in so far as applicable. Reliable means shall be provided to permit the prompt release of inmates from any locked section in case of fire or other emergency.
 - f. All buildings or sections of buildings in penal and mental institution used for manufacturing, storage or office purposes shall have exits in accordance with the provisions of the Code for those occupancies.
 - g. For hospitals (Subdivision C-1), the following shall also be complied with:
 1. Compartmentation shall meet the requirement as per 4.5.2.
 2. Each compartment (see 4.5.2) shall be able to accommodate, in addition to its own, the patients from adjoining compartment also considering 3.5M² per person. If patients are not bed-ridden, a factor of 0.6M² per person is recommended.
 3. All critical patients and those incapables of self-preservation and having physical impairment shall be housed within 30M height.
 4. Other types of patients and occupancies incidental to the hospitals such as consultation rooms, nurses' stations, medical shops, canteens, etc. may be housed at heights beyond 30M but not more than 45M.
 5. Basement shall not be used to store flammables or for pathological or other laboratories particularly those involving usage of chemicals.
 6. Operation theatres, delivery rooms, Intensive care units, recovery rooms, etc., that containing patients lacking self-preservation in case of emergencies shall be fire / smoke separated (120 min minimum rating) from all the adjoining areas.
 7. Aisles, corridors, ramps, etc., through which patients are moved, shall have a minimum width of 2.4M throughout. Aisles, corridors, and ramps in other areas not intended for the housing, treatment, or use of inpatients shall be not less than 1.5M in width.
 8. All exits from hospital or infirmary sections shall be not less than 2.0M in width.
 9. Minimum width of door of single or double occupancy patient room shall be 1.25M while for the wards for 3 to 5 patient beds shall be 1.50M, to permit movement of patients. The minimum width of door for wards for more than 5 patient beds and for areas necessarily requiring patient evacuation on bed (such as ICU, recovery units, delivery rooms, etc.), shall have door width of 2.0M. The width of 2.0M may be reduced to minimum of 1.5M where two such doors are provided in such areas.

10. Any sleeping accommodation or suite exceeding 100 m² in area shall have at least two doorways leading to the exit access corridors.
10. Floor surface of corridors shall not be inclined at a gradient steeper than 1 in 12 to the horizontal.
11. Exit access corridors from a compartment to another compartment shall be divided at the compartment intersection by a fire door of 120 minutes fire rating in the fire compartment wall.
12. Rooms designated for laboratory and the like shall not exceed 100m² in area and if additional space is required, fire separation of 120 minutes shall be provided.
13. Storage of flammable liquids in laboratories or in any other area shall be not more than 3 liter for every 10m² area.
14. Disposal of any equipment and other (particularly hazardous) materials shall be accomplished in the premises by a disposal specialist or at a safe location away from the health care facility by competent personnel using procedures established in concurrence with the safe practices.
15. A stretcher lift in a lift bank shall also act as fireman's lift meeting the requirements of Part 8 'Building Services, Section 5 Installation of Lifts, Escalators and Moving Walks, Subsection 5A Lifts' of the Code.
17. Quick Response Sprinklers shall be provided for all sleeping accommodations.

4.0 FIRE SAFETY MEASURES FOR HOSPITALS

4.1 A Hospital is like a War Zone.

One needs to take Quick & Correct Decision and work in a team.

4.2 Fire Safety Strategy in Hospitals

- Keep the Fire AWAY from patients, rather than move the patients away from Fire.

The main objectives in case of any Emergency are:

- SAVE LIVES of patients, visitors and Staff.
- To Extinguish Fire, if not Control the Fire, with available resources till help arrives.
- To Prevent Fires from occurring.
- To assist Fire Brigade & Police in matters related to Safety & Security.

In case You Notice a Fire.

- Break the glass of the nearest Manual Call Point (MCP), if you are the first to discover the fire.



- Attack the fire with Fire Extinguishers / Hose Reel provided on the floor (after taking guidance from the Fire Warden).



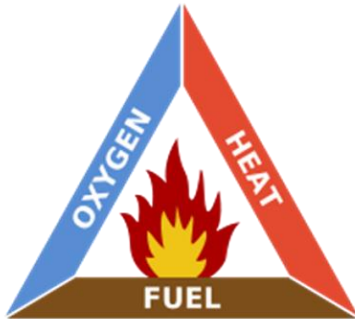
- #### 4.3 Follow the 'Defend in Place' strategy for critical areas, such as OT, ICU, NICU and in a worse situation Evacuate two floors below the Fire Floor, or as directed by the Fire Warden.

Fire Triangle

The triangle illustrates the 3 elements a fire needs to ignite:

1. **Fuel**
2. **Heat**
3. **Oxygen**

A Fire naturally occurs when these elements are present and combined in the **RIGHT** mixture / proportion.



4.4 Fire Hazards in Hospitals

- Main Electrical Panels, Electrical Equipment, Heating & Medical Equipment
- Light Fittings & Switch Sockets
- Storeroom, Path lab, Linen store etc
- Cable Shafts, Service Shafts
- Kitchen & Pantry
- Diesel Generators
- ACP cladding – inside (interior) & outside (cladding)

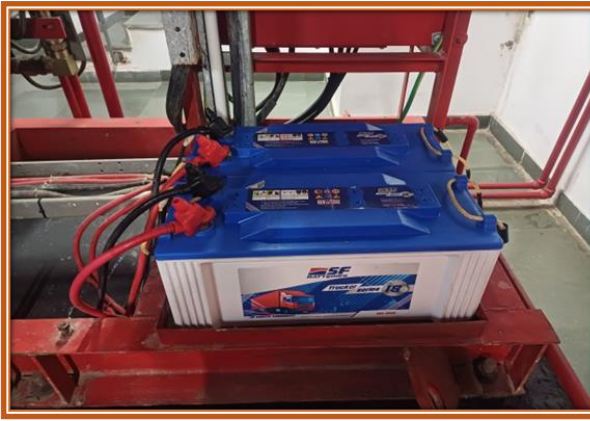


4.5 Explosion Hazards in Hospitals

- **Compressors** – Refrigerators, Deep Freezers, Air Compressors
- **Gas Cylinders** – LPG, Oxygen, Nitrous Oxide

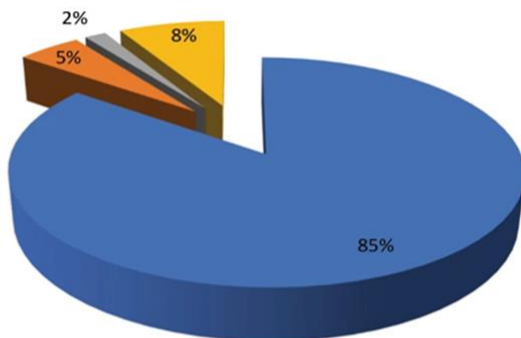


- Diesel Fuel Tank of DG set
- Window & Wall mounted AC's
- Boilers
- Batteries of Inverters, Diesel Pump, EV cars etc.



4.6 Progressive Horizontal Evacuation

Progressive Horizontal Evacuation is of paramount consideration for hospital patients particularly those lacking self-preservation. This calls for moving occupants from a fire affected area to an adjoining area at the same level through a fire operates on the basis of Evacuation from one fire resistant wall, to protect them from the immediate dangers of fire and smoke. Use of adjacent compartment as temporary means of refuge.

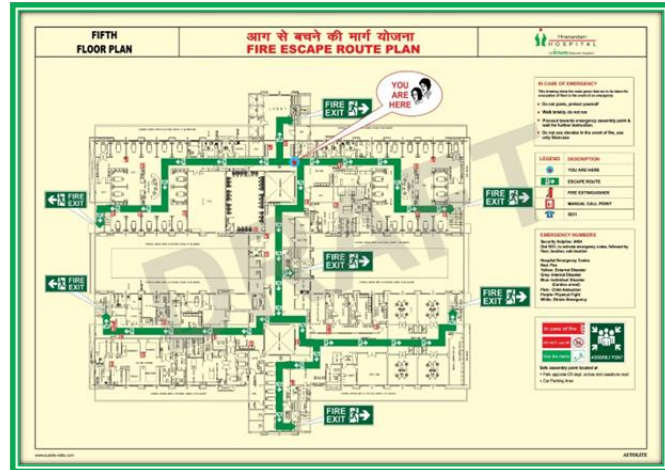


■ Short circuit, ■ Flammable material, ■ Others, ■ Data not available
Cause of fire incidents in the hospitals



Emergency Evacuation Plan for Operation Theatre & Cath Lab Assessment of OT & Cath Lab:

(Understand the layout of the) Operation Theatre and Cath Lab located on the XX floor of the hospital. Identify the two exits inside both Operation Theatre and Cath Lab.



4.7 Options for Evacuation

- **Horizontal Evacuation:** Shift patients from one OT to ICU area or to Cath Lab side.
- **Vertical Evacuation:** If horizontal evacuation is not feasible, patients will be shifted vertically to other areas within the hospital.

➤ Horizontal Evacuation Procedures

- In the event of a fire in Operation Theatre.

Shift OT patients to ICU or Cath Lab Side, utilizing the available exit routes.

- In the event of a fire in Cath Lab:

- Shift Cath Lab patients to ICU or OT side using the available exit routes.

➤ Vertical Evacuation Procedures:

- OT patients will be shifted to XX Ward 8C
- SICU patients will be shifted to Single ward 7D.

- Utilize the available vertical evacuation routes such as stairwells or elevators under safe conditions.

4.8 Medical Operations & Nursing

1. Work with medical/surgical house staff and respiratory therapists to evaluate whether it is appropriate to shut-off oxygen, ventilation equipment and other gases and provide interim support.
2. Children should be handled like other patients, except that in ambulatory evacuation alternate the older and younger children in the evacuation line, if time and circumstances permit;
3. Patients may be rolled in a blanket and dragged to a safe location in addition to using stretchers and beds where feasible.
4. In case of partial evacuation, patients on ventilator or completely bedridden, complete bed can also be wheeled to the other side of building using the fire elevator, keeping strict vigilance on the working of any medical equipment connected with the patient, which cannot be safely removed.

4.9 Evacuation Protocols & Procedures

General Guidelines:

1. Maintain continuity of care by assigning responsibilities for ancillary personnel or volunteers assigned to the Hospital.
1. The immediate safety of the patient at this time must be given preference over aseptic techniques.
2. Make provision for adequate drug and medical equipment to support at least 30 patients at any given time.
3. The Emergency Patient Evacuation Stock to be stocked and maintained as disaster management or patient evacuation requirements & hand tool kit.

While the patient evacuation requirements should be maintained by Emergency Department, the hand tool kit should be maintained in each floor/ individual patient care areas. It is preferable to have the patient evacuation stock maintained at an alternative site as well to ensure accessibility to the stock.

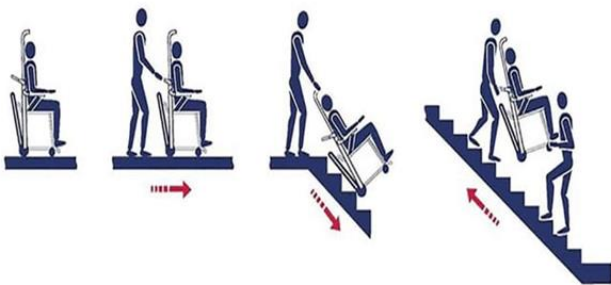
5. Wake-up patients and attendants and ensure that the rooms are vacated. This has to be done carefully, because patient woken up on account of evacuation is likely to panic.



6. Maintain continuity of medical care.
7. Provide adequate drug and medical equipment (e.g., Propaq, Oxygen, IV pump, etc.) to support each patient during transportation and evacuation procedures.
8. Patients in immediate danger first should be evacuated first, followed by ambulatory patients.
9. Use the **Vulnerability Tag** (red/yellow/green mentioned in Section VII) of IPD/ICU patients to prioritize patient movement:
 - a. From IPD, to staging area & assembly area within the hospital, patients who require less assistance, will move first.
 - b. From staging area & assembly area to other hospitals, patients who

require maximum support will move first.

10. Make arrangements for additional stretchers and wheelchairs. Supervise GDAs to ensure availability.
11. Report to and assign staff to communicate with the ERT on patient's movement.
12. Appoint a GDA to go with the patients and lead them to horizontal/partial evacuation at the staging area or to assembly area during vertical/total evacuation.
13. Assist in moving patient from bed to Field stretcher / wheelchair



14. If the bed can move up to staging area, carry the patient on the bed itself.
15. Ensure that doors are closed and mark an "X" (with a sign pen/ pencil) after a patient room is evacuated.
16. Before initiating a horizontal evacuation of patients, do a quick check of the adjoining area of refuge to avoid unnecessary movement to potentially unsafe areas.
17. Identify and procure specialty equipment, as needed, that will be necessary for transportation and continued patient care.



Evacuation
Chair for Vertical
Transportation

18. Place patient records, medications, clothing and valuables in a bag along with the patients while shifting.

To the extent possible, patients should not be left unattended.

4.10 Emergency Patient Evacuation

Stock

Emergency Patient Evacuation Stock to be maintained at Two sites for 30 Patients with quantity to be specified – Each hospital to specify for their respective hospital: (Specify **"To be maintained by whom"- Pharmacy or other Depts?**)

Emergency patient evacuation stock consists of:

Equipment	Drip Stands
	Wheelchairs
	Field Stretchers
	Oxygen Cylinders
	Transport ventilator (optional)
Medicines	Antibiotics
	Lifesaving emergency crash cart drugs
	Analgesics
	Anti-inflammatory drugs
Other	Triage Kit
	Dressing Material
	Suturing material
	Ambu Bag and mask
	Bed Pans
	Urine Pots

ERT (Emergency Response Team)

Personnel Responsibilities:

- Designate trained personnel to assist in patient evacuation.
- Ensure staff members are familiar with evacuation routes and procedures.
- Assign specific roles to staff members during evacuation scenarios.

a) Supporting IRT

(Immediate Response Team)

- If the IRT requires assistance in extinguishing the fire or evacuating patients, staff, and relatives, the ERT steps in to help the Fire Zone In charge and the IRT Team.
- The ERT includes departments such as Housekeeping, F&B (Food & Beverage), Front Office, Nursing, and Doctors.

b) Central Command Nucleus (CCN) Communication:

- If the fire or emergency becomes uncontrollable, the IRT contacts the Central Command Nucleus (CCN) for permission to evacuate the floor or building.
- The CCN briefs the teams on evacuation procedures, including the type of evacuation (vertical or horizontal).

c) Division of Teams:

- After receiving instructions from the CCN, the IRT and ERT teams are divided into four groups:

d) Alfa Team (Security & Engineering):

- Responsibilities include extinguishing fires using fire extinguishers, restricting access to hazardous areas, and evacuating people from immediate danger.
- Crowd Control duties at the assembly area.

e) Beta Team (Front Office):

- Assists the Alfa Team in fire extinguishing, restricting access, and evacuating people.

f) Delta Team (Housekeeping, Nursing & Doctors):

- Focuses on evacuating patients according to priority: ambulatory patients first, followed by conscious but non-ambulatory, and finally, bedridden patients.

- Utilizes equipment such as Ambu bags, Foldable structures, and Evacuation chairs to assist in the evacuation process.

g) Charli Team (F&B and HR):

- Provides water and packed food at the assembly area to ensure the well-being of evacuees.

HR will take a Headcount at Assembly Point.

- **Evacuation Hand Tool Kit** in all Patient Care Areas, a must requirement and to be maintained with Quantity per kit specified on it. It consists of:

Permanent Markers
Rubber Bands for Medical Records
Removable Labels- 2-1/2# round Labels- 250 to a roll- EVACUATED identifies areas that have been checked and evacuated
Laminated Evacuation Triage levels
Pre-Strung Fluorescent Tags (Colors: Red, Yellow, Green)
Sheet Protectors for Transfer Documentation to Accompany Patient
Wind Up Flashlight
Fluorescent Vest

➤ **Patient Transfer Protocol:**

- Prioritize patient safety and comfort during transfer.
- Provide necessary medical support and equipment during the evacuation process.
- Maintain communication with medical staff to ensure patient conditions are monitored and addressed effectively.

➤ **Communication and Coordination:**

- Establish clear communication channels among ICU staff, hospital administration, and emergency response teams.
- Coordinate with other hospital departments and units to facilitate smooth evacuation procedures.

- The immediate contact numbers of all emergency services viz. fire authorities, civil administration, police with names should be displayed prominently in the Security Office/Security Control room and Call Center.

CONCLUSION

Fire prevention in Buildings and Hospitals is very vital in the public life. There are different ways and means to mitigate the fire hazards. It is necessary to understand the standard practices and codal provisions for building and hospital construction which will reduce the fire incidences.



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FIRE-SURVIVAL CABLES: AN ESSENTIAL ASPECT FOR FIRE & SAFETY

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Abstract

Fire Survival cables are designed to maintain the circuit integrity of the cable even during fire conditions. In general, the fire-Survival cables are made up of flame retardant zero halogen materials, so that the fire hazard such as flame propagation and smoke release of these cables are controlled. However, one more fire hazard of these fire-survival cables is nothing, but the heat released from these cables during a fire. Heat release of these cables depends upon the fuel loading of the cables and the energy available in the materials of these Fire

Resistant or Fire Survival (FS) cables. In this paper, construction & salient attributes of FS cables are presented.

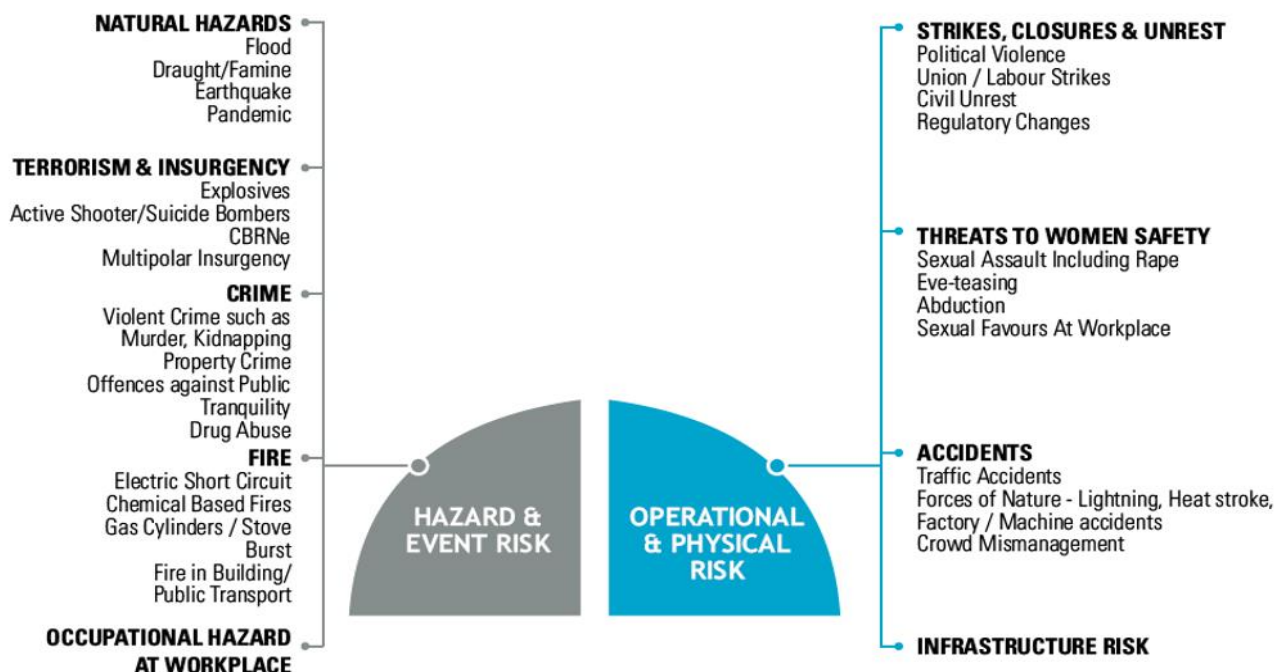
Keywords:

Fire Resistant or Fire survival Cables, Glass-Mica Insulation, test methodologies

1. Introduction

Referring to the black past & basis recent FICCI-Pinkerton “The India Risk survey”, Fire has become a bigger threat to human life since the time, living spaces become limited & human population density increasing every passing day

FICCI-Pinkerton's - “The India Risk Survey”



Numerous numbers of control & power cables of 1.1kV rating are being used in control & power panels of critical equipment and control devices that are housed inside the closed buildings and industries. Control cables are of low voltage rating and

specially designed for the centralized control of electrical equipment. Hence control cables play an important role in life safety and firefighting applications which includes the delivery of power and auxiliary control in fire alarm systems, voice alarm systems, and

emergency lighting systems. The hazardous effect of fire involved in the cables is flame spread, the release of smoke and toxic gases, and heat release. In order to improve the flame retardancy and to make it less smoke emission, various thermoplastic materials such as FR PVC, FRLS PVC, HFFR, and LSZH materials are used in sheathing applications of the Fire-Resistant cables. However, the Fire resistance property is not the same as that of flame retardancy of cables. Flame retardant cables are designed to retard the spread of fire and control the flame spread. Fire resistant cables are designed to maintain circuit integrity and continue to work for a specified period of duration under the normal operating voltage and specified flame temperature conditions. Fire Resistant cables are mainly used in hospitals, underground railway stations, metro coaches, and hazardous environments such as oil and gas platforms.

2. Overview of Fire Survival Tests and Applicable Standards

The fire-resistant cables are of single-core and multi-core cables are suitable for use within a number of Control Circuit categories. The fire-resistant cables are required to withstand four different categories of Fire Resistance tests as per national and international standards. They are as follows:

2.1 Fire Resistance Test with Fire Alone

In this category, the cable shall maintain the circuit integrity throughout the prescribed test duration under the fire application alone with a specified flame temperature.

2.2 Fire Resistance Test with Fire and water

In this category, the cable shall maintain the circuit integrity throughout the prescribed test duration under the fire application of specified flame temperature and also water spray or water jet application for a prescribed duration and at specified intervals.

2.3 Fire Resistance Test with Fire and Mechanical shock

In this category, the cable shall maintain the circuit integrity throughout the prescribed test duration under the fire application of specified flame temperature and also an indirect mechanical impact application for 20 seconds duration and at specified intervals of either 5 minutes or 10 minutes. As per BS 6387, Category Z, the fire is applied for 15 minutes duration and the mechanical impact is applied for every 30 seconds once.

2.4 Fire Resistance Test with Fire, Mechanical Shock, and Water Spray

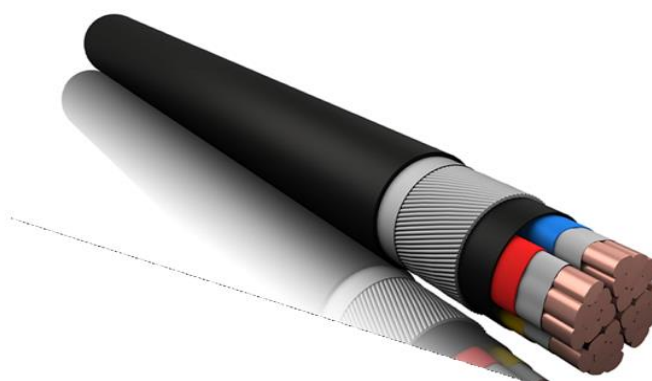
In this category, the cable shall maintain the circuit integrity throughout the prescribed test duration Under the fire application of specified flame temperature and also an indirect mechanical impact application for 20 seconds duration and at specified intervals of either 5 minutes or 10 minutes. However, during the last 5 minutes duration of the test, a burst of water of 5 s duration at 60 seconds intervals is applied for at least 5 bursts of water application.

The applicable standards and the fire resistance test requirements are described in Table 1.

Sl.No	Standard	Name of the standard	Duration of the test
1	IEC 60331-11-1999 & IEC 60331-21-1999	Fire Alone at 750° C, rated voltage up to 0.6/1 kV	90 minutes
2	BS 6387-2013 Category C	Resistance to fire alone test at 950 °C	180 minutes
3	BS 6387-2013 Category W	Resistance to Fire with Water at flame temperature of 650 °C	15 min – flame 15 min – flame and water
4	BS 6387-2013 Category Z	Resistance to fire with mechanical shock at 950 °C	15 min – flame and impact for every 30 secs
5	IEC 60331-1 -2018	Fire with shock at 830 °C for rated voltage of upto 0.6 / 1 kV & diameter exceeding 20 mm	30 min, 60 min, 90 min or 120 min- Impact of 20 secs at 5 min intervals
6	IEC 60331-2 -2018	Fire with shock at 830 °C for rated voltage of up to 0.6/1 kV & diameter not exceeding 20 mm	30 min, 60 min, 90 min or 120 min-flame, Impact of 20 secs at 5 min intervals
7	IEC 60331-3 -2018	Fire with shock at 830 °C for voltage up to 0.6/1 kV tested in a metal enclosure	30 min, 60 min, 90 min or 120 min- flame, Impact of 20 secs at 5 min intervals
8	BS 8491-2008	Assessment of fire integrity of large diameter power cables of safety systems – Fire, Water & Mechanical shock	30 min, 60 min or 120 min-flame, Impact of 20 secs at 10 minutes intervals, 5 mins before the end of the test, at least 5 bursts of water application of 5 secs at 60 secs intervals.
9	IS 17505 (Part-1)-2021 Category F	Resistance to fire alone test at 950 °C	180 minutes
10	IS 17505 (Part-1)-2021 Category W	Resistance to Fire with Water at 650 °C	15 min – flame At least 5 bursts of water of 5 s duration at 60 seconds intervals.
11	IS 17505 (Part-1)-2021 Category S	Flame and Shock application at 950 °C	15 min –flame Impact for 20 secs at 5 min intervals
12	IS 17505 (Part-1)-2021 Category F-30 F-60 F-120	Flame, Shock, and water jet application at 830 °C	30 mins, 60 mins, 120 mins – flame, the impact of 20 secs at 5 min intervals. 5 mins before the end of the test, at least 5 bursts of water application of 5 secs at 60 secs intervals
13	BS EN 50200: 2015 Annex E 30 minutes	Flame, Shock, and water jet application at 830°C	30 mins-flame, Impact every 5 minutes throughout the test, water spray for the final 15 minutes of the test.
14	BS EN 50200: 2015 PH 30 PH 60 PH 120	Flame and mechanical shock	30 mins, 60 mins, 120 mins - Flame, Impact at 5 every mins interval

TESTING INSTRUMENTS

- ☐ Circuit continuity checking and voltage withstand arrangement
- ☐ Source of heat
- ☐ Shock producing device
- ☐ Circuit diagram
- ☐ Gas Flow Console
- ☐ Electric Load Operation Device
- ☐ Water Spray
- ☐ Water Jet
- ☐ Water Sprinkler



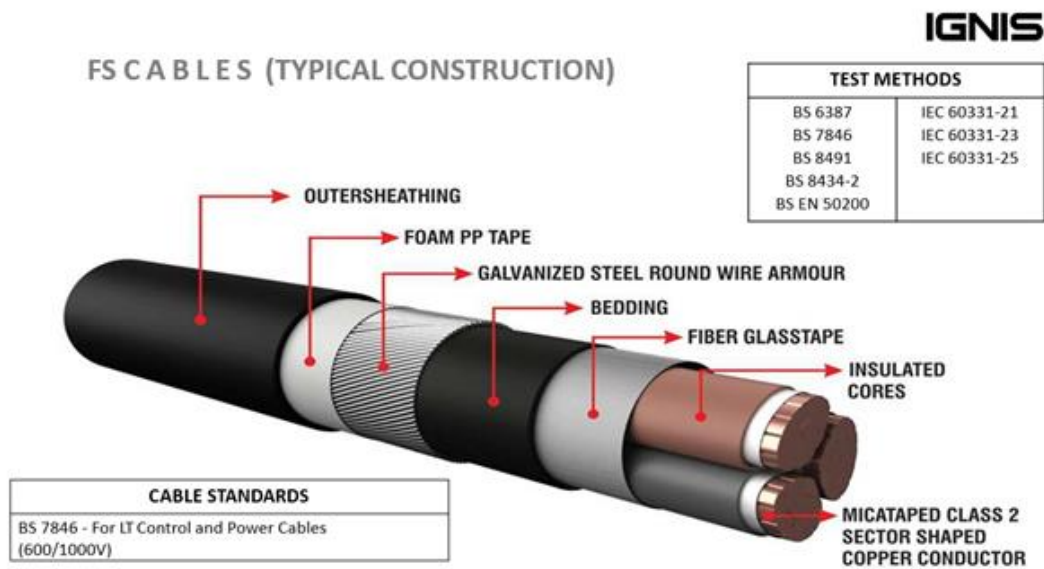
3. Construction of Fire-Survival Cables

In the case of Fire-Resistant cables, to maintain the circuit integrity and to avoid conductor to conductor short circuits, the conductors of the cable should be protected by high-temperature insulation. The mainly used high temperature insulations are Mica/glass tape, XLPE & silicon insulations etc.

3.1 Mica/Glass Tape insulation

In this type of construction of the Fire-Resistant cables, the conductor is of either stranded/flexible Annealed copper conductor, followed by Glass Mica Tape as fire resisting barrier, followed by XLPE/EPR/EVA as primary insulation Material, and Flame Retardant LSZH, HFFR as sheathing material.

Figure 1 shows the Fire-Resistant cables with mica/glass tape construction.



4. Fire Hazards of Cables during the Fire

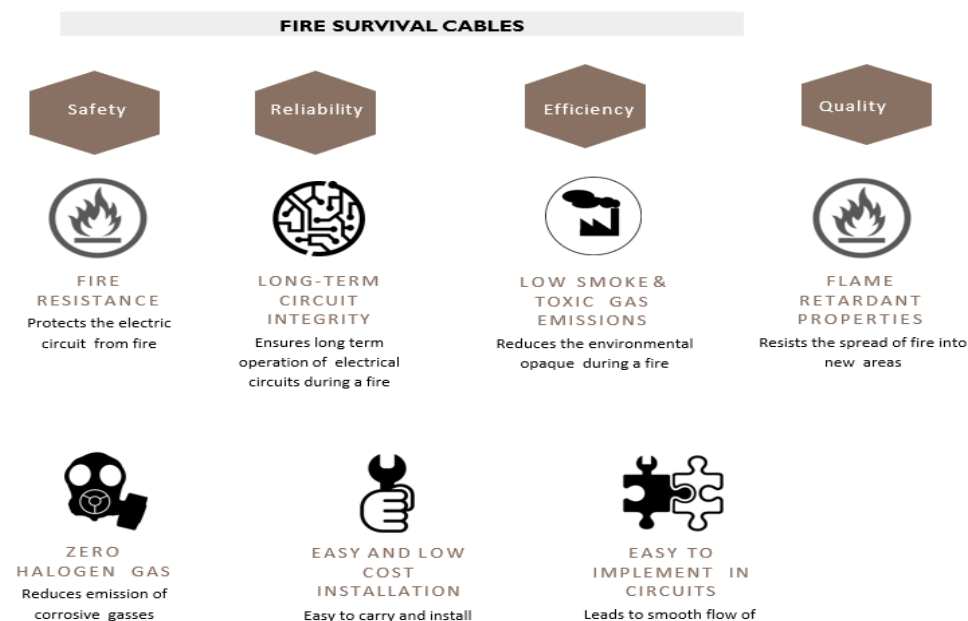
When fire safety is considered, the first and foremost point is to classify the hazards involved during the fire of cables. Most of the fire deaths are caused by the inhalation of toxic smoke and gases, rise in temperature, and depletion of oxygen concentration. The emission of toxic gases is reduced by Using halogen-free materials and the impact of the fire is reduced by using the flame-retardant Property of the halogen-free materials. In general, if the fire spread in the cables is controlled the hazards of the fire in cables can also be reduced to a greater extent. Apart from flame retardancy and smoke release, one of the fire hazards is heat or temperature

release from the cables during a fire. Heat release is directly proportional to the oxygen consumed by the burning cable. Hence certain materials release more heat thereby consuming more oxygen available in the atmosphere which in turn creates an increase in the temperature and depletion of oxygen concentration in the environment. If the cable jacketing or sheathing material releases more heat which is also dangerous to humans causing fatality. Heat release of any material is nothing but the energy or fuel content available in the material. In general materials such as polyethylene, polypropylene, and ethylene-propylene rubber have higher fuel content in them

even though the smoke release of these materials is very less. When cables are installed inside the theaters, high-rise buildings, underground installations,

hospitals, and airports, the volume of insulation of the cables is also more and the fuel content of the electric cables is also high considerably.

FEATURES AND ADVANTAGES



6. Conclusion

From the heat release parameters of FS cables, it is evident that the heat release of individual material in the construction of the FS cable plays an important role in determining the overall heat release of the entire FS cables. Materials that are used in the construction of FS cables to maintain the circuit integrity should not pose another threat of heat release when the FS cables are under fire. During the design of the FS cables along with the properties of fire resistance, flame retardancy, and low smoke emission, heat release from the FS cables also needs importance

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27+years presence in Cable Industry with wider experiences in Technical, Design, Engineering, Quality Systems, New product development.

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GENERAL SAFETY & FIRE SAFETY IN THE EXTRA HIGH VOLTAGE SUBSTATION - ASSESSMENT, CONSTRUCTION PRACTICES & RECOMMENDATIONS

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1.0 INTRODUCTION

1.1 Demand in Power System is increasing day by day which increases number of substation and transmission/distribution lines in the system. Extra High Voltage Substations are important part of large power system as they are handling huge amount of load (1000 MVA), working at Voltage 400kV & above and involves area of more than 45 acre. This substation also has transmission line towers of incoming or outgoing lines in the substation premises. These substations also involve staff which includes Senior Engineers and Junior Engineers as well as other technical/non-technical staff members. These substations include switchyard with large number of equipment working at Extra High and High Voltage levels, control room, open storage, close storage, fire pump house/system, staff quarters, dispensary etc. Safety assessment of extra high voltage substation is very much necessary for promoting, improving and maintaining safety performance in substation that are conducted for meeting not only statutory requirement but also for self-assessing performance of safety management system and site-specific safety improvement of Extra High Voltage Substations.

1.2 The safety in the substation is multidimensional. One is general safety and other is fire safety.

1.3 The presentation below gives brief account of safety assessment aspects of Safety audit and some case studies /

observations in a major EHV substation.

2.0 SAFETY ASSESSMENT OBJECTIVES

2.1 Even though safety and safety assessment are right of power utility companies, safety assessment or audit is carried out in extra high voltage substations with the objectives like

- (i) For providing assesses an opportunity to assess its own Occupational health and safety management systems (OH&S).
- (ii) For determining adherence to implemented OH&S systems with specific requirements and identifying area which requires improvement.
- (iii) Carrying out systematic critical appraisal of potential hazards like fire, electric shocks & injuries which is involving personnel, services and operational methods and
- (iv) Reviewing compliance to existing protection system, preventive measures and statutory/regulatory requirements.

3.0 SAFETY ASSESSMENT AND RECOMMENDATIONS

3.1 Safety assessment of extra high voltage substation should be done considering different points as follows:

- (i) general safety aspects
- (ii) Occupational Health and General Working Condition
- (iii) Safety Aspect (Switchyard Area and Transformer)
- (iv) Safety Aspect (Control Panel and Control Room)
- (v) Safety Aspect (Transformer oil and

and Diesel Storage System)

- (vi) Fire Safety Aspect
- (vii) Personal Protective Equipment (PPE)
- (viii) Safety Education and Training
- (ix) First Aid.

1.1 In order to carry out safety assessment work was done in a substation. Some of the main observations along with their recommendations (for 400/220kV substation) in terms of safety assessment are as follows:

- Earth System (Pit) maintenance is done properly but in auxiliary supply system-1 it is not maintained properly (Refer Image-1 of Exhibit). It is recommended that Earth System (Pit) maintenance should be done properly as per CEA regulations inadequate earthing may cause damage to equipment and also lead to fire.
- Earth pits are provided and electrical equipment are earthed. But earth pits were not identified / numbered equipment wise. Gantry earth pit for Bay-1 was not maintained (Refer Image-2 of Exhibit). It is recommended that earth pits should be identified / numbered equipment wise. Gantry earth pit should also be maintained properly as per standard.
- Water pump near transformer-1 was not guarded properly and guard was corroded (Refer Image-3 of Exhibit). It is recommended that Water pump guard should be maintained properly. This may cause electrical and or mechanical accident.
- Line Shunt Reactor-1 earthing pit as well as cable trench were open (Refer Image-4 of Exhibit). It is recommended that earthing pit as well as cable trench should be kept covered. In Bay-4 of 400kV switchyard, maintenance work of circuit breaker was in progress. Maintenance personnel were working without safety equipment (Refer Image-5 of Exhibit). Also, maintenance online-8 was in progress. Maintenance personnel was working without safety equipment (Refer Image-6 of Exhibit). It is recommended that Maintenance personnel should work with all the required safety equipment.
- Open storage area near 220kV switchyard was not maintained properly and having vegetation growth (Refer Image-7 of Exhibit). It is recommended that open area should be maintained properly and vegetation should be removed which might cause fire when it is dry.
- Vegetation growth was found near 400kV Transformer unit-2, 220kV and 132kV switchyard (Refer Image-8, Image-9 and Image-10 of Exhibit). It is recommended that vegetation should be removed which might be the reason of fire (particularly when it becomes dry).
- Good practice was followed that electrical panel room is well maintained with proper Exhaust system, ventilation & Illumination systems and insulation rubber mat (Refer Image-11 of Exhibit). Even battery Room is properly lined with 'Acid resistance tiles' up to the height of 'Battery Bank'. Battery room is properly ventilated & illuminated (Refer Image-12 of Exhibit). Battery room was kept neat and clean and eye-wash system was also available nearby.
- Fireboxes with hose reels were missing near the fire hydrant points at two locations (Line-1 Bay and Bus Transfer Bay) in 220kV switchyard (Refer Image-13 and Image-14 of Exhibit). It is recommended that Substation Engineer

must ensure fireboxes with hose reels at fire hydrant points.

- Unit-2 of 220/132kV Transformer is not equipped with water sprinkler fire system (Refer Image-15 of Exhibit). It is recommended that comprehensive fire detection, alarm as well as fire protection system shall be installed for the Station in conformity with relevant IS as per Regulation 12 (5) (a), (b), (c) of CEA (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010 which shall be complied with in respect of Fire Detection, Alarm and Protection System.
- In 400kV switchyard area, Portable Fire Extinguisher were kept in open (Refer Image-16 of Exhibit). It is recommended that portable Fire Extinguisher should be kept in closed structure or under the shed.
- On control room ground floor, firefighting control panel was obstructed by unwanted materials (Refer Image-17 of Exhibit). It is recommended that unwanted material should be removed and access to the firefighting control panel should be made easy.
- In substation, it was found that workers / staff are not putting on appropriate job / task specific PPE kits (Refer Image-18 of Exhibit). It is recommended that substation must keep inventory and provide tasks specific PPE kits to all the workers/staff.

Observation Images



Image – 1
Improper
maintenance
of earthing
pit



Image – 2
Improper
maintenance
of earthing
pit



Image – 3
Improper
covering of
motor
pump



Image – 4
Open
earthing pit
and cable
trench



Image – 5
Maintenance
personnel
working
without
safety
equipment



Image – 6
Maintenance
personnel
working
without
safety
equipment



Image – 7
Vegetation
growth in
switchyard
area



Image – 12
Properly
maintained
battery
room



Image – 9
Vegetation
growth in
switchyard
area



Image – 13
Fireboxes
without
hose reels



Image – 9
Vegetation
growth in
switchyard
area



Image – 14
Fireboxes
without
hose reels



Image – 10
Vegetation
growth in
switchyard
area



Image – 15
Transformer
without
Water
Sprinkler
Fire System



Image – 11
Properly
maintained
control
room



Image – 16
Portable Fire
Extinguisher
in Open

4.0 Normal fire protection system in the EHV switchyard & control room.

4.1 The fire protection system in EHV switchyard & control room has three distinct categories. They are described in brief as under

4.1.1 The switchyard fire protection system comprises three sections. The first section is to protect the oil filled Transformers and Reactors. The second session is to prevent stray fires in the switchyard due to dry grass/weeds and other inflammable material (like wood, Plastic, oil etc.) stored /lying in open. Such stray fire is most likely due to short circuit on bus or equipment and resultant spark or explosion. The third section fire protection of control room building which may include control area, offices, battery room, passages, conference room, DG set room, storeroom etc. This third part can have fire detection and alarm system as well.

4.1.2 The oil filled transformers and reactors are protected against fire by two different methods as follows

a. Muti fire Protection (Water Mist) System.

In this system when fire takes place on the transformer/reactor, the Quartzoid bulb fitted near the tank blow off at temperature more than 70°C. The pressures in the pipes carrying Quartzoid bulb drops and operates deluge valve which allows water at 10kg/cm² into the pipes surrounding the transformer/Reactor. The nozzles fitted at the end sprinkle water with high velocity & quenches the fire in short time. The main pump in the pump house starts pumping Water and maintain the pressure.

This system of Quenching the fire has been vogue for almost three decades but it is now being replaced by other system due to the infrastructure requirements

such as large water tank, Pumphouse (main & Jokey pump) water header pipes & hydraulic system, etc. The system is also needed periodic maintenance.

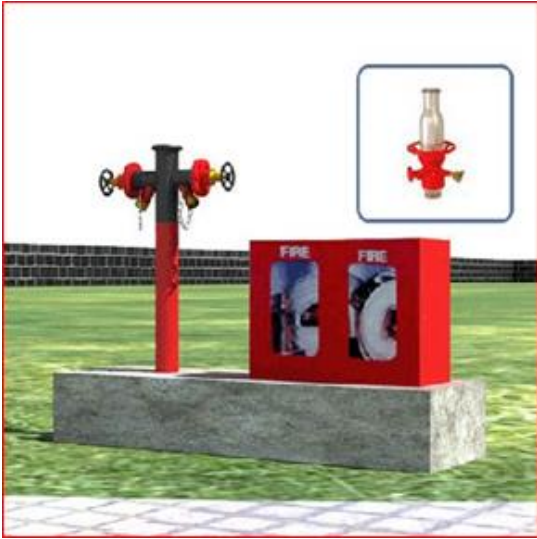
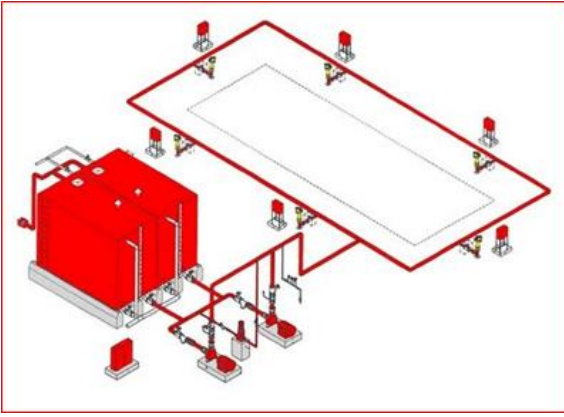


b. Nitrogen Injection Fire Protection System

Whenever fire occurs in Transformer or Reactor about 10% oil from the tank suddenly drains down. The spare created in the tank is occupied by Nitrogen gas and the fire is quenched in very short time. This system needs less infrastructure and now it is widely deployed.



4.1.3 For stray fires in the switchyard Hydrant system is used. A Header pipe with pressurized water is installed on the boundary of the switchyard with posts at small distances. The post carries a box containing hose pipe. In case of stray fire, the nearest hose pipe will be used to force water through nozzles.



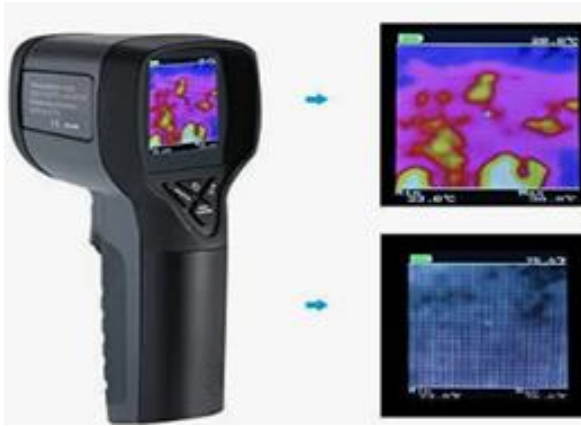
In this system also we need water tank, pumphouse & piping system. This system of protecting the yard from stray fires is also being replaced by mobile equipment which cost less and are easy to maintain. Very large substation (particularly the pooling Substation) also has a provision of Fire Tender & Fire Protection Staff.



4.1.4The control room and administrative building in large substation is equipped with portable fire extinguishers and cleaned sand buckets. The fire & smoke detectors are provided in various rooms and the passages. They are addressable and connected to fire Panel. In case of fire or smoke (before the fire) the detectors will sense it & send signal to the panel which will show indication & the spot where fire is likely or has occurred.



4.1.5Now days thermal imaging cameras are being used to monitor hot spots in the switchyard & elsewhere. They give advance warning & eliminate the chances of fire/short circuit.



4.1.6 To prevent the spread of the fire from one transformer / reactor to other, fire protection walls are constructed in between



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ELECTRIC FIRE AND EXPLOSION HAZARD PREVENTION FOR POWER TRANSFORMER AND REACTOR

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❖ INTRODUCTION

Transformers and reactors are critical components in electrical power systems, converting high-voltage energy into lower, usable levels. However, due to the presence of insulating oil, high operating voltages, and significant heat generation, transformers and reactors are susceptible to fire and explosion hazards. Preventing such hazards is vital to protect people, property, and ensure continuity of power supply.

Fires and explosions in transformers and reactors can be triggered by various factors, including insulation failure, overheating, arcing, short circuits, or electrical faults. Insulating oil can ignite if exposed to heat from electrical arcing, potentially leading to a catastrophic fire, if not contained.

❖ To mitigate these risks, effective fire and explosion hazard prevention practices must be implemented. These practices are described below:

1. Proper Design and Maintenance:

Transformers and reactors should be designed with adequate safety features such as pressure relief devices, temperature monitoring, and oil level sensors. Regular inspection and maintenance help in detecting early signs of overheating or electrical faults, minimizing the risk of ignition.

2. Oil Type and Fire Suppression

Systems: The use of less flammable insulating oil or alternatives like dry-type transformers can reduce fire risk. Installing fire suppression systems, such as automatic sprinklers, CO₂, or nitrogen

systems, provides an extra layer of safety. However, dry type transformers have limitation of capacity.

3. Cooling and Ventilation: Proper cooling is essential to prevent overheating, which is a common cause of transformer fires. Effective cooling systems, adequate ventilation, and monitoring devices can help maintain safe operating temperatures.

4. Protective Relays and Monitoring Systems: Protective relays are designed to detect abnormal conditions, such as overcurrent or overvoltage, and isolate the transformer from the power supply, reducing the risk of fault escalation. Continuous condition monitoring, including thermal and gas detection, helps identify potential issues before they lead to an accident.

5. Physical Barriers and Distance: Ensuring physical barriers between transformers and other equipment can limit the spread of fire. Maintaining adequate distance between transformers and critical infrastructure helps reduce the impact of an explosion.

6. Personnel Safety and Training: Personnel involved in transformer operation and maintenance should be trained in identifying hazard signs and emergency response protocols to ensure safety in the event of an incident.



❖ Purpose of Protection System:

- Minimize the risk of the fire occurring.
- Protect the potential fire victims, humans and adjoining equipment in the substation from fire damaged.
- Restore the supply as early as possible after the fire.
- Avoid pollution and contamination of the environment

Transformer explosion generally result from an insulation failure:

This may be caused by: Vibration, Loose Mounting, Overload, Switching Surges, Lightning Surges, etc.

Major reasons for origin of transformer fire

- Bushing
- Internal arcing (flashover)
- OLTC and others

❖ Transformer and Reactor Fire Protections:

Transformer and reactor fire protection is crucial to ensure the safety of personnel, reduce equipment damage, and minimize the risk of power outages. Fire protection measures for transformers typically include a combination of prevention, detection, and suppression systems. Below are the main

aspects of transformer fire protection:

1. Preventive Measures

- **Proper Design & Installation:** Ensuring transformers are designed to handle expected loads and are installed with adequate spacing between units.
- **Regular Maintenance:** Routine inspection of bushings, oil levels, and cooling systems to identify potential faults before they lead to fire.
- **Oil Testing:** Conducting Dissolved Gas Analysis (DGA) and Breakdown Voltage (BDV) on transformer oil to detect internal faults that could lead to overheating.
- **Overload Protection:** Monitoring transformer loads to prevent overheating due to overloading.

2. Fire Detection Systems

- **Temperature Sensors:** Monitoring the transformer temperature continuously to detect any overheating that could lead to a fire.
- **Gas Detectors:** Sensors to detect combustible gases (e.g., hydrogen) released from transformer oil, which may indicate an internal fault.
- **Smoke Detectors:** Used to detect smoke as an early warning of an impending fire.

3. Fire Suppression Systems

- **Automatic Sprinklers or Water Spray Systems:** High-velocity water spray systems can quickly cool down the transformer and suppress flames.
- **Foam Systems:** Special foam can be used to suppress fires by creating a film on top of the burning oil to prevent re-ignition.

- **Deluge Systems:** These systems release a large volume of water in the event of fire detection, providing effective suppression and cooling. This is part of Water Spray System.

4. Fire Barriers and Spacing:

- **Firewalls:** Concrete firewalls or barriers are often installed between transformers to prevent the spread of fire from one unit to another.
- **Adequate Spacing:** Transformers should be placed with adequate space between them to minimize the risk of fire spreading.

5. Bunds and Oil Containment:

- **Oil Storage Pit:** An Oil Storage Pit is placed around transformers to contain spilled oil in case of a leak, preventing it from spreading and causing a fire.
- **Oil Drains:** Designed to channel oil away from transformers (which is under fire) and avoid fire risks in case of leaks. This oil is discharged into the burnt oil pit.

4. Emergency Shutdown and Cooling

- **Rapid Pressure Relief Devices:** Prevent transformer tank explosions by relieving internal pressure.
- **Cooling Systems:** Transformer cooling systems, such as radiators and oil pumps, help maintain safe operating temperatures. The cooling system can be AN /ON or AN/AF or AN/OF or its combination.

5. Monitoring and Alarming

Control Systems: Continuous monitoring of transformer parameters

- **Remote Monitoring:** Integrating monitoring systems with SCADA to enable remote detection and alarm of any fire-related conditions.

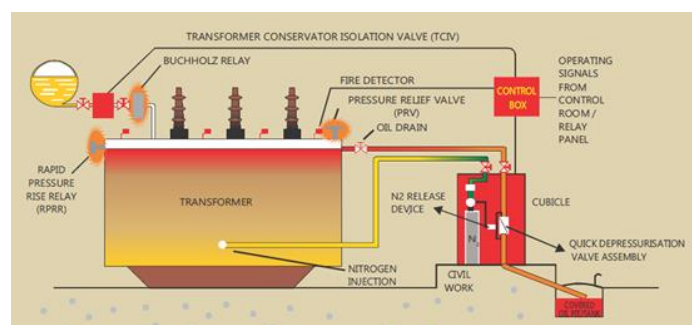
6. Fire Extinguishers

- **Portable Extinguishers:** Carbon dioxide or dry chemical extinguishers should be available near transformers

for quick action by personnel.

9. Nitrogen injection fire prevention and extinguishing system:

- ❖ The **Nitrogen Injection Fire Prevention and Extinguishing System** (NIFPES) is a specialized fire suppression mechanism used in oil-filled power transformers. It prevents fire by rapidly injecting nitrogen gas, which displaces oxygen and reduces internal pressure, effectively stopping combustion. Here's a detailed breakdown of how this system works:



❖ Working Mechanism of the Nitrogen Injection System

1. Detection of Fire or Fault Condition

- The system continuously monitors transformer parameters, including **temperature, smoke, gas concentration, and internal pressure**.
- **Sensors** such as smoke detectors, temperature sensors, pressure relays, or dissolved gas analyzers trigger the system when a potential fire hazard is detected.
- The system can also be activated when a **rapid pressure rise** is detected in the transformer tank, indicating an internal arcing event or explosion.

2. Activation of the Nitrogen Injection System

- Upon detection of a potential fire or high-pressure condition, the control panel automatically activates the nitrogen injection system.
- The control panel initiates the process

by opening valves that allow nitrogen gas to be released from storage cylinders into the transformer.

3. Oil Drain Mechanism

- As the nitrogen injection system is activated, a **valve opens to drain a portion of the transformer oil** into an external containment.
- This step is crucial to reduce the internal oil level, thereby preventing any increase in pressure that could lead to tank rupture.
- Reducing the oil level also creates space for the injection of nitrogen gas into the transformer tank.

3. Nitrogen Gas Injection

- **Nitrogen gas** stored in high-pressure cylinders is injected into the headspace of the transformer.
- **The nitrogen injection serves two primary functions:**
 1. **Displaces Oxygen:** The injected nitrogen displaces oxygen in the transformer, which is necessary for combustion. This suffocates the fire by removing its oxygen supply.
 2. **Suppresses Combustion and Cools Hotspots:** The nitrogen also acts as a cooling agent, helping to cool down any hotspots inside the transformer, thereby preventing further ignition.

4. Pressure Control and Safety Features

- The system is designed to work alongside pressure relief devices that vent excess pressure in a controlled manner to prevent damage to the transformer tank.
- Nitrogen injection is controlled to ensure that the pressure within the transformer remains stable during the process, thus protecting the structural integrity of the transformer.

5. Completion and Stabilization

- Once the nitrogen has been injected

and oxygen levels are minimized, the fire is extinguished, and the transformer temperature is reduced.

- The system continues to monitor the transformer until the situation is fully stabilized.

❖ Key Functions of Each Component

- **Nitrogen Storage Cylinders:** These cylinders store nitrogen gas at high pressure, ready for immediate use during an emergency.
- **Oil Drain Valve:** It opens during activation to partially drain the transformer oil and make space for nitrogen.
- **Injection Piping System:** Directs nitrogen into the transformer tank, ensuring even distribution and effective suppression.
- **Fire Detection Sensors:** Monitor critical parameters to detect any internal fault, overheating, or combustion.
- **Control Panel:** Central control for managing the overall system, coordinating oil drainage, nitrogen release, and alarm signals.

❖ Advantages of Nitrogen Injection System

1. **Rapid Suppression:** Quick response time helps in immediately suppressing fire, reducing potential damage.
2. **Effective Oxygen Displacement:** Nitrogen effectively displaces oxygen, eliminating one of the fire triangle elements, thereby extinguishing combustion.
3. **Minimal Damage:** Unlike water-based or foam systems, nitrogen does not cause electrical damage or leave behind residues that require extensive cleanup.

4. **Cooling Effect:** Nitrogen cools the transformer and prevents further ignition.
5. **Minimum Auxiliaries.** This system has minimum auxiliaries compared to other systems.

❖ Applications

- **Power Transformers and Reactors:** Ideal for oil-filled transformers and reactors in power stations and substations, especially for high voltage transformers.
- **Critical Installations:** Transformers in critical installations that need continuous operation, where downtime must be minimized.

The nitrogen injection system provides a safe and efficient way to both prevent transformer fires and suppress fires quickly when they occur, thus ensuring minimal damage to equipment and maintaining power supply reliability.

Flow Sensing Valve



❖ Fire Sensing Quartzoid Bulb

Fire sensing quartzoid bulb, often referred to as a **frangible bulb**, is a critical component used in fire suppression systems, particularly in automatic sprinkler systems. It works by detecting elevated temperatures that indicate the presence of a fire and subsequently activating the fire suppression mechanism.

1. Structure of a Quartzoid Bulb:

- **Glass Bulb:** The quartzoid bulb is a small, sealed glass tube that contains a colored liquid. The liquid is designed to expand when heated.
- **Colored Liquid:** The liquid inside the bulb has a predetermined expansion coefficient, which causes the bulb to break at a specific temperature. Different colors are used to indicate different activation temperatures (e.g., red, green, blue, etc.), providing a quick way to identify the temperature rating.
- **Size and Placement:** The bulb is typically a few centimeters in size and is positioned at the nozzle of a sprinkler head, holding back a plug that prevents water from flowing until the bulb bursts.



2. Working Principle of a Quartzoid Bulb:

- **Temperature Rise:** When a fire occurs, the ambient temperature around the sprinkler head rises. The heat is transferred to the quartzoid bulb.

- **Expansion of Liquid:** As the temperature increases, the liquid inside the glass bulb expands. The glass bulb is designed to burst at a specific temperature threshold based on the type of liquid and the expansion properties.
- **Bulb Breaks:** When the temperature reaches the activation point, the pressure of the expanding liquid causes the bulb to shatter.
- **Activation of Sprinkler:** Once the bulb shatters, it releases the plug or cap (normally the deluge valve) that was holding the sprinkler closed, allowing water (or another extinguishing agent) to flow out and suppress the fire.

3. Types of Quartzoid Bulbs by Temperature Rating

Different colors are used to indicate the activation temperature rating of a quartzite bulb, which helps in selecting the right bulb for specific environmental conditions:

- **Red:** 57°C (135°F)
- **Yellow:** 68°C (155°F)
- **Green:** 79°C (175°F)
- **Blue:** 93°C (200°F)
- **Purple:** 141°C (286°F)

These temperature ratings ensure that the sprinkler head activates at the correct time, avoiding accidental discharge due to normal variations in ambient temperatures.

❖ Conclusion

1. System must be automatic, remote operation and emergency manual operation (not only automatic).
2. Response time of fault detection and response time of system operation are key parameters in transformer protection success.
3. Importance of relay configuration at site in successful protection of system.
4. The system shall cover oil fires in cable box, OLTC apart from tank oil fire.
5. Oil must be drained considering core coil assembly and should not expose to air.
6. Quantity of gas, nitrogen injection pressure, nitrogen injection flow, setting of nitrogen pressure at which alarm to provide are important parameters for effective protection of transformer using N2 based system.
7. Importance of mechanism to avoid entry of leaking gas into energized transformer.
8. Fast response time: quick oil drain mechanism, nitrogen injection mechanism and isolation of conservator oil by flow sensitive valve.
9. System operation on substation DC source used for control and protection.
10. Utilization of flow sensitive (transformer conservator isolation valve) should be regularized for transformers and reactors to protect in case of bushing rupture / fire.

ENHANCING ELECTRICAL FIRE SAFETY IN AN INDUSTRIAL FACILITY

A CASE STUDY

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Abstract

This paper presents a case study on improving electrical safety at a manufacturing plant where repeated electrical overheating incidents were observed in 2023 due to an inadequate earthing system. The plant experienced insulation failures, equipment damage, and operational disruptions, all attributed to improper grounding of fault currents. To resolve these issues, a comprehensive redesign of the earthing system was undertaken, including the installation of Surge Protection Devices (SPDs) and the adoption of a TN-S earthing system. Post-implementation results indicate a 50% reduction in equipment failures and no further incidents of overheating. This study underscores the critical importance of effective earthing systems in industrial environments to ensure operational safety and reliability.

I. Introduction

Electrical safety is a fundamental concern in industrial facilities, where high-power equipment and intricate electrical systems operate under severe conditions. Poorly designed earthing systems can lead to serious safety hazards, including equipment damage, overheating, and fire risks. This paper focuses on a case study of a manufacturing plant in 2023 that encountered severe electrical issues due to an insufficient earthing system. The issues were resolved through a combination of technical interventions, including the installation of SPDs and an upgrade to a TN-S earthing system.

This case provides a clear demonstration of how proper earthing can mitigate electrical short circuit and resultant fire risks as well as improve overall system resilience.

II. Case Study Background

In early 2023, a manufacturing plant reported several incidents of electrical overheating, primarily due to improper grounding of fault currents. Insulation breakdowns occurred frequently, and electrical faults led to operational downtime and equipment damage.

Overview of the Problem

- **Location:** Industrial manufacturing facility.
 - **Key Issues:**
 - Overheating incidents due to improper grounding.
 - Recurring insulation failures.
 - Inadequate fault current management, resulting in equipment damage.
 - Operational disruptions, with potential for severe safety hazards including fire.
- The facilities management sought to investigate and mitigate the root causes of these electrical issues.

III. Investigation and Analysis

A thorough investigation of the electrical infrastructure revealed that the facility's earthing system was insufficient to handle fault currents, leading to frequent electrical failures and safety risks.

A. Assessment of the Earthing System

Upon review, it was found that the existing earthing infrastructure was outdated and not adequately sized to discharge fault currents, which had caused several incidents of

overheating and electrical insulation failures. The earthing resistance was above recommended levels, allowing stray currents to accumulate within the system, which posed a significant fire risk.

B. Insufficient Fault Current Management

The system was not equipped to properly manage transient over voltages, such as those caused by external disturbances (e.g., lightning). The insulation breakdowns were attributed to the excessive stress imposed by uncontained electrical faults.

C. Impact on Facility Operations

These electrical issues resulted in:

Equipment Downtime: Regular disruptions in production lines due to equipment malfunctions.

- **Safety Risks:** Increased likelihood of electrical fires and personnel injury.
- **Operational Losses:** Significant financial implications due to downtime and repair costs.

IV. Solution: System Redesign

To resolve these issues, a comprehensive electrical system redesign was executed. The primary interventions included the installation of SPDs and the adoption of a TN-S earthing system.



A. Surge Protection Devices (SPDs)

SPDs were installed at critical points within the facility to protect against transient over voltages. These devices prevent high-energy faults from entering the electrical system by safely discharging over voltages to the ground.

- **Function:** SPDs protect equipment from electrical surges due to external factors such as lightning or internal switching operations.
- **Placement:** Devices were strategically placed at the main switchgear panel and near sensitive equipment to ensure adequate coverage.

B. TN-S Earthing System

The existing earthing system was replaced with a TN-S configuration, which provides separate conductors for neutral and protective earth throughout the facility. This system offers enhanced protection against electrical faults by providing a clear path for fault currents to safely dissipate.

- **Key Benefits:**
 - Separation of neutral and earth conductors eliminates potential for neutral-to-earth faults.
 - Increased capacity for fault current discharge reduces overheating risk.
 - Improved safety and reduced electrical hazards across the entire facility.



V. Results and Improvements

Following the implementation of these upgrades, the facility experienced significant improvements in electrical safety and system performance:

A. Reduction in Equipment Failures

Post-implementation inspections showed a 50% reduction in equipment failures attributed to electrical faults. The improved grounding and overvoltage protection minimized the occurrence of electrical faults that had previously caused disruptions.

B. Elimination of Overheating Incidents

The redesign addressed the root cause of the facility's overheating issues. Since the system upgrade, no further overheating incidents have been reported, which highlights the effectiveness of the TN-S earthing system in managing fault currents.

C. Improved Operational Efficiency

The reduction in equipment downtime and operational disruptions led to an overall increase in productivity. The facility reported fewer maintenance issues and significantly lower repair costs.

VI. Discussion

This case study demonstrates the critical importance of maintaining a robust earthing system in industrial facilities. Electrical safety is not only about avoiding immediate dangers but also ensuring long-term operational stability and reducing the risk of catastrophic failures.

A. Lessons Learned

- 1. Importance of Regular Inspections:** Facilities should regularly inspect their earthing systems to ensure they are functioning effectively, particularly in environments with high fault currents.
- 2. Role of SPDs:** Surge protection devices are essential in protecting against transient overvoltage events that could compromise insulation and lead to equipment damage.
- 3. TN-S Earthing System:** The TN-S earthing system provides a reliable, scalable solution for fault current management and should be considered in any facility experiencing frequent electrical issues.

VII. Conclusion

The electrical issues faced by this manufacturing plant highlight the dangers of insufficient grounding and fault current management. Through the installation of SPDs and the adoption of a TN-S earthing system, the facility was able to significantly reduce electrical risks, eliminate overheating incidents, and improve overall system reliability. This case underscores the necessity for industrial facilities to invest in proper earthing systems and regularly review their electrical infrastructure to prevent future incidents.

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CHANGE YOUR SAFETY ATTITUDE

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1. Introduction:

The unprecedented development all over the country, there has been a steep rise in accidents from various elements including fire. The large public establishment covering Industries, Power Plants, Hospitals, Malls etc. are worst affected. The Central & State Governments are proactive in monitoring safety. As a matter of fact, these days every big establishment and the construction sites deploys safety officer and staff. The Governments have safety departments. The NGO like safety councils also has its share in bringing awareness about fire safety.

2. Safety Issues:

Safety issues can be mitigated only by change in Safety Attitude & giving priority to Safety by owner, Chief Executive Officer, Directors of Company / Organizations, etc. Safety Starts from top to bottom level. It is universal and fundamental principle in the Safety. Safety awareness by the general public is as important as that by an individual. Safety culture in every work of life is the need of the day.

3. Proposed Steps:

As per the experiences of the author in the field of Industrial Safety/Electrical Safety/Fire Safety / Disaster, Followings few steps are vital to achieve positive Safety Culture at workplaces.

- To give interaction platform to workers/site engineers to represent actual facts & finding to owner of the company who is directly responsible for occupational Safety & Health.
- 100% Safety Compliances to be completed as per commitment of

Owner/Director.

- Zero tolerance policy is to be prepared by Owner/Directors for OH & S related activities in terms of funding and set minimum time frame for completing the Safety Compliances.
- OH & S motivational policy is finalized for all level workers /engineers/ CEO/ Directors on monthly basis.
- Safety Awards ceremony shall be arranged every year for all Group of Company for motivation of Safety & positive Safety Culture.
- Short terms & long terms Safety related issues shall be resolved by Owner/ Directors and to reduce legal litigations as well as increase in growth of company.
- Casual attitude to safety shall be removed at all level for growth of company & strict policy shall be framed.
- For increasing of production with safety system problems / issues shall be resolved by Root cause analysis report recommendations / Accident investigation recommendations within minimum time period
- To introduce Safety Key Performance Indicator (KPI) at all level of employees' annual appraisal.
- To prepare centralize purchase policy for uniformity and quality of PPEs to employees.
- World's latest technology shall be adopted for industrial safety/ Electrical Safety/ Fire Safety/ Disaster resources & to reduce incident rate.
- To use Safety Management Software as per Workers/ Engineers/ Director needs for monitoring of OH & S

compliances and to reduce repetition of work as well as uniform policy in the organization

- To use video analytic Safety Software for increasing production efficiency, positive Safety Culture & resolving legal compliances.
- To adopt long terms and short terms Safety Culture programmes for all level of employees as well as contract workers.
- To engage qualified & experience manpower / supervisor with Safety qualification as per Indian Act / Rules.
- Last five years Safety performance records shall be considered for Vendor selection / qualifying in work contract tender.
- Regular mock Drill for Fire Safety is vital.

Normally evacuation plans are also prepared by each industrial unit to ensure that in case of fire the personnel shall come out quickly. Even hotels have evacuation plan.

Conclusion:

The Safety in general & Fire Safety in particular can be handled properly by the involvement of all the stake holder. Safety should be an habit and not compulsion.

About the Author



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POWER TRANSFORMERS FIRE ROOT CAUSE ANALYSIS

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1.0 Abstract

1.1 Power Transformers are costly, heavy, and crucial equipment in power system. While in service power transformers generate heat, insulating oil which is used for insulation purpose also serve the purpose of heat transformation. Heat generated inside the core and copper windings are transferred by oil to atmosphere by way of cooling mechanism – radiator, fans etc. Any issue in cooling circuit or overloading of power transformer results in more heat generation, it ultimately results into temperature rise of power transformer. Overheated power transformers are ready to catch fire. Flash point of insulating oil is higher, however there is hot oil inside ready to catch fire if any small spark generates and oxygen is available. The chances of spark are also there due to current flow in windings. Any loose joints, or faults inside the power transformers generate sparks. Any abnormality in power transformer not noticed in time lead to power transformer failure, but when such abnormalities are converted into fire of power transformers, it affects the power system utilities. In such case, restoration of power supply becomes second priority to douse the fire first, and in many cases dousing the fire also becomes second priority, first-priority to prevent healthy equipment. Power Transformer main tank is filled with oil and in service oil gets heated and oil immersed paper is ready to catch fire, if small spark and oxygen available. If power transformer catches fire, it is quite difficult to douse the fire and for that utilities must switch of the healthy part of sub-station. If first line of protection operates correctly, there is less chance of fire. In this paper few

case studies of power transformers fire incident are carefully analyzed and root cause analysis of each incident is derived as a lesson from failure. To prevent fire incident what type of action is required by power utilities are also discussed in this paper.

2.0 Introduction

2.1 The **fire triangle** or **combustion triangle** is a simple model for understanding the necessary ingredients for most fires. The triangle illustrates the three elements a fire needs to ignite: heat, fuel, and oxygen. A fire naturally occurs when the elements are present and combined in the right mixture. As per Fire triangle all three ingredients required are available in power transformer.



Figure:1 Fire Triangle

2.2 A fire can be prevented or extinguished by removing any one of the elements in the fire triangle. For example, covering a fire with a fire blanket blocks oxygen can extinguish a fire. In large fires where firefighters are called in, decreasing the amount of oxygen is not usually an option because there is no effective way to make that, however in power transformer in tank fire blanket can be created by way of injecting nitrogen gas from bottom of the transformer, and by way of water jet can be removed to douse the fire.

3. Prevention of fire -Power Transformer

Power Transformers are designed to withstand terminal fault as well as capable of delivered its full load current capacity in any atmospheric condition. First of all, we discuss about fire, oil used in power transformers are generally have flash points more than 150°C, it means oil catch fire if it gets that much temperature, not only that oxygen is required for continuation of fire. In power transformer there is no oxygen available in main tank. At the time of fault inside the main tank if protection operates correctly, then also no sufficient energy available for power transformer to catch the fire. For fire of power transformer followings are the reasons

- Bushing failure
- Excessive terminal short circuit
- Fault cannot be identified by protection system timely

- Hot glow on outside of transformer not attained timely
- Heavy fault inside the transformer resulting bursting of main tank
- Constant overload and temperature, monitoring system will not work
- Direct lightning stroke on transformer
- Cooling circuit issue
- Failure of fire prevention system

Due to any above reasons, power transformer can catch the fire. At present mostly two types of fire prevention systems are used in sub-station.

4. Water Sprinkle System

In this system high pressure water pipeline surrounding power transformer arrange in such a manner that at the time of fire water jet spray to all over the power transformer



Figure:2 Water Sprinkling System



Figure:3 Water Sprinkling System in operation

5.0 NIFPS

In this system at the time of fire in transformer, NIFPS system operates, and top oil of main tank is drained to storage tank and

high-pressure nitrogen gas is injected from bottom. Hence nitrogen blanket is created in top and fire is quenched. NIFPS arrangement is shown below.

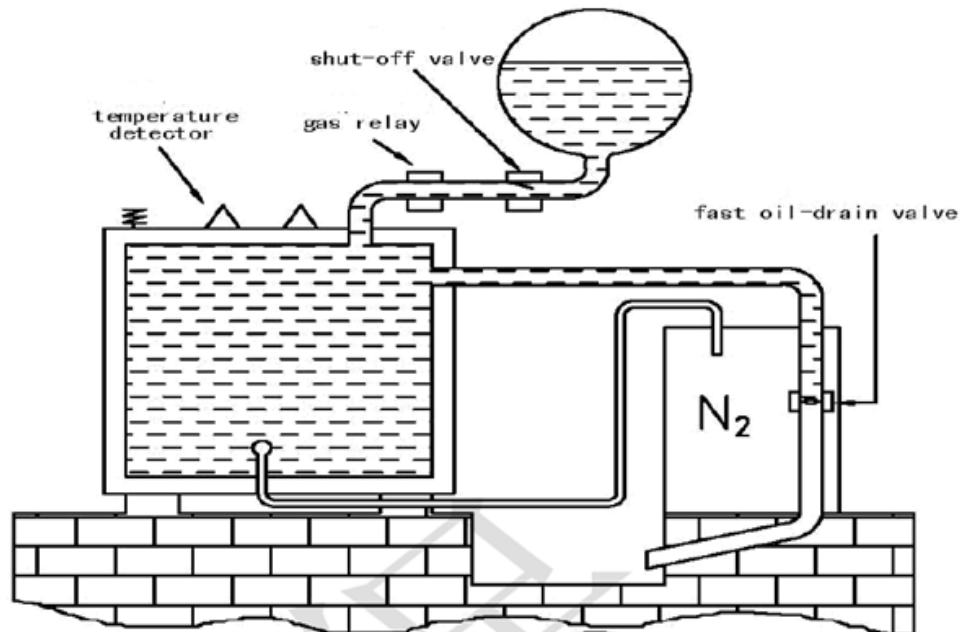


Figure:4 NIFPS lay out

6.0 Field Case Study

Now in this section we will discuss various case studies of fire in transformer.

6.1 Case-Study 1 – Issue in cooling circuit

- At 220KV Substation, on 09-04-2021 at 15:43 Hrs.; 100MVA, 220/66kV transformer No.2 tripped with heavy blast. The Transformer caught fire. As per observation by the substation staff, the fire was initiated from LV Side of the Transformer. The fire was quite big, and in no time, it was spread to HV side of the Transformer. Control cables of the adjacent Transformer i.e. 100MVA, 220/66kV transformer No.4 were damaged during the Incident. Therefore, it tripped on Differential Protection.

Due to heavy flames and fumes, flashover took place on flyover strings of LV Side gantry of 220/66kV transformer No.2 leading to 66kV Bus fault.

Because of wind direction, R Phase Flyover Insulator string flashed over completely. Therefore, remaining 220/66kV Transformers i.e. 100MVA, 220/66kV Transformer No. 1 and 3 tripped from LV side. This resulted into zero power in the substation.

Fire fighters from Nagar Palika and ONGC reached within 30 to 40 minutes to control the fire. However, all parts of the transformer were damaged heavily due to the fire. All transformer parts including Bushings, Radiators, Conservator tank damaged badly due to the fire.

L2 portion of LV R Phase Bushing of 100MVA, 220/66kV transformer No.2 failed. The rectangle shaped Turret of the same bushing could not withstand the sudden pressure developed due to failure of the L2 part of the bushing. Its plate torn out from the welding joints, through which hot oil came out-initiating the fire.

Pre fault waveform and Data:

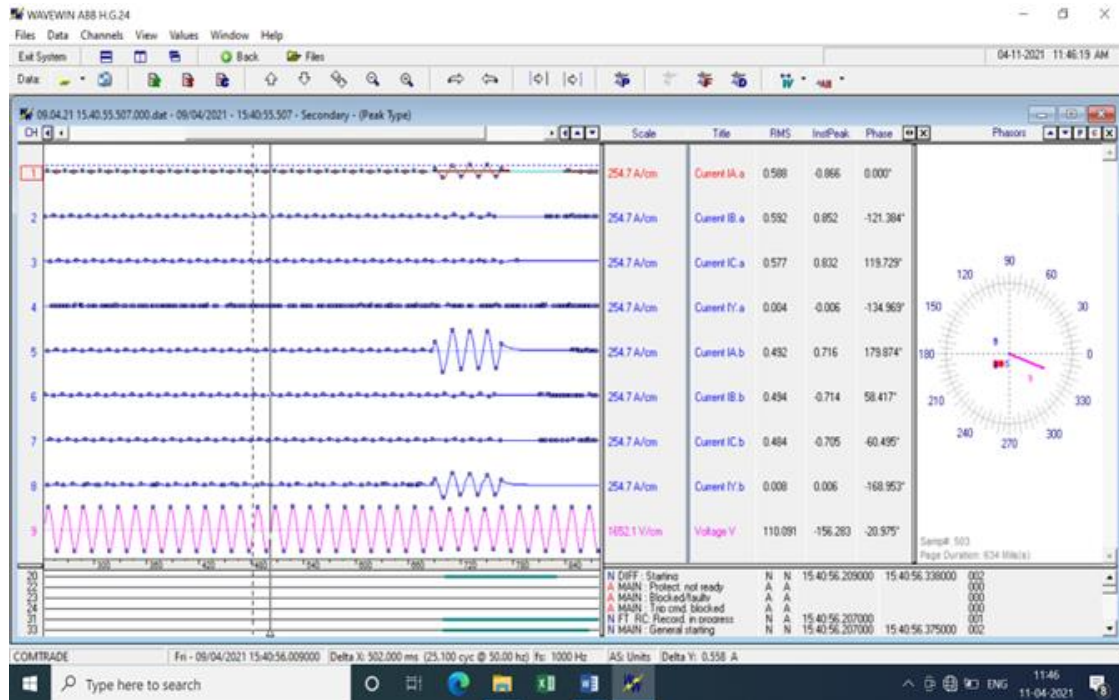


Figure:5 HV (220kV) side Current & Phase angle

R-phase -176.4 Amp with angle 0°
 Y-phase -177.6 Amp with angle 121.384°
 B-phase -173.1 Amp with angle 119.729°
 Here in pre fault data transformer HV and LV current shows normal in magnitude and phase angle and nothing abnormal observed. As this transformer, vector group is YNyn0

and ratio is 220/66, HV and LV current phasors were normal.

Fault Inception Point:

In below figure screenshot of DR is for point of fault start and fault current increase after onwards. It indicates fault start with high impedance

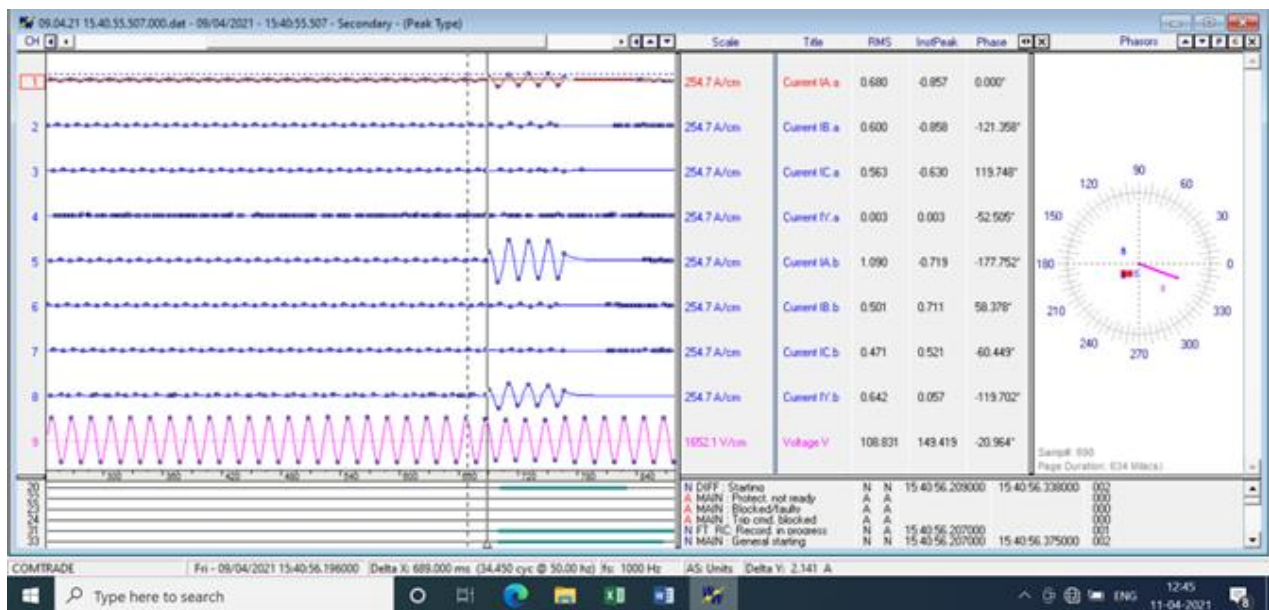


Figure:6 LV R-phase bushing failed at this moment



Figure:7 After Fire extinguished

Investigation

The detailed investigation revealed that the cooling fans of this transformer were not working. Therefore, the AN/AF system of cooling was working only AN. Due to increase in loading on transformer, the oil temperature shot up causing reduction in BDV value. This caused bursting of R phase 66kV bushing. Due to spark and pressurized oil exposed to oxygen there was fire. Suddenly the transformer was engulfed with fire and because of no control on the fire, the transformer burnt completely. NIFPS would have saved the transformer.

6.2 Case-Study-2

On 01-11-2019 at 12:45hrs, at 220kV S/S; suddenly fire took place in 100MVA, 220/66kV transformer No.2. Differential relay operated for same Transformer. HV Side breaker tripped, but LV Side breaker didn't trip due to issue in Master relay. First line of protection failed to operate and due to external flashover on bushing fault persisted for a long time and transformer caught fire. LV side fault currents persisted for around 450ms. Around, 16.7KA current was recorded for LV R phase. Fire was extinguished by fire fighter of Nagarpalika. From the inspection and study of DR, it was concluded that due to external flash over and primary protection failure, transformer caught the fire.



Fig:8
Transformer fire

It was observed that there was no damage inside the transformer and SFRA test confirmed that winding was intact. Only LV busing and HV Neutral bushings were

damaged. PRV, Marshalling box, Buchholz relay etc. also were damaged. The photograph taken after fire was extinguished is shown below.



Figure:9 After fire extinguished

Investigation: The detailed examination on top of transformer revealed that external flashover took place as bird carrying metal

part for its nest may have fallen on bushings as the HV, Neutral and LV R phase found damaged as shown



Fig:10 Damaged bushings

Transformer was put back to service after replacing all damaged parts as shown in below photo



Figure:11 Transformer put back into service

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FIRE SAFETY AND PREVENTION IN SUBSTATION EQUIPMENT: FOCUS ON INSTRUMENT TRANSFORMERS

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Abstract:

Fire safety in high-voltage substations is critical to ensuring the reliability and protection of electrical infrastructure. Instrument transformers, such as current transformers (CTs), voltage transformers (VT), play a vital role in power system operation but are also prone to failures that can lead to fire hazards. Factors like insulation breakdown, internal arcing, and thermal runaway can cause catastrophic failures if not properly managed. This article provides an overview of fire safety measures, failure prevention strategies, and protective mechanisms to mitigate fire risks in substation equipment, with a focus on instrument transformers. By implementing robust maintenance and protection protocols, substations can significantly reduce the likelihood of equipment failures and enhance operational safety.

Substations are essential elements in the transmission and distribution of electrical power, containing critical equipment such as transformers, circuit breakers, and lightning arrestors, capacitor banks, switchgear, Busbars and underground cables & terminations etc. The electric system provides the efficient and secure transmission of power over extensive networks. Although substations possess a sturdy architecture, they remain susceptible to fire hazards. Fires at substations can lead to disastrous outcomes, including extensive power outages, substantial equipment damage, and considerable safety risks for staff and surrounding people.

Preventing equipment failures that could

cause fire hazards is far more effective and desirable than dealing with the consequences of a fire after a fault has occurred. This proactive approach focuses on early detection, regular maintenance, and design improvements to minimize the risk of faults that could lead to fires, rather than relying on reactive measures once a fire has already broken out.

It is a multifaceted approach that combines design improvements, proactive monitoring, predictive maintenance, and strict operational procedures. By focusing on these areas, the risk of equipment failure and subsequent fire hazards can be significantly reduced, enhancing overall safety and reliability.

Modern technologies such as IoT-based monitoring, predictive analytics, and advanced protection systems play a crucial role in reducing fire risks, making electrical systems safer and more reliable in critical applications like substations and industrial facilities.

This presentation will examine the primary fire hazards associated with substation equipment and evaluate effective preventive and protective measures. The focus will be on critical equipment failures, with an emphasis on current transformers (CTs), inductive voltage transformers (IVTs). This article will also look at modern technologies that are revolutionizing fire safety standards in substations.

Principal Fire Hazards in Substations

Substations encounter several fire threats owing to the characteristics of the equipment and the high-voltage environment in which they function.

The primary risks include:

- **Combustible Materials:** Numerous substation components, especially transformers, employ flammable insulating fluids and paper insulation. In the occurrence of a defect or malfunction, these materials may ignite, resulting in extensive flames.
- **Electrical Faults:** Short circuits, insulation failures, and arcing in equipment can produce intense heat and sparks, heightening the fire hazard.
- **Aging Equipment:** Over time, insulation and internal components degrade, increasing the likelihood of faults.
- **External Factors:** Lightning strikes, animal interference, and vandalism can induce electrical faults or physically damage equipment, resulting in fire outbreaks.
- **Mechanical breakdowns:** Over time, substation equipment may endure overloading, overheating, and mechanical stress, leading to breakdowns and consequent fires.
- **Environmental Conditions:** Severe weather phenomena, like strong winds or lightning, can intensify fire hazards by affecting equipment.
- **Lack of Maintenance:** Poor maintenance can lead to unnoticed issues such as oil leaks, insulation deterioration, or improper connections, all of which can trigger failures.

Implications of Substation Fires

Substation fires can result in extensive and expensive repercussions:

- **Power Outages:** Fires may result in extensive blackouts, interrupting both residential and industrial power supplies, hence incurring substantial economic losses.
- **Equipment Damage:** Compromised equipment, such transformers or circuit

breakers, may necessitate costly repairs, resulting in prolonged downtimes and service disruptions.

- **Safety Hazards:** Fires provide significant dangers to personnel operating within the substation and may endanger adjacent populations, particularly if hazardous chemicals are implicated.
- **Environmental Impact:** The combustion of materials such as insulating oils can release toxic smoke and other harmful emissions, leading to environmental damage.

Significance of Fire Safety and Preventive Measures

Due to the significant risks involved, it is imperative to have a proactive strategy for fire safety in substations. A proficient fire prevention plan encompasses:

- **Fire Detection Systems:** Early warning mechanisms, including smoke and heat sensors, provide prompt identification of possible fires, permitting remedial steps prior to escalation.
- **Fire Suppression Systems:** Active fire suppression systems, including sprinklers and automated foam or gas extinguishing systems, assist in controlling and suppressing flames during their first phases.
- **Proactive Maintenance:** Routine inspections, testing, and upkeep of substation equipment are essential for detecting and alleviating possible fire hazards. Condition monitoring methods, such as thermal imaging, facilitate the detection of overheating components.
- **Fire-Resistant Design:** Employing fire-resistant materials, in conjunction with appropriate firewalls, firestops, and sufficient distance between oil-filled apparatus, can mitigate the danger of fire propagation and limit possible occurrences.

- **Workers Training:** It is essential that substation workers are proficient in fire safety standards and emergency response procedures. Consistent fire drills and evaluations of emergency protocols enhance preparedness.
- **Compliance with Standards and Regulations:** Adhering to recognized worldwide and local fire safety standards, including those set by IEC, IEEE, NFPA, and relevant regulatory authorities, guarantees alignment with optimal practices in fire prevention and management.

Advancements in Fire Prevention Technology

The fast progression of contemporary technology has introduced innovative instruments to improve fire safety in substations:

- **Thermal Imaging and Condition Monitoring:** Thermal cameras and condition monitoring systems detect abnormal temperature elevations in substation equipment, enabling operators to take preventive actions before a fire occurs. Advancements in this technology enable the comprehensive scanning of substations using infrared cameras and specialized software designed for this application.
- **AI-Enhanced Fire Detection Systems:** AI is being used to monitor substations for fire dangers and operational concerns. While acceptance is still maturing in India, advanced countries have widely used this technology. AI-powered monitoring systems can aid in the early detection of fire threats by utilizing real-time data processing, pattern recognition, and predictive maintenance models. These systems may combine data from a variety of sensors, including thermal imaging,

smoke detectors, and gas leak monitors, to detect early warning signals of a fire.

- **Remote Monitoring:** Substations situated in remote areas can implement remote monitoring and control systems that continuously evaluate substation conditions and enable the remote activation of fire suppression systems in emergencies. In India, GETCO is the leading utility utilizing a remote monitoring system, having automated over 50 substations, the majority of which are managed through remote monitoring. By mitigating these risks, substations can markedly diminish the danger of fire, therefore safeguarding both equipment and personnel. By employing proactive maintenance, fire-resistant design, modern technology, and rigorous compliance with fire safety requirements, substation operators may enhance safety while ensuring system dependability.

Focus on Instrument Transformers

High voltage substation equipment, including power transformers, instrument transformers, oil circuit breakers, capacitor banks, and lightning arresters, are prone to explosions and fires. Instrument transformers are the most sensitive component, and their failure can cause harm to surrounding equipment. The explosion may cause damage to the bushings of power transformers, potentially leading to a fire within the power transformer. Instrument transformers are widely used for measuring and protection purposes. These transformers are essentially hermetically sealed and have a normal operational lifespan of 25 years assuming no active component repairs or oil filtration are performed. Transformers that employ oil and paper as an insulating medium are more vulnerable to insulation failures, which can result in internal arcing and significant

damage.

Internal Arc

An internal arc is an electrical discharge that occurs within oil-filled electrical equipment, such as Instrument transformers, power transformers, oil- circuit breakers, and more due to a breakdown in insulation or a fault condition. Unlike external arcs, which occur in open air, internal arcs are confined within the equipment's enclosure, leading to intense heat, pressure, and other damaging effects like explosion.

The equipment are subjected to prolonged operational stresses, including electrical, thermal, and mechanical stress. Insulation degradation can occur over time as a result of various factors, including aging, moisture ingress, and overheating. This degradation may lead to a breakdown of internal insulation, which can subsequently result in arcing within the transformer. If this internal arc is not properly managed or contained, it can lead to explosions and fires and ejection of shrapnel which present substantial risks to personnel and equipment. It also causes environmental contamination, specifically from insulation oil.

The IEC 61869 standard, which regulates instrument transformers, incorporates the provisions for “Internal Arc Fault Testing” aimed at improving the safety and reliability of instrument transformer designs. This test confirms that the transformers are capable of efficiently handling the energy produced by an internal arc, thus minimizing the potential risks to personnel and adjacent equipment.

Internal Arc Testing Overview and Post-Test Evaluation

An internal arc test simulates severe fault conditions within electrical equipment, resulting in significant damage. This test is designed to assess the equipment's ability to contain the energy of an internal arc, without producing explosion and minimizing damage

to nearby equipment. During the test, equipment experiences extreme internal stresses, including explosive forces and intense heat.

Test Requirements and Criteria

The IEC 61869 standard outlines specific parameters for conducting the internal arc test. These include:

1. Arc Inception and Test Conditions:

- The arc is initiated by placing a conductive wire between the high-voltage and low-voltage shields at the location of maximum voltage stress. The power supply in the testing lab must be robust enough to maintain the fault current for the required test duration. When voltage is applied, a short-circuit current flows through the wire, creating a significant arc inside the equipment to simulate real fault conditions. The arc produces extensive heat and pressure inside the enclosure, and if it is not capable to withstand this effect the equipment may be damaged or explode.
- The normal locations of insertion of shorting wire.
 1. For dead- tank CTs- The location of failure is normally at the bottom of the main insulation.
 2. For Live-Tank CTs- The location is normally at top of main insulation.
 3. For Inductive Voltage Transformers- The location is normally at the bottom of the insulation.

2. Performance Variability:

- The performance of the equipment may vary depending on the location of the arc within the apparatus. If the arc occurs in a different part of the equipment during real-world operations, the behavior and performance might differ from the test conditions, indicating that the test is not

an absolute guarantee for all possible fault scenarios. The heat and the pressure can have different effects on the transformer, and its performance will be evaluated by the criteria given in the standard as below.

- **Performance Criteria for compliance of the requirement of the test:**
- Arc Fault Current to be specified by the users depending upon the power system.
- As per 61869-2023, the arc fault duration will be **0.3 seconds**.
- There are two classes specified, **Class 1A1 and 1A2**

For **Class 1A1**, requirement specifies that the “Fracture of the housing and fire is permitted, but all the projected parts to be confined within the prescribed reference area. Insulating paper or oil is not considered in projected parts.”

For **Class 1A2**, requirement specifies that “No fracture of the insulator or housing, except operation of suitable pressure release device. No lateral projection of harmful objects or fluids, no emission of burning liquids.”

- The prescribed reference area encircling the object under test shall be defined as limit for projected parts. The diameter of this area shall be equal to the transformer diameter (largest dimension) plus Twice the instrument transformer height including the pedestal, with minimum diameter of 2M. For example, 245kV CT or PT will have approximately 11 to 12M encircling diameter beyond which projected parts should not fly for compliance to Class 1A1.

According to the standards, (IEC 61869 for Instrument Transformers and IEC 62271-200 for switchgear), no electrical

tests are specified following an internal arc test as the internal parts get substantially burnt or damaged. The focus is instead on physical inspection as detailed above.

Importance of Design Parameters in IEC 61869 Internal Arc Testing

The standard focuses on evaluating the performance and limitations of equipment under fault conditions. It emphasizes the necessity of design parameters utilized during testing to ensure equipment reliability. Here are some significant aspects about the role of design parameters:

Internal Arc Testing Limitations: The standard specifies that internal arc testing demonstrates the equipment's ability to handle fault conditions under certain controlled scenarios. However, it explicitly states that this test is not a guarantee that the equipment will contain all possible short-circuit events created by insulation break down. The test provides insights into how the equipment performs under specific fault scenarios (e.g., arc location, fault current, and duration). If a fault occurs in a location different from the tested one, the performance may vary, meaning the test doesn't cover all potential real-world conditions.

Test Outcomes and Real-World Application:

The results of the internal arc test give confidence in the equipment's safety and performance, but they do not guarantee containment of faults in every possible scenario. The test confirms that the equipment meets a certain safety level under typical fault conditions.

This means that while the test demonstrates conformance to standard fault scenarios, it is not an absolute assurance of equipment behavior under all operational stresses or fault types. The test is a risk mitigation

measure, not a foolproof solution.

Adherence to Design Specifications used for test:

The equipment's real-world performance heavily relies on adhering to the specific design parameters that were used during testing. If the equipment deviates from the tested design (e.g. thinner walls, fewer stiffeners, or insufficient pressure relief), its ability to handle faults may be compromised. These include critical factors such as:

-Tank thickness: The structural integrity of the equipment housing must be strong enough to withstand internal pressure during an arc fault.

-Stiffeners and Fasteners: These components ensure that the structure remains intact under fault conditions and do not compromise safety by failing or coming loose.

-Pressure Release Devices: Proper pressure relief mechanisms allow for safe dissipation of excess pressure, preventing explosions or fires during a fault.

-Expansion Bellows: These components absorb the stresses from thermal expansion or pressure build-up, helping to contain the fault.

Thus, compliance with the design specifications is essential for maintaining equipment integrity during real-world operations, especially under unforeseen or more severe fault conditions than those tested. While IEC 61869 specifies internal arc testing as a special test rather than a necessary test, many utilities require this test from manufacturers as a design validation test before certification to supply.

Failure of instrument transformers at Site: Response and Assessment

When an internal arc failure occurs in the field, the primary concerns are safety and damage control. Immediate actions include evacuating personnel from the vicinity to

ensure no one is harmed by debris or fire and extinguishing the fire and ensuring that it does not spread to surrounding equipment.

After containment, a thorough damage assessment is essential. This includes evaluating the extent of equipment damage and planning for repair or replacement depending on the severity of the failure.

For instrument transformers (such as CTs and VTs), damage from internal arcing is often irreparable. Due to their relatively low cost and the extensive nature of damage typically incurred, it is generally more practical to replace them rather than attempt repairs.

In contrast, power transformers, which are more expensive and robust, may be repaired depending on the severity of the damage. Repairs are only feasible if the internal arc and fire are contained quickly enough to prevent significant damage to core components like windings, insulation, and bushings. The decision to repair or replace a power transformer depends heavily on how fast the fire was extinguished and the overall condition of the remaining components.

Thorough documentation of the incident is crucial. This includes:

-Recording the sequence of events leading up to the failure.

-Analyzing the extent of damage to understand the root cause and failure mechanisms.

-Investigating contributing factors such as operational conditions, maintenance records, and potential design flaws.

This article helps develop strategies for preventing future incidents, improving equipment design, and enhancing safety measures. Learning from these incidents through analysis and improving the design or maintenance practices can significantly

reduce the likelihood of similar failures in the future.

The causes of the internal arc failures can be shortlisted as under:

- **Insulation Failure:** aging of OIP insulation.
- **Mechanical Damage:** Physical impacts, vibration, improper handling.
- **Contamination** with moisture, dust.
- **Loose Connections:** Poor tightening, corrosion,
- **Overvoltage Conditions:** Lightning strikes, switching surges.
- **Manufacturing Defects:** Poor quality, inefficient processing etc.
- **Ferro-resonance** in IVTs because of interaction between non-linearity of magnetic core and system capacitances.

Damages and effects-

Thermal Effects: It generates extremely high temperatures (up to 20,000°C or more), melting and vapourising most of the components.

Pressure Effects: It creates a significant pressure increase within the enclosure that can cause rupture and explosion.

Light and Radiation: It emits ultraviolet (UV) and infrared (IR) radiation. And can cause damage to the eyes.

Electromagnetic Interference (EMI): It generates electromagnetic fields, which can interfere with electronic equipment and communication systems.

Chemical Effects: It can decompose insulating materials, releasing toxic and corrosive gases and posing risks to health.

Fire Hazards: It can ignite flammable materials, such as insulating oil, cable insulation, or other components causing fire.

Mechanical Damage: It can eject debris and shrapnel that damages other components, leading to fire.

Current and voltage surges: Arc can cause sudden surges that may damage relays, electronic components and circuits.

Detection of Internal Arcs:

Detecting electrical arcs, especially in high-voltage equipment, is crucial for preventing equipment damage, fire hazards, and ensuring personnel safety. Various methods have been developed to detect arcs effectively and quickly. Here are some common arc detection methods.

Optical Sensors: Optical detection involves using sensors to detect the intense light emitted by an arc. Since arcs produce bright flashes of light, including ultraviolet (UV) and visible light, this method can be very effective.

Arc Flash Relays: These devices use optical sensors to detect the light produced by an arc and quickly trigger protective actions, such as tripping a circuit breaker.

Acoustic Sensors: Internal arcs generate characteristic sounds, and acoustic sensors can detect these sounds to provide early warning of arcing. Ultrasonic detection is used to capture the high-frequency sounds generated by partial discharges and arcs, which are not audible to the human ear. These sensors are useful for detecting early signs of arcing and insulation breakdown.

Gas Sensors: Sensors that detect gases produced by arcing (such as ozone) can be used to monitor equipment for signs of internal arcing.

Thermal Detection: Infrared cameras or thermal sensors can detect the heat generated by internal arcs, helping to identify hot spots or fault conditions.

Electrical Monitoring: Monitoring changes in current, voltage, or harmonics can help detect arcing conditions and initiate protective actions.

Partial Discharge Detection: PDs are small-scale electrical discharges that occur due to insulation defects and can precede full arcing events. Detecting these discharges can provide early warning signs. Partial discharge sensors like HFCT can detect small

small discharges before they develop into full arcs.

Electromagnetic Detection: Arc events generate electromagnetic emissions across a wide range of frequencies, from radio frequencies to microwaves. Detecting these emissions can indicate the presence of an arc.

Radio Frequency (RF) Sensors: RF sensors can detect the electromagnetic emissions produced by arcing. These sensors can be installed near equipment or inside enclosures to continuously monitor for RF signals that indicate arcing.

Prevention and Mitigation

Regular Maintenance: Conduct routine inspections and maintenance to identify and rectify potential issues, such as insulation degradation, loose connections, or contamination.

Condition Monitoring: Implement condition monitoring techniques, such as partial discharge monitoring, thermal imaging, and dissolved gas analysis, to detect early signs of potential arcing conditions.

Proper Design and Quality Control: Ensure equipment is designed with adequate clearances, robust insulation, and high-quality components to minimize the risk of internal arcing.

Use of composite insulators: They are fire resistant with superior electrical and mechanical properties, that make them highly effective at preventing fire propagation and containing damage. Unlike porcelain insulators, which may shatter and scatter debris, composite insulators may deform but without breaking into dangerous fragments.

Training and Safety Protocols: Train personnel on the risks associated with internal arcs and establish safety protocols, such as lockout/tagout procedures and safe operating practices.

Conclusion:

Ensuring fire safety in high-voltage substations, particularly in relation to instrument transformers, is essential for the reliable operation of electrical systems as thousands of this equipment are deployed in the system. They are susceptible to failures that can lead to fire hazards if not properly maintained. By implementing robust inspection, monitoring, and protection measures, such as condition monitoring and insulation testing, surge protection, and fire suppression systems, the risks of internal arcing, overheating, and catastrophic failures can be significantly minimized. A proactive approach to maintenance and safety protocols ensures the long-term stability of substation operations, safeguarding both equipment and personnel.

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CAUSES AND MITIGATING MEASURES OF RISING FIRE INCIDENTS IN HOSPITALS

WAYS TO PREVENT FIRE ACCIDENTS IN HOSPITALS

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1. Introduction:

The hospitals have many Electrical, Mechanical & Pneumatic appliances and gadgets. Each one of them have standard operating procedure (SOP). However, due to passage of time or due to negligence maloperation may cause leading to fire and accident. Electrical short circuit is the most common cause of fire in hospitals.

When fire takes place, it becomes very difficult to evacuate the patients in a very short time.

The IS:732-1989 is reference to connections and joints of wires, conductors, terminal blocks, etc. It must be used instead of soldered or tape covered joints to avoid sparking.

The hospitals have many electrical, mechanical and pneumatic appliances and gadgets. Each one of them have Standard Operating Procedure (SOP). However, due to the passage of time or due to negligence mal operation may be caused leading to fire and accidents. Electrical short circuit is the most common cause of fire in hospitals. When Fire takes place, it becomes very difficult to evacuate the patients in very short time.

2. Preventive Measures:

Preventive measures to reduce fire risks in hospitals are different from the fire safety measures adopted in other places such as schools, office, and industries.

➤ A hospital has many combustible substances, chemicals, and gases, heat dissipating equipment, and electrical wiring, which can lead to a serious fire accident if appropriate safety measures are not observed.

- Ventilation is an important aspect of the hospital buildings and for any electrical installations.
- The NFPA-National Fire protection Association protocols are not followed failsafe and in letter and spirit, in Indian hospitals.
- Central AC system should replace the split and window ACs.
- Electrical wiring is not done professionally,
- The cylinder storage or O₂ control room should not be located near a car parking lot or in the basement. It should be at least 4 meters away from a parking area.
- Layout of electrical wiring should be performed by Govt. authorized professional and knowledgeable electricians.
- Connections made by twisting wires and wrapping insulating tapes (use terminal block connectors instead), haphazard layout, disregard of the color codes for electrical wires, are problems of training and attitude of staff, and should be avoided so as to prevent fire.
- An alternative (or emergency) exit door should exist for patients/persons in each room/ward, which preferably should be away from the usual exit. It is dangerous to violate this ground rule for a hospital or any public place.
- Awareness among hospital staff, doctors, and administrators must be created to encourage and ensure the failsafe compliances of statutory provisions regarding electrical supply system, NFPA protocols and other necessary allied measures.

- Recommendations for changes in system practice, which are in conformity with the National Fire Protection Association, are to be made applicable in preventing fires at hospitals and public places.
- The hospital management should ensure that their buildings are fire safe all the times.
- Every hospital must have well-planned exit ways and well-maintained fire lightning equipment to ward off the casualties and damage to assets.
- Hospitals stack a lot of combustible materials like chemicals, cylinders, surgical equipment, etc. in lots of cases, in basements when such space is available to hospitals. This practice must not be allowed.
- Adequate fire prevention methods must be designed and developed including the fixed evacuation points, regular maintenance of fire equipment and electrical equipment must be ensured to prevent a fire hazard.
- Every member of the hospital must be aware of a well-charted and detailed action plan which everyone needs to follow in case of a fire breakout. Fire drills must be carried out on a regular basis to make sure that hospital staff including doctors must know how to respond during emergency situations.
- Fire detection is the first step towards preventing fire hazards. Hospitals must have fire detection equipment such as heat detector, smoke detector, fire gas detector, flame detector, etc., installed at important locations. Not only the installation of fire detection equipment is essential, it must also be ensured that these devices are working properly by checking them on a periodical basis.
- Hospitals can seek help from professional bodies for conducting fire safety audits to make sure that the adequate fire prevention measures are observed in the hospital. If the authority recommends any changes, it should be implemented diligently.
- Faulty wiring systems can be a cause of fire outbreak. To prevent fires from electrical equipment, maintenance must be carried out at least once in a month and other electrical equipment that can lead to fire hazard must also be properly maintained.

3. Conclusion:

- Fire in hospital may cause heavy loss of equipment, property and human lives.
- Proper mitigation plan and preventive maintenance is important for avoiding fire.



Hospital equipped with Fire



Exit sign must be in Hospital



Smoke detector



Fire Staff uses Hydrant



Fire extinguisher



Various Signs in Hospital



Technical & Marketing Partners



NASA has more than 40 years of experience in technological development in Fire Prevention and Maintenance of a given new green field project; be it Industrial, Commercial or residential in nature. Over last 2 decades, as an obvious extension, it has brought innovations in Fire Extinguishers for all class of Fire (particularly Class A – Solid – Coal, Rubber Wood, Polymers and others). This is made possible with patented fire extinguishing media and offers solution with it getting reignited (for a longer duration). NASA has Clean agent technology, which offers Safety not only to human lives but also to valuable assets, like; Data Centers, Electrical and Instrumentation Panel & its housing, highly expensive equipments in Pharma and Healthcare segments.

NASA was pioneer to make Fire Extinguishers of Stainless Steel body and with patented design of valves, allows it to make unique offering of 10 years straight life without any maintenance and life-long Reliability and Durability.



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UPL is India's oldest & largest manufacturer of Agri-Chemicals. It is also a largest manufacturer of DB [Denatonium Benzoate], bitter most Chemical for repelling (importantly; not killing them) Rodents and Termites, for preventing fires initiated from short circuits in Wires and Cable industry.

UPL also Flame Retardant [FR], primarily for Technical Textiles and Wires & Cable Industry and Defense, which is Phosphorous and Nitrogen based formulations. This is by-far safest and most effective and improved version of new generation FR, as it does not emit Halogens and smoke (which lowers visibility in case of fire and release poisonous CO), making it absolutely safe in case of any fires.

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THE ADVANTAGES OF NASA FIRE TECHNOLOGY LIMITED'S SOLUTIONS OVER TRADITIONAL FIRE EXTINGUISHERS

Shri Pratik Trivedi

Shaligram Associates, Mumbai

Introduction:

In the realm of fire safety, the choice of extinguishing equipment can mean the difference between a minor incident and a catastrophic event. Traditional fire extinguishers have long been the standard in fire suppression, but as fire hazards evolve, so too must our approaches to fire safety. NASA Fire Technology Limited is at the forefront of this evolution, offering advanced fire extinguishers and suppression systems that significantly outperform traditional models. This article explores the distinct advantages of NASA's products over conventional fire extinguishers, highlighting their effectiveness, safety, environmental impact, and overall value.

Clean Agent Technology: A Paradigm Shift

One of the most significant advancements in NASA's product line is their emphasis on clean agent technology, particularly the use of HFC 236FA. This innovative solution effectively replaces traditional Dry Chemical Powder (DCP) and Carbon Dioxide (CO₂) extinguishers, providing an environmentally friendly option that is safe for both users and their surroundings. Clean agents work on all classes of fire and are particularly suitable for indoor applications, as stated in IS 2190. Their non-destructive nature makes them ideal for use in sensitive environments, especially for CLASS A fires including sensitive areas as Data Centres & Instrument & Electrical Control panels, Hospitals, Commercial Offices, Schools & Colleges, Airports & Institutions and high-value manufacturing areas.

Addressing Class A Fire Challenges

Recent studies conducted by NASA revealed alarming trends in Class A fires, particularly in settings featuring synthetic polymers commonly found in modern furniture and construction materials. The rapid spread of flames, combined with the production of toxic black smoke, poses significant risks to life and property. Traditional extinguishing agents—DCP, CO₂, and even clean agents—have shown limitations in controlling these high-temperature fires.

In response, NASA has developed an innovative silicate-based fire extinguisher specifically designed to tackle the unique challenges presented by Class A fires. This advanced formulation can extinguish flames reaching temperatures of up to 1100°C, effectively combating coal and other combustible materials. Additionally, the silicate composition helps reduce toxic smoke production and mitigates the risk of reignition, enhancing overall safety.

Let's have a look at the basic advantages of NASA Fire Safety Products over conventional products

1. Advanced Materials and Design - - - Stainless Steel Construction

Pros:

- **Durability:** NASA's fire extinguishers are made from high-grade Stainless-Steel SS 304, which offers superior resistance to corrosion and wear. In contrast, traditional extinguishers, often constructed from mild steel or aluminium, can degrade over time, especially in harsh environments.
- **Maintenance-Free Design:** NASA's unique SS 304 valve technology ensures

leak-proof performance, making their extinguishers virtually maintenance-free. Traditional extinguishers typically require regular inspections and maintenance to ensure functionality, adding to their overall lifecycle costs.

2. Clean Agent Technology - - - HFC 236FA

Pros:

- **Environmentally Friendly:** NASA's clean agent extinguishers utilize HFC 236FA, a compound that does not deplete the ozone layer. Traditional extinguishers, particularly those using Halon or CO₂, can have detrimental environmental impacts.
- **Non-Destructive:** Unlike conventional extinguishers that often leave residue (e.g., Dry Chemical Powder or CO₂), clean agents do not damage sensitive equipment. This makes NASA's products particularly suitable for environments like data centres and hospitals, where equipment integrity is critical.

3. Comprehensive Fire Class Coverage - - - Multi-Class Efficacy

Pros:

- **Versatile Applications:** NASA's clean agent technology is effective on all classes of fire (A, B, C, and more), providing a one-size-fits-all solution. Traditional extinguishers often require multiple types to cover different fire classes, which can complicate safety planning and inventory management.
- **Specialized Solutions for Class A Fires:** With the introduction of silicate-based extinguishers, NASA specifically addresses the challenges posed by high-temperature Class A fires. Traditional extinguishers may struggle to suppress these intense fires effectively, particularly in environments with modern synthetic materials.

4. Enhanced Safety Features - - - Linear Heat Sensing Tube System

Pros:

- **Automatic Fire Detection and Suppression:** NASA's Linear Heat Sensing Tube suppression system automatically detects and extinguishes fires in live electrical environments, eliminating the risks associated with manually operated extinguishers. Traditional systems require human intervention, which may lead to delays in response times.
- **Live Environment Compatibility:** This system is specifically designed for use in electrical panels and server racks, where traditional extinguishers can pose safety hazards. The automatic nature of NASA's system minimizes the risk of electrical shock or damage.

5. Long Shelf Life and Reliability - - - Extended Durability

Pros:

- **Ten-Year Shelf Life:** NASA extinguishers come with a shelf life of up to ten years, significantly longer than many traditional models that may require more frequent replacements. This not only enhances reliability but also reduces long-term costs for organizations.
- **Consistent Performance:** With NASA's emphasis on high-quality materials and advanced technology, users can trust that their fire safety equipment will perform when needed most. Traditional extinguishers may degrade in performance over time, leading to potential failures during critical moments.

6. Reduced Environmental Impact - - - Sustainable Solutions

Pros:

- **Eco-Friendly Alternatives:** The clean agent technology and silicate-based

formulations developed by NASA are designed with sustainability in mind. Traditional fire extinguishers, particularly those using older chemical agents, can contribute to environmental damage and require careful disposal methods.

- **Less Toxicity:** NASA's products produce less toxic smoke during combustion, ensuring a safer environment for occupants and first responders. In contrast, traditional extinguishing agents can release harmful substances, posing additional risks during a fire incident.

7. Cost-Effectiveness - - - Long-Term Value

Pros:

- **Lower Total Cost of Ownership:** While the initial investment in NASA's advanced fire extinguishers may be higher, their durability, maintenance-free design, and extended shelf-life result in lower total ownership costs over time. Traditional extinguishers often incur higher maintenance and replacement costs.
- **Insurance Benefits:** The use of advanced fire suppression systems can lead to lower insurance premiums, as insurers recognize the reduced risk associated with high-quality fire safety equipment. Organizations using traditional extinguishers may not benefit from such incentives.

Conclusion

NASA Fire Technology Limited's innovative approach to fire safety represents a significant advancement over traditional fire extinguishers. With a focus on durable materials, clean agent technology, enhanced safety features, and long-term value, NASA's products are tailored to meet the modern challenges posed by fire hazards. As industries and organizations prioritize safety, investing in advanced fire suppression solutions becomes not just a necessity but a strategic imperative.

By choosing NASA Fire Technology Limited, businesses can ensure that they are equipped with the most effective, reliable, and environmentally friendly fire protection systems available, safeguarding lives and property in an increasingly complex fire risk landscape.

About the Author



Shri Pratik Trivedi, an MBA with over 8 years of experience in senior management at NASA Fire Technology Limited, is dedicated to advancing fire

safety solutions. With a mission to make fire safety products more reliable and modern, Pratik focuses on developing innovations that not only perform effectively but also require minimal maintenance, ensuring safety and convenience for users. His leadership has been instrumental in shaping the company's vision for cutting-edge fire protection technology.

TACTICAL VENTILLATION FOR MITIGATING FIRE HAZARDS

Er. SS Mishra

Fire Officer, GUVNL, Vadodara

1.0 Introduction

1.1

As we all know that a major cause of deaths in fire is from hot toxic smoke rather than from the fire itself. Hence, control and removal of the smoke from the building is one of the vital components in any fire protection system. One traditional approach is to create openings in the roof or walls of the building to allow hot gases and smoke to escape, which helps to improve visibility and reduce the risk of flashover. But such method can sometimes be inadequate. We may require a system that using more positive and readily controlled fan powered units. Let us understand the various tactical methods that can be employed to mitigate corrosive & toxic smoke cloud creation due to fire.

Ventilation can be defined as the removal of heated air, smoke and other airborne contaminants from a structure, and their replacement with a supply of fresh air. Self-ventilation occurs when fire damages the structure so that increased ventilation occurs. Automatic ventilation occurs when pre-installed vents are activated automatically, usually in the early stages of fire, by the fire detection system or fusible link devices.

Tactical Ventilation, on the other hand, requires the intervention by the fire service to open the building, releasing the products of combustion and allowing fresh air to enter. It can be used as a tactical option during firefighting.

Ventilation, if properly used, has significant benefit. These are

1. Restricting the spread of smoke on

escape.

2. Improving visibility.
3. Aid to rescue operations by reducing the smoke and toxic gases which hinder search activities.
4. Reducing risk of flashover and making it easier to control back draught.
5. Speed up attack and extinguishment by removing heat; and
6. Reduce property damage where the fire can be located and tackled more quickly and limiting the movement of smoke and hot gases, restrict fire spread.

The basic principles in commencing ventilation are as under:

1. Identify the purpose of ventilation. Determine whether the approach is to offensive or defensive.
2. Ensure effective communication between fire fighters
3. Identify the wind direction
4. Decide whether to adopt vertical or horizontal ventilation
5. Properly select the locations of the inlet and outlet vents
6. Arrange for outlet vents to be covered by manned charged hose lines
7. Decide whether firefighters inside the building need to be withdrawn whilst ventilation takes place
8. Notify all concerned of the intention to start ventilation
9. Make outlet vent first
10. If the inlet is also the firefighter's point of access, no further action may be necessary
11. If being used, start up the PPV/NPV fan.

There are various techniques for tactical ventilation. These are

1. **Vertical or top ventilation:** It is performed by making an opening at high level, (usually through the roof) such that the buoyancy of the hot gases and smoke enables them to escape vertically.
2. **Horizontal or cross ventilation:** It is performed by making openings in the external walls like windows and doors so that the wind assists in the removal of the hot gases and smoke.
3. **Natural ventilation:** It is like forced ventilation when mechanical means are **not** used to assist in removing the hot gases and smoke. This includes the use of pre-installed vents, windows, doors etc.
4. **Forced ventilation:** It is collectively the techniques of the vertical and horizontal ventilation when mechanical means are used to assist in removing the hot gases and smoke, or in proving
5. **Offensive ventilation:** When ventilation is performed close to the fire to have a direct effect on the fire itself, to limit fire spread, and to make conditions safer for fire fighters.
6. **Defensive Ventilation:** When ventilation is performed away from the fire, or fire is out, to have an effect on the hot gases and smoke, particularly to improve access and escape routes and to control smoke movement to areas of the building not involved in the fire.
7. **Positive Pressure Ventilation (PPV):** It is performed by forcing air into a building using a fan. The effect of this will be increase the pressure inside, relative to atmospheric pressure. It simply refers to blowing air in through the inlet vent. It can be used as offensive or defensive method. PPV defensive method can be used to clear smoke rapidly and cooling the workplace. PPV as an offensive method is suitable for domestic premises, stairwells, corridors, cellars, small workshops and stores etc.

8. **Negative Pressure Ventilation (NPV):** It is performed by extracting the smoke and hot gases from the outlet vent. This will have the effect of reducing the pressure inside the building, relative to the atmospheric pressure. It can be achieved by fans or water sprays.

The calculations of mass of smoke generation, smoke temperature, and heat production from a burning material are of vital importance in the process of ventilation. Its proper calculation would assist in designing of ventilating system and to perform ventilation process in a proper manner. The following are some of the general guidelines with equations found helpful in calculation during the process of tactical ventilation.

The quantity of smoke produced by a fire depends on three factors:

1. The perimeter of the fire
2. The temperature of the flames in the plume
3. The effective height of the column of hot gases above the fire.

Amongst the above three factors smoke production only varies with the square root of the absolute temperature of the fire and, under the large fire theory, is much less important.

The two most important factors are the perimeter of the fire and the effective height of the smoke column. These two factors affect the smoke production linearly and to the power of 1.5 respectively.

If we assume a flame temperature of 800°C and an ambient air temperature at 17°C (density 1.22 kg/M³), production of smoke from a fire can be obtained by simple expression

$$M = 0.19 P Y^{1.5}$$

where,

M= Mass of smoke produced in kg/sec.

P= Perimeter of the fire in meter

Y= Height of the smoke layers in meters

The temperature of the smoke can be calculated by using formula

$$\Theta = Q_s / M$$

where,

Θ = Temp. of the smoke in °C above ambient

Q_s = Heat carried by the smoke in kilowatt

M = Mass of smoke production in kg/sec.

The total heat output of a fire (Θ_f) can be established by:

$$\Theta_f = \text{Burning rate} \times \text{Fire Area}$$

(kW) kW/M² (M²)

The burning rate depends on materials involved in fire. For retail shop or factory premises it would be 500 kW/M². In office, a maximum burning rate of 230 kW/M² can be taken as an average rate.

We, generally, require to express the smoke production in M³/ sec. The equation for calculating smoke in M³/ sec is

$$V = \frac{M (T_s + 273)}{1.22 \times (T_a + 273)}$$

where,

T_a = ambient temperature +27°C

T_s = Temperature in smoke = (Θ + 27)°C

The above equation becomes

$$V = \frac{M (\Theta + 300)}{366}$$

where,

V = Vol. of smoke in M³/sec.

Θ = Temperature of smoke in °C

M = Mass of smoke in kg/sec.

It should be noted that the proper usage of the above formula is of utmost important. If the ventilation is performed incorrectly, it can initiate back draughts, and cause fire spread and place firefighters at risk.



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He has 30 years' experience in handling Fire Service.

Worked as a Fire-Safety Auditor for all GSECL Power Stations.

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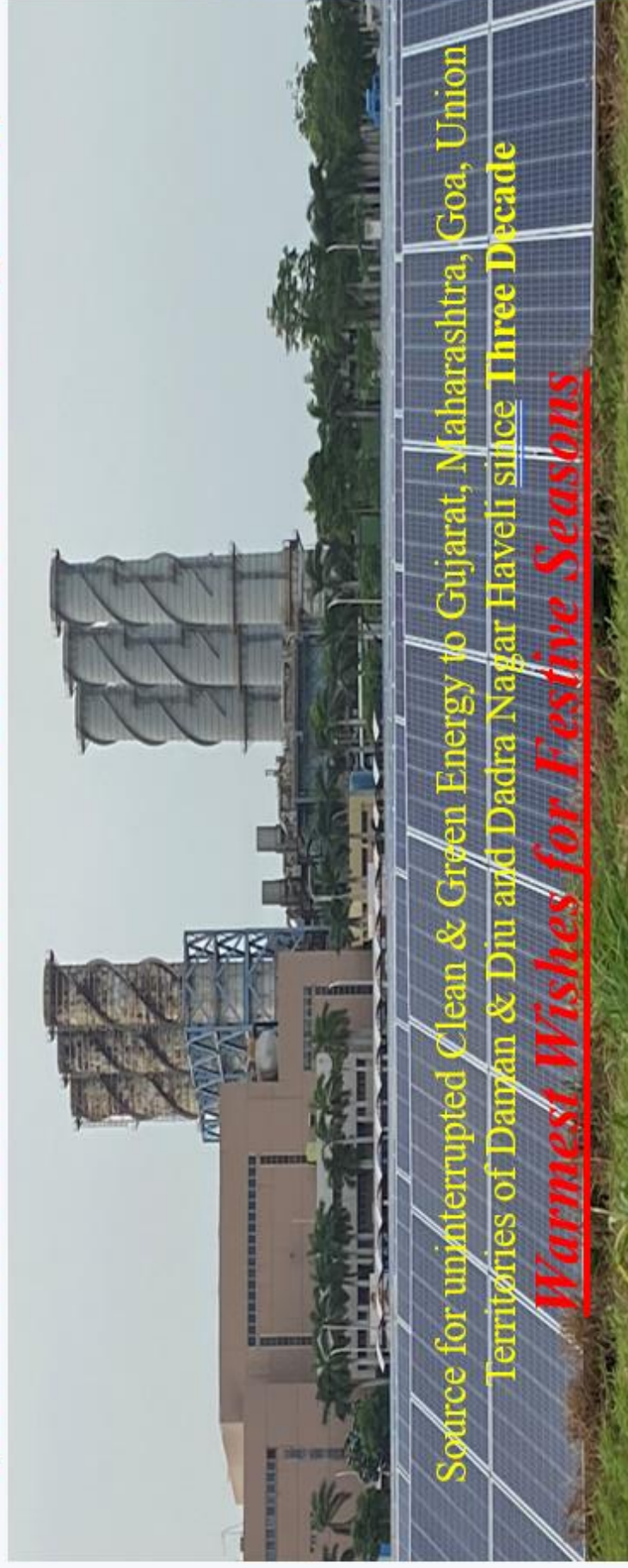
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LESSONS LEARNT FROM ELECTRICAL FIRE INCIDENTS

Er. Hemendra Raval, BE(Mech.)

Industrial Health, Safety, Environment, Quality, Fire & Hygiene
Management and Engineering Consultant

1. Introduction

Industrial Safety is defined worldwide as Accident Prevention, Freedom from Hazards and Managing Risk. Recent trend expresses it as Sustainability. Total Loss Prevention and Oxy richness as well. In recent years safety and security are being given equal priority in every walk of life.

2. Accident and Associated Risks:

As we know, Accident is undesired, unexpected, unplanned, unintended and sudden event. It is equated as human + Hazard. Technically, it is energy exchange beyond the threshold limit of a system. 10 kW/m² energy exchange can kill a man. Accident is unusual occurrence having not acceptable risk. It is also described as unusual occurrence that result in bodily injury in the course of and out of course of employment. According to ISO: 45001-2018, it is unusual occurrence resulting in bodily injury and illness.

Accident potential is termed as Hazard. It is a qualitative term and being inherent part of human life exists everywhere and every time. It can never be zero. Our all efforts are to tends to make it zero. Potential, Aspect, Cause, Reason etc. are synonyms of Hazard. Risk is likelihood of an accident. It is a qualitative term and mathematically multiplication of probability of accident of the severity of it. Likelihood, Probability, Severity, Consequence, Result, Effect, Harm, Impact are some synonyms of Risk.

3. Fire:

Fire, physically a combustion and chemically an oxidation, usually used for destructive effects. It is high time to go beyond the Fire Triangle with the advancement of science

and technology. According to me it is Fire Pentagon having five fire elements namely- Fuel in flammable range, Minimum Oxygen Concentration, Minimum Ignition Energy, Chain Reaction and Catalyst. The basic five fire extinction methods are Starvation, Smothering, De-energization, Breaking chain reaction and Inhibition. Now, this updated classical fire pentagon can well explain Fire Prevention, Protection and Fighting. Fire is surface phenomena. Higher the surface area, higher the hazards. Gaseous phase is the most hazardous, liquid more hazardous and solid is the least hazardous.

The Author has witnessed many accidents, for some of them the author got opportunity to investigate. Lessons learnt from such electrical accidents are briefed and tabulated below:

4. Case Studies

Various case studies related to Power Sector and Industries are described below: The case wise Event, Root Cause, Corrective And Preventive Action – CAPA and Lesson Learnt are as under:

4.1 Event: At a Power Plant, 6 MW Turbine rotor damaged the body and flew in air damaging ceiling with flash fire. There was no personal injury. But the power plant remained shut for a few days. I was working with drawing & Design department at that time.

Root Cause: A small, imported part was not readily available and hence the Power Engineer fabricated and fitted that part to the Turbine to avoid shut down.

Corrective And Preventive Action - CAPA
The part was imported and replaced.

Further, few months later, the Power Engineer was terminated from the job

Lesson Learnt: (a) Interchangeability of critical machinery parts should be thoroughly studied, and no short cuts should be allowed. (b) Accountability should be set for any accident, not to blame someone but to set an example.

4.2 Event: FRP shed of a few metres (~50-60m) length was burnt out with a rocket rapid flame at GIDC, Halol. Welding work was on at one end of the shed. Permit was issued

Root Cause: Welding spark reached the shed ignited FRP. It was not known that FRP is combustible.

CORRECTIVE AND PREVENTIVE ACTION - CAPA:

- (a) A new shed of non-combustible material was fabricated.
- (b) The Welder was cautioned.
- (c) Risk should be thoroughly assessed while issuing Permit.

Lesson Learnt:

- While hot work permit issue, risk should be assessed thoroughly. Properties of nearby materials should be verified.
- FRP is burning at a rapid speed. Burning Rate parameter should be taken in account.

(The incident was investigated by Author. Later, the Author also witnessed similar Fire at a chemical giant at Dahej resulting in stoppage of plant for few months. The Author shared my earlier experience there also)

4.2 Event: Fire at Hotel Taj after terrorist attack

Root Cause: Short circuits and fire of combustibles due to bullets firing.

CORRECTIVE AND PREVENTIVE ACTION - CAPA: The part was replaced. Emergency evacuation was explained with HAZCHEM code.

Lesson Learnt: - Consider Classical Fire Pentagon (Polygons). The Author was involved in post-reactive activities to the event. The Author proposed classical fire pentagon to overcome old fire triangle. The Author also designed a short-term Fire Prevention and Industrial Safety course for NIOS through NFA.

4.4 Event: Takshsheela Fire at Surat due to short circuit by overloading. There were approximately 27 fatalities in the Fire.

Root Cause: Short circuit, Power overloading, combustible construction wood, Curtains and paper boards. No fire NOC. Terrace with only one wooden access.

CORRECTIVE AND PREVENTIVE ACTION - CAPA:

Strengthened Fire Brigade. 100 x 16 batches trainings were conducted of fire marshals. More fire stations (two out of four proposed) were developed and Corrective and Preventive Action - CAPAbility improvement was made.

Lesson Learnt: Proactive approach rather than reactive approach for fire. Design safety should be taken in account. NBC provisions should be ensured.

4.5 Event: Patel Welfare Hospital Fire, Bharuch. At corona time, the patients were on ventilators. The ventilators were hot due to overloading. One patient was being treated by a Nurse, meanwhile there was sparking from the ventilator igniting back of apron of the Nurse. Patients tried to save themselves by removing oxygen mask that accelerated the fire. About 23 fatalities were there. Only one Nurse survived due to not having panicky and running. The entire hospital was burnt to ashes

Root Cause: Short circuit of overloaded ventilator and oxygen accelerated the fire.

Corrective And Preventive Action - Capa: Oxygen behavior should be well

well understood by workers and fire professionals.

Lesson Learnt Oxygen accelerates Fire.

- Oxygen deficient and oxygen rich both environment are harmful for worker. Confinement space entry and air/oxygen cylinder should be clearly understood.
- Hospital and fire professional should be trained for such emergency.
- Fire lift is must for multistoried hospitals.
- Similarly, Oxygen release at Nashik Hospital and Vadnagar Hospital cases happened.

4.6 Event: A pesticides manufacturing factory at Panoli, experienced series of panel fires intermittently in a year. All fires were typically same and in circuit breaker. As a part of Safety Audit, RCA was assigned to the Author. Author coopted retired electrical engineer from State Electricity Board, retired Chief Electrical Engineer from Refinery who spent his career in investigating electrical accidents and one electrician who worked with the Authro during my industrial working tenure.

Root Cause: The contact metal parts of circuit breaker was of same material and of copper. Initial doubt was faulty grounding system which was not the case.

Corrective And Preventive Action -

CAPA: The contact metal parts were changed to two different alloy material other than copper. This problem is solved lifetime and the solution was given by the technician made.

Lesson Learnt:

- Electrical contacting metals should be different and alloyed.
- The Author's investment in highly qualified and rich experienced person was wasted and the same was cropped up by the technician. Skill is more important.

4.7 Event: Platform Fires at Bombay High

due to static/short circuits. People were not capable to extinguish the fires. Russian fire brigade was called many times before 2014.

Root Cause: They were using fire water jet which was becoming violent.

Corrective And Preventive Action -

CAPA: Fire water jet application was changed to use of Fire water fog.

Lesson Learnt:

- Understanding fire flame well as well as its behavior specific to fire extinction medium. HAZCHEM code was more clarified and understood well. OISD and API guidelines.
- Then training were imparted to Refinery Engineers from all over India. LPG and Oil terminal professionals and the same was cropped up by the technician. Skill is more important.

4.8 Event: Building Fire at Andheri, Mumbai. Chopper was called for firemen rescue. One fire fighter was rescued, and another killed.

Root Cause: Short circuit. Fire fighters ran faster to climb building floor. Dense smoke killed fireman.

Corrective And Preventive Action -

CAPA: People including fire fighters, should be made aware of not to run in emergency, walk fast.

Lesson Learnt:

- Halogen free fire-retardant cables should be used with porcelain cover. NBC & GFPLSMA provisions. HAZCHEM code awareness.
- All fire professionals from Western India were invited at Vadodara to attend specific training.

4.9 Event: Methanol fire in glass line reactor column followed with explosion damaging the reactor at GIDC, Ankleshwar

Root Cause: Short circuit. Fire fighters ran faster to climb building floor. Dense smoke

killed fireman.

Corrective And Preventive Action -

CAPA: People including fire fighters, should be made aware of not to run in emergency, walk fast.

Lesson Learnt:

- Halogen free fire-retardant cables should be used with porcelain cover. NBC & GFPLSMA provisions. HAZCHEM code awareness.
- All fire professionals from Western India were invited at Vadodara to attend specific training.

4.10 Event: Aero plane collision fire on airport.

Root Cause: Static voltage due to friction.

Corrective And Preventive Action -

CAPA: Air traffic control at airport.

Lesson Learnt:

Besides dissipation of static charge (voltage) in the aero-plane body, the static charge should be discharged outside fuel (metal and aviation fuel both) flammable range. Static discharge probes should be provided on aircraft. Shock absorber should be provided wherever possible.

4.11 Event: Flash fire at control room of mobile phone towers. The fire was suppressed by clean agent automatically without evacuating personnel.

Root Cause: Sparking observed in electrical fixture.

CORRECTIVE AND PREVENTIVE ACTION - CAPA: All control rooms and electrical/electronic rooms should be protected with clean agent suppression.

Lesson Learnt:

Clean agent suppression is the most effective extinguisher for control rooms. If it is inhaled by personnel, there is no adverse health effect. This was experienced during safety Audit.

4.12 Event: Coal Mines Fire at Jharkhand.

Root Cause: Static charge / voltage due to excavator impact.

Corrective And Preventive Action -

CAPA: Dry Chemical Powder - DCP spray on coal mine wall prior to excavation. Fire trolley to carry burning coal outside mines.

Lesson Learnt:

There shall be proper spray of DCP. Learned while preparing training presentation to Tata coal miners.

About the Author



Er. Hemendra Raval is a Mechanical Engineer in Industrial Safety. He worked in industries for 19 years at various capacities in various functions like Projects,

Drawing & Design, Systems Engineering and HSE of chemical industry. Then he started free lancing consultancy since 1998. He has rich experience of 44 years. Risk Assessment, Safety Audits & Trainings is his core competence. He has provided training at IIT, Kanpur for Hazard Analysis and Inherent Safer Design of Plants. He designed unique Fire Hydrant System for a few organizations in India and outside it as well. He has conducted many workshops and seminars on HSEF. He is a visiting faculty for many Universities and Institutions. He has conducted Risk Assessments, Audits, training. He has presented many papers at various forums and published articles through many periodicals.

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CONDENSED AEROSOL SYSTEMS - BASIC DESIGN CONSIDERATIONS

Er. Krishnan

FirePro Systems Limited

mail@firepro.com

1. Introduction

1.1 Condensed aerosol technology gained popularity in the 90's due to the phase-out of Ozone-depleting substances - a result of the Montreal Protocol enforced on January 1, 1989. With almost three decades of worldwide use, the technology is regulated according to international standards and guidelines, such as the UL 2775, NFPA 2010, EN15276, ISO15779, VdS regulations, LPS 1656, LPS1204 Issue 3.2, BRLK23001, and IMO MSC.1 / Circ.1270 for Sea Going Vessels under SOLAS74.

1.2 Alike conventional gas suppression systems, Condensed Aerosol is classified as a Total Flooding agent. For system design and installation, the physical and technical parameters of the protected area, such as the class of fire, volume and height need to be taken into consideration. However, unlike its gas counterparts, the efficiency of fire suppression using condensed aerosol lies predominately in interrupting the chemical chain reactions occurring within the flame, rather than cooling or depleting the oxygen content in the protected enclosure.

1.3 Upon detection and confirmation of a fire, the solid aerosol forming compound contained within the generators, transforms from a solid state into a rapidly expanding two-phase fire suppression agent, consisting of potassium carbonate (K_2CO_3) – the active agent – as particulates of size smaller than 10 μm suspended in a gaseous blend. The gas-type 3D properties of condensed aerosol facilitate its even distribution in the

the protected volume, as well as its flow into the natural convection currents of combustion.

2. System Components

2.1 A fire suppression system consists of several components that work together to detect, extinguish and/or control fires. The fundamental elements include a detection system, responsible for identifying the presence of a fire, a control panel that orchestrates the system's operation, and various alarm devices to alert occupants and other systems.

2.2 Expanding on the foundational elements of condensed aerosol fire suppression systems, the core components are the pre-engineered, non-pressurized generators. When activated, these generators release the designed amount of fire suppression agent in the enclosure. The Aerosol generators are an all-in-one device and are the equivalent of the agent/cylinder, piping and nozzles of conventional gaseous systems. The quantity and model of generators to be used are determined by the agent density required, which differs from one manufacturer to another and is derived from fire suppression tests. These tests are defined in protocols set out by relevant standards such as UL2775, EN15276 part 1 and ISO15779, conducted by accredited bodies and listing Authorities.

3. Design Principles for total Flooding Systems

Designing a condensed aerosol system is regulated by engineering standards which also address the way these systems are installed, commissioned and maintained

Such standards are EN15276 part 2, ISO15779 and NFPA 2010. For the system to be compliant to these standards, all components must be certified, approved or listed.

Below are the main considerations for a designer applying the requirements of NFPA 2010 standard as an example.

3.1 Agent Quantity calculation

Condensed aerosol systems are simple to design without the need for complex hydraulic calculations. To determine the mass of aerosol-forming compound i.e. the total flooding quantity required, in the absence of special conditions that would affect the extinguishing efficiency, one needs to take three factors into consideration.

1. Volume M^3 (V)
2. Design Application Density g/M^3 (da)
3. Additional Safety factor (fa)

By multiplying the three variables, we can derive the total solid mass (m) of condensed aerosol required.

$$m = da \times fa \times V$$

The number of generators required are then derived by dividing the total mass (m) by the amount of solid compound contained in the generator type selected.

3.1.1 Volume and integrity of the enclosure (V)

Defining the fire boundaries is the initial step when dealing with any total flooding fire suppression system. Boundaries must be physical objects capable of withholding the agent at the required concentrations for the 10-minute minimum Hold Time, as specified in all international standards.

Achieving the Hold Time requires the assessment for leakages on the fire boundaries. Condensed aerosol systems

can tolerate small openings in the enclosure without the need for a door fan test to quantify the level of leakages, provided that a visual inspection offers sufficient insight of the room's integrity. Openings can be kept to a minimum by either permanent sealing or with automatic closures. Condensed aerosol system manufacturers are required to provide specific calculations to determine if additional agent is required. In standby mode, condensed aerosol systems are non-pressurized. Upon discharge, they do not significantly contribute to a pressure increase, considering their low discharge pressure, therefore pressure relief vents are not mandatory.

As previously mentioned, aerosol generators are self-contained devices that are installed within the protected enclosure at high level – either on walls, ceilings, or both and consequently do not require dedicated floor space. The positioning of the aerosol generators should be such to ensure a uniform distribution of the agent throughout the protected volume, along with ensuring the required minimum safety air clearances from personnel and combustible material. In the event of any alterations to the enclosure layout, the generators are versatile, allowing for easy repositioning as needed.

3.1.2 Design Application Density g/M^3 (da)

A fundamental step of the design stage involves the identification of the Fire Class within the enclosure. In many scenarios, the presence of a combination of fuels is common, and adhering to NFPA guidelines becomes crucial in

designing an effective condensed aerosol fire suppression system. In cases of mixed fuels, NFPA recommends applying the highest Design Application Density. The Design Application Density can vary among different fire classes. It includes the Extinguishing Application Density, derived from fire suppression test protocols as defined by the UL2775 standard, and incorporates an additional 30% safety factor.

It is important to note that each aerosol manufacturer has a different extinguishing application density resulting from the engineering differences of the generators as well as the chemical formulation of the solid aerosol forming compound.

3.1.3 Additional Safety factor (fa)

In addition, the NFPA 2010 states that additional quantities of agent will be provided through the use of additional design factors to compensate for any special conditions that would affect the extinguishing efficiency.

Other factors which need to be taken into consideration during the design stage are Space Occupancy and Post activation Measures.

4. Space occupancy

4.1 A common misconception is that all condensed aerosols are the same, but this is far from the truth. In fact, one may generalize that aerosols are well suited for industrial type applications (non-occupiable spaces and normally unoccupied spaces) but a select few are also approved for use within normally occupied spaces. Approval can be verified through competent agencies such as the United States Environmental Protection Agency (EPA). However, even though an aerosol may be approved for normally occupied spaces by (EPA), the

use of safety mechanisms must be incorporated into the design, to prevent or reduce the likelihood of persons being exposed to an unintentional discharge. Typical safety mechanisms that must be used are the Auto/Manual key switch, an Isolation switch, an Abort switch, count-down timer delay and other warning devices.

5. Post Activation Measures

5.1 Once it is established to be safe, the condensed aerosol agent is extracted from the enclosure, and any residue deposited on surfaces should be cleaned by following the manufacturer's guidelines. The degree of post activation cleaning depends on ambient conditions and the speed of agent extraction. It is always recommended to quickly ventilate the area if an aerosol system discharges.

5.2 Finally, condensed aerosol systems are simple to design as they do not require complex hydraulic calculations. Importantly, they have a low maintenance footprint compared to their conventional counterparts. The agent itself is environmentally friendly, with a Zero Global Warming Potential (GWP), Zero Ozone Depletion Potential (ODP) and a Negligible Atmospheric Life (ALT). It does not contain harmful chemical substances such as per- and polyfluoroalkyl substances (PFAS), Hydrochlorofluorocarbons (HCFCs) or Hydrofluorocarbons (HFCs) and Perfluorocarbons (PFC), making it unlikely to face future restrictions. When designing an aerosol system, it is advisable to seek approval from relevant authorities, as geographical regions or countries may adhere to

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PROVISIONS UNDER NATIONAL BUILDING CODE FOR SAFETY OF BUILDINGS

Dr. Rital Gajjar
Associate Professor & HoD

Er. Binal Modi
Associate Professor

1. Introduction

The National Building Code is constituted by Government of India in 2016. The main aim of the Code is safeguarding the public and property. Few codes regarding Buildings (Building, Hospital, Hotel, Theatre, Public Place, etc.) are discussed below:

2. Fire and Life Safety

As per National Building Code 2016 Part 4 the provisions shall be provided for Fire and Safety in Building, Hotels, Hospitals, etc. It has been adopted by many state governments and rules are also made and enforced, in these rules' requirements of Fire Officer and Trained Staff is insisted for certain types of occupancies

- High rise buildings (30M).
- All hotels, identified under classification three star and above and all hotels above 15 m. in height with 150 beds capacity or more without star category.
- All hospital buildings of 15 m. and above/ having number of beds exceeding 100.
- Underground shopping complex where covered area exceeds 1000 square meters.
- All high hazard industries.

Few Photographs are exhibited below



Fire in high rise building



Fire in Hospital



Fire in Hotel

3. The fire crew shall be available per shift as per NBC:

- Is there fire squad identified in each shift?
- Standing fire order is available with latest revision
- How is the communication with fire station?
- Did fire safety inspections carry out?
- Does emergency procedure available for leakage or flammables?
- What measures are available to control the fire load in the plant area?
- Whether technical knowledge and skills of the manager and staff responsible for overall fire safety of the plant is adequate?
- How many major and minor incidents / fires during the last five years?
- All the fires / incidents been investigated and corrective actions taken?

4. Following Resources shall be available in the Fire Station:

- a. Adequacy of protective clothing (coat, trouser, gloves, boots and helmets).

- b. Availability of SCBA and spare cylinders (at least 2 for each SCBA);
- c. Adequacy of hose, nozzles, ladders, lighting equipment and pumps; and
- d. Communication facility at fire station, walkie talkie sets during firefighting

5. Built in Safety in Electric Circuits and Equipment

- **Electrical equipment in farmable atmospheres:** Electricity being one major source of Ignition in Hazardous area. IS-5572: 2009 deals with the **Hazardous Area Classification (HAC)**. Auditor has check this ensure compliance
- **CEA regulations 2023:** must be referred for compliance all electrical equipment safety (dealt in previous session) The IS code 2309 1989: Code of practice for protection of building and allied structures against lightning can be referred for details of design and protection requirements. (New Code IS/ IEC 62305).
- **Lighting Arrestor:** Protection from lightning shall be provided on Building, Storage Tanks, Grain Elevators etc. as under:
 - Building with explosives or highly flammable substances.
 - Storage tanks containing oils, paints or other flammable liquids.
 - Grain elevators
 - Buildings, tall chimneys/stacks where flammable gases, fumes, dust/ likely to be present.
 - Sub-station buildings and outdoor transformers and switch yards.

6. Electrical and Allied Installation: This shall be as per NBC 2016, Chapter 8, and Section. This should be referred while auditing key issues of electrical safety in building.

- Install stand by electric generator to supply power to staircase, corridor
- lighting circuits, lifts, detection system, fire pumps, pressurization fans, bowlers, PA system, exit sign, smoke extraction system,
- Electric sub-station safety measures
- Avoid sub-station in the basement. If sub-station is in the basement, then exits from basement electric substation shall have self-closing fire smoke check doors of 2-hours fire rating near entry to ramp.
- Electric substation enclosure must be completely segregated with 4-hour fire rating wall from remaining part.
- Oil filled transformers shall be protected with high velocity water spray system / Nitrogen Injection System/ CO₂ total flooding system preferably have oil less dry transformer in building

7. Fire Detector and Alarm System- Statutory Requirement as per NBC provisions

Statute	Rule	Provision
IS 2189		Selection, Installation and Maintenance of Automatic Fire Detection and Alarm System - Code of Practice
Fire Protection Manual of Tariff Adv. Committee	9.3	Direct Telephone/ Radio Communication/ wired alarm/siren system be provided subject to prior approval of the Committee.

Statute	Rule	Provision
The National Building Code of India, 2016	Part – IV Table 23	Manually Operated Electronic Fire Alarm Systems Automatic Detection and Alarm System
The Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Central Rules, 1998	Rule 148: Water for firefighting	An audible fire alarm is provided to warn the building workers whenever a fire breaks out on an excavation or tunneling work;

- **Power requirements for fire alarm** and signaling systems are specified in the NBC code, requires a system to have either two sources of power (primary and secondary) or a single Uninterruptible Power Supply (UPS)
- **IS2189 -2008 6.3 siting of detectors must be referred during audit key provisions are**
- Detectors shall not be mounted within 500 mm of any walls,
- Detectors shall not be mounted within one (1) meter of any air inlet (supply air inlets of HVAC system) or a forced ventilation system.
- Detector siting shall be such that a clear space of 500 mm is maintained below each detector.
- All stairwells, lift shafts, other utility shafts, etc. shall have a detector at the top.
- All unenclosed staircase shall have one detector at each main landing within the

staircase Lift machine rooms shall be provided with a detector

- The detector shall also be provided in cable tunnels, ducts, false floors, AC and AHU room, long AC return ducts and distribution boards.
- No detector shall be subjected to any interior decoration treatment, i.e. painting, alteration of exterior cover, etc.
- Every enclosure (that is, room or cabin) shall have a detector at ceiling level
- Voids in false ceiling/flooring more than 800mm shall be protected with detectors with spacing like in normal installation
- Smoke detectors for heights between 7 M and 10M – room is ok. Beyond 10M height - Only beam detectors or aspirating type detection systems to be used
- there is at least one smoke detector for every 100M²
- **Inspection and testing to be done as follows:**
 - OEM requirements.
 - IS: 2189:2008
 - Initial Installation Tests
 - Maintenance Schedules
 - Daily by User: Panel indications / faults
 - Weekly - Operate one device. (Complete all zones in 13 weeks), battery checks.
 - Yearly - operation of at least 20% devices in year.

Guidance to Check Compliance

- What type of fire detection and alarm system is provided?



- Whether all fire prone areas of the plant are covered with fire detection system?
- Whether fire detection equipment and smoke alarms in good operating condition?
- Whether the number of fire call points are adequate and free from obstruction?
- Whether regular inspection / maintenance / testing carried out and records maintained
- Whether any atmospheric monitoring is carried out for explosive mixture.
- Whether emergency power supplies are provided to fire detection

- Whether smoke detectors are located considering ventilation pattern?
- Whether annunciation of fire is local or in the control room or in both places?
- Whether fire panel is constantly **attended?**

About the Author:



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PREVENTION OF TRANSFORMER EXPLOSION AND FIRE

A REPORT OF SATISFACTORY SERVICE EXPERIENCE

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CTR Manufacturing Ind. Pvt. Ltd. India

1. INTRODUCTION:

Explosion and consequential fire resulting from failed transformers are the most fearsome consequence of a transformer failure, more so if the transformers are installed near populated locations. With restrictions of free space near load centres, every effort needs to be made to minimise the explosion and fire from the failed transformers. With the transformer failure rate around 1% of transformer-years as per CIGRE statistics, the threat of explosion of the failed transformers seems real and alarming. While great efforts are being continuously made by transformer and utility engineers to constantly improve the reliability and life of the transformers, failures at random are realities which need to be constantly addressed and are being addressed by the manufacturers and utilities alike.

Fortunately, every transformer failure does not cause explosion and /or fire. Reportedly and mercifully only around 10% of total transformer failures cause major destruction including explosion and fire. But this number in absolute terms is significant enough considering the large number of transformer population in service. A transformer explosion and the consequential fire is often dangerous, and every effort need to be exercised to minimise this hazard. Around 30% of the total operation of the protection system are due to bushing failures. Both the LV bushings and HV bushings contribute to the failures in equal measure, whereas the other 70% of the failures has been attributed to the transformer internal failures and other reasons. It is necessary that the explosion and fire

protection system employed must be comprehensive to address all the possible faults in the transformer.

Historically, many protection systems have been tried out by the power system personnel. Water sprinklers to simple pressure relief rupture discs to the advanced combination of differential relay and rapid pressure sensors are vogue with varying degrees of success. Sensing of the fault-arc inside the transformer through arc sensors have been mentioned in certain air insulated applications. The arc sensing technique in air or gas filled apparatus such as bus ducts, cable box, switchgear panels etc. which have air or gas as the insulating media are in vogue. Oil filled transformers however present a different challenge to detect accurately the internal arc. Research and experiments are being conducted at some laboratories to constantly detect the transformer failure as early as possible within a few milliseconds of its inception.

The transformer internal pressure rises exponentially due to the short circuits or winding failures & the key management for the prevention of the transformer tank explosion, therefore is the sensing of internal pressure rise and deflating the internal pressure at a speed so as not to cause any tank rupture or shearing of the components. The early sensing of the transformer fault through the fast-acting differential current relays, fast sensing of the internal dynamic pressure rise through a variety of pressure sensors, early cutting off of the power supply to the faulty transformer, system operation for draining of the transformer oil to depressurize

the pressure built up due to the fault and the regulated injection of high-pressure nitrogen into the tank are programmed in designated sequence and executed in milliseconds.

Worldwide, the transformer technical experts, designers and safety engineers are exploring possibilities for minimizing the failure causes in the transformer including the peripheral influential factors such as the tank strength and the structure, the adequacy and quality of the welded joints, the flanges, the bushings etc. Several improvements that will minimize the explosion and the consequential fire inside and around the transformer are being developed, practiced, and are being watchfully introduced. Considering that the bushings contribute to around 60 to 70 % of the explosion, the OIP bushing are selectively changed into more reliable RIP/RIS bushings. Changing transformer fluid into less flammable fluids are claimed to reduce the possibilities of transformer fire. This however needs to be data analyzed based on the population of such transformers in the field. The management of the internal pressure rise due to the fault-arc is the key and insufficient data is available on the internal pressure rise with the new fluids or with RIP/RIS bushing. No doubt, the transformer specialists and the power system safety personnel naturally are still looking for adequate field reports of any change that may be introduced inside or peripheral to the transformer. This will include the fault sensing systems and the logics that may be incorporated in the protection system as well.

It needs to be kept in mind that transformers are not six-sigma compliant devices. Power Transformers are not mass produced to a standardized design such as consumer products or even distribution transformers. Mostly they are custom designed to take care of the individual customer's needs and hence

every batch of power transformers may have variations in many design or manufacturing parameters. There will be many assumed parameters in the manufacture of the transformers. For that reason, failure of transformers is often a reality which needs to be addressed through explosion and fire prevention systems. Condition monitoring and Online diagnostics to some extent provide warnings of advanced health conditions which can minimize unexpected sudden failures. This monitoring has reduced unexpected failures and is certainly a tool to possibly retire and replace the ageing power transformers in due time. The cost of the power transformers is huge and naturally early or premature retirement or withdrawal of a now- healthy transformer from service is a million-dollar decision.

In short, it will be more correct to say that every equipment has its life, that life ends many times at unexpected times and such ends may lead to catastrophic consequences. The effect of such failures can be minimized by the explosion and fire prevention systems which have proven their worth in large number of installations.

This paper is a result of the investigation and compilation of the field performance of nitrogen gas-based transformer explosion prevention and fire protection system of transformers, which covered real field case studies of the transformer failures and operation of the system along with end user experience. Satisfactory operation of over 200 protection systems experienced in over 18000 field installations underlines the efficacy of the protection system in detection and quenching of the fault and deflating the internal pressure even at high fault energy levels. This paper is expected to be perhaps the only paper based on 3 decades of field experience of large number of transformer

explosion and fire protection systems with special focus on Indian experience. More data is being compiled and will be presented and discussed in subsequent papers.

2. WHY DO TRANSFORMERS EXPLODE?

The transformer failure reasons are not a subject matter for this paper. It falls in the domain of transformer designers and the users. Every effort is being made by the industry and the utility to reduce the transformer failures such as improvement in the design parameters, the transformer tank structure, the materials used in the construction, the manufacturing process adopted, and the usage of fail-safe components. The transformer failure due to winding failure or any component failure generates a very high temperature of 1000°C and above, very high internal pressure of the order of 10 bar, the dynamic pressure waves travelling at the speed of sound and generates extreme turbulence near the fault area in the transformer. The pressure wave amplifies near the tank corners and the weakest spot in the tank, welded area, weak tank structure, components mounted on the tank etc. causes rupture in the tank and the hot oil is pumped out which causes fire in the rupture-mouth and in the nearby areas. So, the efforts to prevent the fire solely rests with the containment of the tank rupture. The entire physics of explosion prevention thus is how effectively the internal pressure is contained within the safe limits of the tank withstand pressure. The essence of doing this pressure containment is to remove the cause of the excessive pressure generation. The early sensing and removal of the electrical fault which causes the pressure rise therefore is the key to prevent the explosion of the tank. The logics for the early and accurate sensing of the fault thus assume great significance in the transformer

protection system. The failure or success of the protection system thus depend greatly on the robustness and reliability of the fault sensing logic system.

Summary of the over 200 satisfactorily operated explosion prevention system indicate the fault arc energy varied in the range of 2MJ to 7 MJ, the differential relay picked up the fault signal in 2 to 3 milliseconds of the fault inception, fault current of the order of 20 to 25 kilo Amperes was experienced, importantly the fault clearing time was observed to be under 85 milliseconds. The Churning of the hot oil with Nitrogen gas continued for a few minutes more, ensuring the internal temperature reduces drastically and thus minimizing further damage to the internal components of the faulty transformer.

3. THE PROTECTION SENSING LOGICS:

A few logic systems have been tried for historical reasons.

Pressure sensing and pressure rupture devices have been used since the early days for the release of the excess pressure and prevention of the tank explosion. They have been noticed to have the limitation of inaccurate and inconsistent operation as the 'pressure originating location' cannot be accurately ascertained and the 'pressure containment device' cannot be accurately placed near the pressure originating location. Often it is noticed that the tank rupture precedes the operation of the pressure containment device. Further, numerous devices need to be placed around a big transformer tank in order to be statistically near any failure location which will affect the economics adversely.

Early sensing of the arc associated with a transformer fault has been used as an alternate protection logic. This type of sensing is commonly used conventionally in

switchgear busbar ducts, control panels, and small electric enclosures such as cable box bushings often gas filled or air enclosed. Its effectiveness in a huge transformer tank in the presence of hot transformer oil has serious challenges. For arc sensing to be effective, the arc and the sensing device need to be 'seeing each other' or need to be in the 'line of sight'. This often is not the case as the fault location can be anywhere in the transformer, often inside or in-between the windings. This intricacy poses the first challenge for effective usage of arc sensing as a reliable sensing technique. The presence of hot transformer oil in the transformer tank poses other challenges for effective arc sensing. The oil turns turbulent as soon as a fault or an arc occurs or many times even just prior to an impending fault, thus restricting the optical- reach to the sensor. Additionally, there is a good probability that the optical reach will be routinely adversely affected as the oil turns colour and becomes turbid with ageing. The optical reach, sensitivity and the optical pickup become critical in an oil filled apparatus. A detailed plan of experimentation with reliability evaluation should precede the usage of optical sensors. Some laboratories are already conducting research in this area. The best and the proven logic system employed in this analysis consists of an electrical differential protection system in combination with any of the multiple pressure sensing devices. The electrical differential system ensures that the fault is inside the transformer and is causing rapid pressure rise in the transformer tank. A combination of these 2 sensing systems have been found to be fast acting, reliable, effective, proven and repeatable in all cases of transformer failures. Over 200 successful explosion prevention

occurrences from a population of over 180000 explosion prevention systems in service for over 3 decades is supporting this inference. This means around 200 transformers have been prevented from explosion to the satisfaction of the various utilities testifying to the effectiveness of the logic system and the Nitrogen Injected Explosion and Fire Prevention System.

4. NITROGEN INJECTED EXPLOSION PREVENTION AND PROTECTION SYSTEM

The protection system for transformers under discussion in this paper essentially employs the following principle. The sensing of the electrical abnormality associated with the transformer, or its accessories, is done through a differential protection system. The internal oil turbulence and the dynamic pressure rise are sensed through a variety of relays such as rapid pressure rise relay, Buchholz Surge relays, conservator oil surge relays, over pressure relays, etc. The fastest of the sensed pressure signals in combination with differential relays activate a master trip device which enables the master breaker to trip the circuit. The Nitrogen Injected Explosion prevention and Fire Protection System now gets into action through a programmed predetermined sequence. The conservator oil is blocked from feeding into the transformer tank, the oil drain from the transformer tank begins to quickly deflate the internal pressure, nitrogen is quickly pumped with a predetermined flow into the transformer tank to quench the arc inside and cool the oil by the churning process. The entire process of activation gets completed in a few hundred milliseconds.

The schematic of the Protection System is as shown in Fig 1 below:

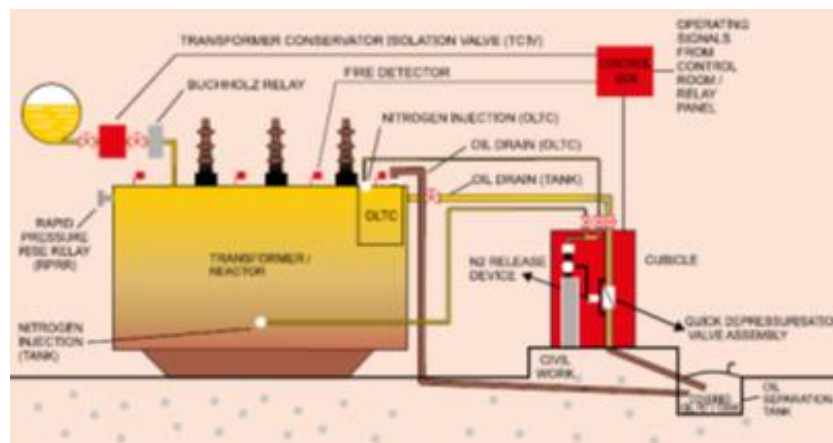


Fig 1: Schematic of the protection system and the protection equipment

5. THE FUTURE

Worldwide, the transformer technical experts, designers and power safety engineers are exploring the possibilities for minimizing the failure causes in the transformer, strengthening the peripheral influential factors such as the tank structure, validating the adequacy and quality of the welded joints and the flanges, and enhancing the reliability of the bushings. A few improvements that will minimize the explosion and the consequential fire inside and around the transformer are being developed, practiced, and are being watchfully introduced. Considering that the bushings contribute significantly to the failure and explosion, OIP bushing are now being changed into the more reliable RIP/RIS bushings. Changing transformer fluid into less flammable fluids is claimed to reduce the possibilities of transformer fire though the explosion causes may still remain. The management of the internal pressure rise in a very quick time is the key and insufficient data is available on the internal pressure rise with the new fluids or with RIP/RIS bushing. No doubt, the transformer specialists and the power system safety personnel naturally will constantly look for adequate field reports of any change that might be introduced inside or peripheral to the transformer. This will include the fault sensing systems and the logics that that may be incorporated in the protection

system as well. Advanced work related to Optic based fault detection is being currently done, as the essence of explosion prevention system is early detection of the arc and initiating the deflation of the internal pressure.

6. CONCLUSION

- Explosion and Fire in a failed transformer, however less in number, is a hazardous event. This need to be minimized, as such an event result in huge cost, threat to life, threat to environment, and often lengthy loss of power due to the long replacement time.
- Continual improvements in the material, design and process of transformers are attempted worldwide, nevertheless, the need for a protection system to prevent explosion and fire in a faulty transformer is essential as the explosion of the faulty transformer is seen as a reality and need to be curtailed at all costs.
- Data collected of the service experience of over 18000 Nitrogen Injected Explosion and Fire systems captured over 3 decades across the globe point to the satisfactory performance of the system in preventing explosion of the faulty transformer.
- Optic based arc fault detection sensors enable very early detection of faults leading to early actions to prevent

explosion and are often used in air or gas insulated switchgear installations. However, the suitability and reliability evaluation in oil filled transformers need to be ascertained through rigorous experimentation as presence of hot oil in the transformer poses certain technical challenges.

- The data analysis of over 200 satisfactorily operated explosion prevention systems in the field indicate the internal arc energy level in the faulty transformers to be in the range of 2MJ to 7MJ, first detection of the arc fault within 2 to 3 milliseconds for the Nitrogen Injected Explosion Prevention System and the fault clearing in about 85 milliseconds.

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Er. Amit Jaiman

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