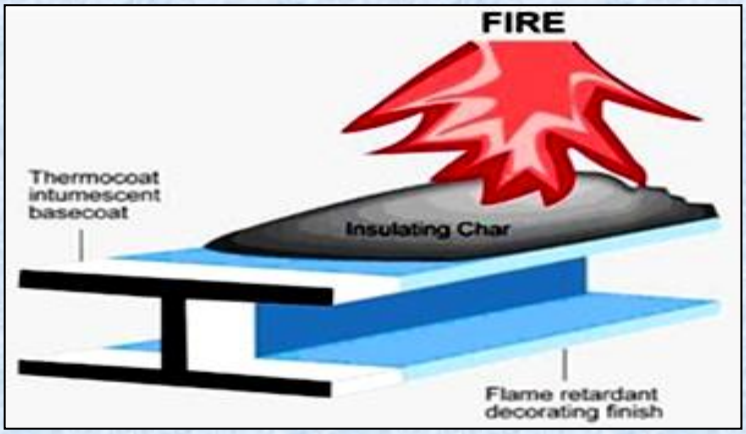
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भारत सरकार – **Government of India**
रेल मंत्रालय – **Ministry of Railways**

अग्निरोधी सामग्री

FIRE RETARDING MATERIALS



केमटेक / 2014 / सि / एफ आर एम / 1.0
CAMTECH/2014/C/FRM/1.0

मार्च – 2014
March – 2014

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अग्निरोधी सामग्री

FIRE RETARDING MATERIALS

प्राक्कथन

मानव जाति के इतिहास में देखा जाए तो आग मानव बस्तियों के लिए एक निरंतर खतरा बन गई है। हमारे देश में, खासतौर से शहरी क्षेत्रों में गगनचुंबी इमारतों सहित इमारतों की संख्या में भारी बृद्धि के रूप में चहुँओर सामाजिक–आर्थिक प्रगति हुई है।

इमारतें जिन्हें रहने, काम करने एवं अन्य प्रयोजनों के लिए उपयोग किया जाता है, को अग्निरोधी सामग्री का समावेश करते हुए आग, विस्फोट एवं अन्य खतरों से बचाया जाना चाहिए। आग की वजह से नुकसान को कम करने के क्रम में, योजनाकारों, वास्तुकारों तथा अग्नि सुरक्षा सेवाओं को डिजाइन एवं अग्नि सुरक्षा के बेहतर व उन्नत तरीके विकसित करने के लिए जिम्मेदार होना चाहिए।

केमटेक द्वारा तैयार इस पुस्तिका में अग्निरोधी सामग्री जो कि भवनों में कोटिंग्स, छत और विभाजन बोर्डों आदि के रूप में तथा अग्निशमन में फोम, जैल और कपड़े के रूप में आमतौर पर लागू की जाती है, को शामिल किया गया है।

यह उम्मीद की जाती है कि भारतीय रेल के समस्त सिविल इंजीनियरिंग स्टाफ के लिए यह पुस्तिका निश्चित रुप से उपयोगी सिद्ध होगी।

केमटेक, ग्वालियर *(ए. आर. तुपे)*
दिनांक 28, मार्च 2014 *कार्यकारी निदेशक*

FOREWORD

Right from the history of mankind, fire has been a constant threat to human habitations. In our country, there is all round socio-economic progress in terms of enormous increase in the number of buildings, including high-rise buildings, especially in the urban areas.

The buildings, which are used for living, working and other purposes should be protected against fires, explosions and other hazards through incorporation of fire retardant materials. The planners, architects and fire protection services should be responsible to evolve better and improved methods of design and fire protection in order to mitigate losses due to fire.

The handbook prepared by CAMTECH incorporates fire retardant materials, which are generally applicable in buildings in the form of coatings, ceiling and partition boards, etc. and in fire fighting in the form of foam, gel and clothing.

It is expected that the handbook will be quite helpful to civil engineering staff of Indian Railways.

CAMTECH/Gwalior ***(A.R. Tupe)***
Date: 28, March 2014 ***Executive Director***

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भूमिका

एक बड़ा संगठन होने के नाते भारतीय रेल के पास सिविल इंजीनियरिंग संरचनाओं एवं भवनों की विशाल सम्पदा जिसमें बड़ी मात्रा में विभिन्न उत्पाद तथा सामग्री का, चाहे वो ज्वलनशील हो या अज्वलनशील, प्रयोग किया जाता है। अधिकांश ज्वलनशील वस्तुओं को अग्नि से दूर रखने के लिए, विशेष ध्यान देने की जरुरत है। जब आग लगती है तो यह प्रत्येक जीवित/अजीवित पहचान को नष्ट कर देती है। जैसा कि हम जानते हैं अग्नि मानवजाति के लिए प्रकृति का एक उपहार है यदि इसका उपयोग उत्पादकता के रुप में किया जाए। इसका उपयोग विभिन्न उद्धेश्यों जैसे कि खाना बनाने, गर्मी प्राप्त करने, तथा विभिन्न उत्पादों के निर्माण के लिए किया जाता है।

अतः अग्नि के विनाशक स्वरुप को देखते हुए, प्रायः सभी भवनों चाहे वे आवासीय, संस्थानक, शैक्षिक, सभागार, इत्यादि, को अग्निरोधी सामग्री से उपचारित किया जाए, जिससे कि मानव जीवन एवं सम्पत्तियों के अग्नि से होने वाले नुकसान को, कम किया जा सकता हो।

भवनों एवं अन्य महत्वपूर्ण संरचनाओं के निर्माण तथा रखरखाव में शामिल सिविल इंजीनियरिंग तकनीकी स्टाफ के मार्गदर्शन के लिए **'अग्निरोधी सामग्री'** से संबंधित जानकारी का प्रसार करने हेतु इस पुस्तिका को तैयार किया गया है। इस पुस्तिका में अग्नि का मूल स्वभाव, मौलिक निर्माण सामग्री की अग्नि के प्रति प्रतिक्रिया, भवनों में प्रयुक्त अग्नि/ज्वाला को मन्द करने वाली सामग्री, इत्यादि शामिल है।

यह पुस्तिका वैधानिक नहीं है तथा इसमें दी गई जानकारी का उद्धेश्य केवल मार्गदर्शन है। किसी न किसी रुप में अधिकांश डेटा एवं जानकारी, साहित्य सर्वेक्षण तथा इंटरनेट खोज पर आधारित है। अधिक जानकारी के लिए, इस पुस्तिका में निहित किसी भी जानकारी को अंतिम रुप से लागू करने से पहले विषय पर उपलब्ध प्रासंगिक साहित्य का अध्ययन संदर्भ रूप में किया जाना चाहिए।

इस पुस्तिका में अधिक सुधार हेतु पाठकों के किसी भी सुझाव का हम स्वागत करते हैं।

केमटेक, ग्वालियर — *(एस.के.सक्सेना)*
दिनांक 25, मार्च 2014 — *उप निदेशक/सिविल*

PREFACE

Indian Railway is a big organisation having large assets of civil engineering structures and buildings, where large varieties of products or materials, whether they are combustible or non-combustible are used. Special attention is required to keep most of the combustible materials away from fire. When the fire occurs, it destroys each and every living/non-living identity. As we know, fire is a nature's gift to mankind, if used productively. It is used for various purposes like for cooking, warming, and manufacturing of various products, etc.

Therefore, keeping in mind the destructive nature of fire, almost all buildings whether residential, institutional, educational, assembly etc. are required to be treated with the fire retarding materials so that the losses due to fire, to human lives and properties can be minimised.

This handbook is prepared with the objective to disseminate the information related to ***'Fire Retarding Materials'*** for the guidance of civil engineering technical staff involved in construction and maintenance of buildings and other important structures. It covers the basic nature of fire, reaction of basic material to fire, fire/flame retardant materials used in buildings, etc.

This handbook is not statutory and contents are only for the purpose of guidance to the civil engineering technical staff. Most of the data & information in some form or the other are based on literature survey and internet search. For more in-depth information, the relevant literature on the subject may be referred before final implementation of any information contained in this handbook.

We welcome any suggestions from our readers for further improvement of this handbook.

CAMTECH/Gwalior ***(S.K. Saxena)***
Date: 25, March 2014 ***Dy. Director/Civil***

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इस हस्तपुस्तिका के लिये भविष्य में प्रकाशित होने वाली संशोधन पर्चियों को निम्नानुसार संख्यांकित किया जायेगाः

The correction slips to be issued in future for this handbook will be numbered as follows:

केमटेक / 2014 / सि / एफ आर एम / 1.0 / सीएस # XX दिनांक _____

CAMTECH/2014/C/FRM/1.0/CS # XX date _____

जहॉ XX सम्बन्धित संशोधन पर्ची की क्रम संख्या है (01 से प्रारम्भ होकर आगे की ओर)

Where "XX" is the serial number of the concerned correction slip (starting from 01 onwards).

प्रकाशित संशोधन पर्चियॉ
CORRECTION SLIPS ISSUED

क्र.सं. / Sr. No.	प्रकाशन की तारीख / Date of issue	संशोधित पृष्ठ संख्या तथा मद संख्या / Page no. and Item No. Modified	टिप्पणी / Remarks

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1.0 परिचय/INTRODUCTION

The mankind since beginning of civilisation is much familiar with the nature of fire that has tremendous power to create and destroy. In India, the weather conditions are severe in summer and winter where the maximum temperature becomes as high as 48^0C and minimum temperature as low as -20 to 20^0C respectively. The excessive heat may make the combustible materials susceptible to be ignited with even a very mild source of fire. Among the fires, electrical fires resulting from failure of electrical equipments are fairly common and lie either in poor connectors and terminal boards or in defective protective gear such as fuses. Most electrical failures have the potential of developing into fires.

Buildings, which are used for living, working, entertainment or for other purposes, form an integral and major constituent of human habitat. The vulnerable parts of any building with respect to fire are the materials comprising the surface coverings of walls and ceilings, curtains, furniture, etc. While only a few commonly used materials can readily be ignited by a small source of heat, others may ignite and continue to burn when subjected to flame from the burning contents of building. If the materials already used in a building are found to be of a lower class, these can be upgraded by employing physical fire retardant techniques, e.g., the application of a fire retardant paint.

The development of a fire in building as related to the burning of materials follows three stages, namely the growth, burning and decay periods of a building material when it gets ignited. The materials with prolongation of heat release and flame spread would delay the growth period.

With the technological advances on all fronts, not only the factor of susceptibility, but the complexity of fires, explosions and the hazards which the buildings are exposed to have also increased many-fold. These hazards have been instrumental in causing heavy losses in lives and property throwing up fresh challenges to planners, architects and fire protection services in evolving better and improved methods of design and fire protection in order to mitigate such losses. Now the modern technology gives emphasis on prevention of these fire hazards rather than post operative measures. The technology stresses on retarding the surface spread of flame on combustion materials, thus minimizing the fire hazards. It will result in a longer time for the evacuation of the buildings.

The architectural and structural designs of a building and construction have a significant effect on its fire safety standards. Similarly, the fire protection measures incorporated for the building, both active and passive, also provide reasonable safety from the effects of fire. It is also recognized that absolute safety from fire is seldom attained in practice.

2.0 आग की मूल बातें/FIRE BASICS

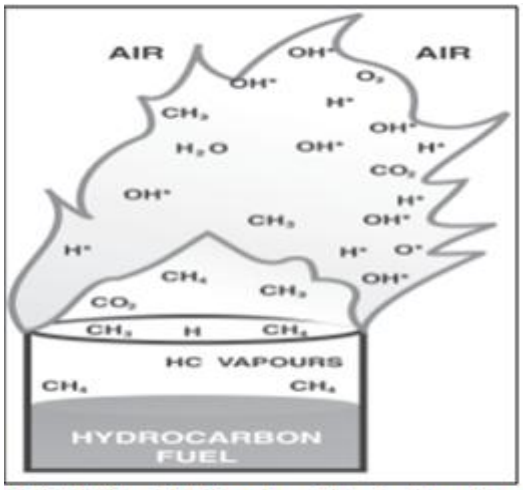
An understanding of the basic principles of combustion or fire, causes and sources of ignition, fire growth and fire spread is necessary for understanding the principles of fire control and extinguishment.

- Fire presents three major concerns: Flame, Smoke and Toxic Fumes
- Combustion requires three conditions: Oxygen, Heat and Fuel Source

- Fuel sources can be: Polymers, Plasticizers, Process oils and Resins (Hydrocarbon)

Combustion (or fire) usually involves an exothermic chemical reaction between a substance or fuel and oxygen. Unlike slow oxidation, a combustion reaction occurs so rapidly that heat is generated faster than it is dissipated, causing a marked increase of temperature, even upto a few hundreds of degrees. Very often, the temperature reaches so high that visible light or flame is generated. Combustion, therefore, is a type of chain-reaction.

Flames are actually gases that are burning at a very high temperature. The burning of most materials produces a flame. A flame front stemming from a local ignition source is established in a flammable medium. A form of chemical reaction is set-up in the layer of gas adjacent to this source with the result that heat and what are called chain carriers pass into the next layer of gas and continue the cycle of the operations there, rather like runners in a relay race. Chain carriers are believed to be atoms or part of molecules, known as free radicals (OH*, H* and O*) and these are extremely reactive.



Uninhibited / Unbroken Chain Reaction showing active radicals like H*, O* & OH* in the flame

In brief:

- Flame is the visible part of a fire
- Flames are actually hot glowing gases
- The color of flames is dependent upon the material burning and the temperature of fire
- Fire is rapid oxidation of materials caused by combustion
- Fire can be controlled as in a gas stove, or uncontrolled as in forest fires

The prerequisite for combustion are heat, fuel and oxidising agent and a suitable chemical reaction path. Any method for inhibiting combustion must involve one or more of the followings.

- Removal of heat faster than it is released
- Separation of fuel & oxidising agent
- Dilution of vapour phase concentration of fuel and oxidising agent below that which is necessary for combustion
- Termination of chain reaction

It is well known that fire causes deterioration and destruction to almost all kinds of building materials. However, a fire can be caused only if three conditions are satisfied viz.,

- The material must be combustible
- There must be an excess of air (oxygen) and
- There must be a source to cause ignition

As far as the materials of construction and their reaction to fire are concerned, the thermal and mechanical properties are the basic determinants of their ability to prevent and confine the fire. It

is therefore, important to evaluate the relative fire resistance and fire rating of different building elements and possibly of building as a whole if possible.

2.1 सामग्री की आग प्रतिरोधकता/FIRE RESISTANCE OF MATERIALS

The fire resistance of materials, or their assemblies, is that property which prevents or retards the passage of excessive heat, hot gases, or flames, under the standard conditions of test. Materials, or their assemblies, are assigned a fire resistance rating, which is the time in hours, or fractions thereof, that they will resist fire exposure as determined by the standard fire test. Materials or assemblies are tested as used - e.g. columns, beams, walls, floors, ceilings, doors.

The fire resistance rating of structural elements becomes significant in preventing the collapse of the compartment and may be of the building as well. This implies that the structural elements of proper fire rating should be used. For the material normally used in buildings, fire resistance ranges from 30 minutes to 4 hours. A 1hr. rating indicates that the assembly/ member can withstand the standard test for minimum 1 hr. without failure. A reference may be made to IS 1642:1989 for fire resistance rating of structural and non-structural elements.

2.2 कुछ मौलिक सामग्री की आग के प्रति प्रतिक्रिया/REACTIONS OF SOME BASIC MATERIALS TO FIRE

When different materials are exposed to or come in contact with fire, their load carrying capacity and stability changes depending on properties such as modulus of elasticity, strength, thermal expansion, creep etc. at the elevated temperature. Some material may even contribute in combustion thus causing spreading of fire. Time taken for complete collapse or disintegration and the rate of spread of flame through the material varies in each case. The factors, which affect these variations, are:

- Nature of materials, that is whether it is combustible or not;
- Ignition temperature of the material if it is combustible;
- Intensity of fire to which the material is exposed;
- Size, particularly the thickness, of the element/component;
- Physical load or stresses on the structural components.

2.2.1 लकड़ी/WOOD

- Combustible vapours are emitted when wood comes in contact with fires, and ignites spontaneously as the temperature reaches 400^0C. The ignition temperature of wood depends on the species of wood, porosity, density and the type of surface coating.
- The outside layers get charred after ignition. The charring continues at a lower rate as moisture-less wood char has lower thermal conductivity and the char layers act as protective coating.
- In India, old buildings often have thick wooden structures and this is advantageous as the surface char formed provides thermal insulation for the underlying wood. Thin and splintered wood can get ignited and burnt much easily.

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2.2.2 कंक्रीट/CONCRETE

- The free water in the form of steam is rapidly released when concrete is exposed to an intense fire resulting in breaking concrete into chips and fragments.
- Concrete has relatively low thermal conductivity which decreases by 20% when heated to 800^0C due to the loss of moisture.
- As concrete is exposed to fire, it changes its colour between 300^0C and 800^0C from grey to pink and then to red due to the oxidation of iron compounds in concrete. The colour of concrete gets bleached to white at 800^0C.
- Polymers are being incorporated in concrete with many advantages but actually polymers contribute the fuel to fire. Polymer concrete therefore, should be used only in non-fire sensitive structures.

2.2.3 स्टील/STEEL

- Cold-rolled steel used in steel structures loses strength rapidly when exposed to 400^0C, as the fire increases the temperature.
- Cold-drawn wire used in pre-stressed concrete loses strength at a much faster rate. The yield strength decreases to about half as the temperature of fire rises above 600^0C.
- The creep of steel also decreases at a rapid rate as the temperature of fire rises above 550^0C. The extent of deformation can ultimately cause the failure of the structures.
- Steel has a thermal conductivity and a thermal diffusivity over 1000 times higher than that of concrete and wood. This becomes the biggest drawback of steel when it is exposed to fire, as it results in warping and distortion. This may lead to the collapse of the structure as the steel cools.
- Polysteel forms used in buildings are better fire resistant, moisture proof and energy efficient. The method of construction consists of placing hollow polystyrene forms over steel rods, stacking them on top of one another and then sealing the space with cement. Thus steel gets surrounded by the polystyrene as insulating material to fire.

2.2.4 प्लास्टिक/PLASTICS

- Plastics are made of monomers and when exposed to high temperatures, they decompose to release their monomers. When exposed to fire, the plastic materials often generate highly toxic gases which are most harmful to human beings. In molten form, they stick and continue to cause damage.
- The solvents used in building sealants, include chlorinated hydrocarbons (toxic to liver) and aromatic solvents that are carcinogenic.
- The amines used in plastics as curing agents (for epoxide) cause dermatitis, and if inhaled, cause serious respiratory problems; even when mildly heated they are very harmful.
- Polyurethane foam burns to release hydrogen cyanide along with dense black smoke.
- Phenolic resins used in wood based panel products are suspected to release formaldehyde which is highly harmful to health.
- On burning, plastics evolve noxious gases, exposure to which causes more deaths than the fire itself.

- When commonly used plastics like water pipes, water tanks and surface coatings catch fire, they become highly dangerous to the health and environment.

2.2.5 ईटें/BRICKS

- Bricks generally have a very low thermal conductivity and nearly approach fire proof stage if all stones and foreign materials are removed from them.
- First class bricks moulded from good clay can stand exposure to fire for a considerable length of time.
- The properties of bricks, which render them fire resistant, are the size of bricks, the method of construction and the component of fire-resistive material in bricks i.e. clay, etc.
- It has been well established that brick masonry construction is most suitable for safeguarding the structure against fire hazards.

2.2.6 ग्लास/GLASS

- Glass conducts heat faster than metal and when heated, tends to crack easily because of its low thermal conductivity and uneven expansion. The cracks can be minimised by the use of glass reinforced with steel wire netting.
- Even when the cracks are formed, the fractured glass remains in its original position, as the embedded wire holds the cracked portion and does not allow it to fall.
- The reinforced glass has a higher melting point than the ordinary glass, and as such it is commonly used for fire resisting doors, windows, sky-lights etc.

2.2.7 एस्वेस्टस/ASBESTOS

- Asbestos, the fibrous form of several minerals and hydrous silicates of magnesium, can be moulded or woven into various fabrics and when combined with Portland cement to form a material having great fire resistive value, are largely used in the construction of fire resistive partitions, roof etc.
- It is non-flammable and a poor heat conductor. It has been widely used to make fire-resisting products such as safety clothing for fire fighters and insulation products such as hot-water piping.

2.2.8 प्लास्टर या गारा/PLASTER OR MORTAR

- Cementitious plastering materials because of their higher bound water content are able to better withstand high temperatures.
- Plaster or mortar is incombustible and as such, by suitable choice of the type of mortar, the walls or ceiling of a building can be made more fire resistant. Cement mortar preferred to lime mortar is liable to calcine.
- The resistance of the plaster to fire hazards can be increased by using it in thicker layers or reinforcing the plaster with metal laths.
- Gypsum plaster when applied over structural members like steel columns etc. makes a good fire resistive quality.

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2.3 आग तथा धुएँ की बृद्धि एवं फैलाव/GROWTH AND SPREAD OF FIRE AND SMOKE

The fire growth stage is the most important to life safety. In this stage, the space or room of fire origin eventually becomes uninhabitable, making human survival difficult. It is for this reason that fire detection and action to protect or rescue the occupants have to be speedily initiated during this stage itself. Materials burning near a wall will have a faster rate of fire growth than materials burning in the centre of the room. This is because of the re-radiation from the heated walls to back to the burning fuel.

When a fire spreads across the ceiling, heat builds up throughout the room and becomes faster, eventually leading to flashover. Occupant's survivability becomes impossible at this point. The spread of smoke and fire to the other parts of the building exposes the occupants in these areas also to survival problems. Building features such as vertical shafts, ducts, plenums, void spaces and even windows can all contribute to spread of fire and smoke. Large complex structures such as multi-storeyed shopping malls, atrium buildings etc. require thorough planning and design for smoke control measures.

2.4 आग की चतुर्पार्श्वीय/TETRAHEDRON OF FIRE

The triangle of fire representing three basic constituents of fire is the conventional concept. Fire scientists have now found that there is a fourth constituent in all flaming fires which plays a vital part in the fire growth and sustenance. This is the unbroken or uninhibited chain reaction. Thus, as per modern concept, the figure of triangle of fire has been transformed into a tetrahedron of fire, each of its four sides representing one of the four basic requirements: *fuel*, *temperature*, *oxygen* and *unbroken or uninhibited chain reaction*. This last factor comes into play only in flaming mode of combustion which is normally applicable in the case of flammable liquids and gases.



3.0 ज्वालारोधी/FLAME RETARDANTS

The term flame retardant refers to a function, not a family of chemicals. A flame retardant enables materials to resist burning when exposed to relatively a low energy ignition source such as cigarettes, match-sticks, candles, stove burners. Flame retardants are compounds added to manufactured materials, such as plastics and textiles, and surface finishes and coatings that inhibit, suppress, or delay the production of flames to prevent the spread of fire.

3.1 ज्वालारोधी सामग्री का व्यवहार/BEHAVIOUR OF FLAME RETARDANT MATERIALS

There are two cases which can be considered how flame retardant materials behave:

- *The flame retardant material is subject to the primary ignition source:* If this is a small flame or other low energy source like a cigarette butt, the presence of flame retardants in the material may cause it to smoulder and smoke somewhat, but will severely impede ignition and in most cases no fire will develop. If burning is sustained, the release of heat and the

spread of flames will be severely hindered by flame retardants allowing people more time to escape from the fire.

- *The flame retardant material is not the first item ignited but is involved in a fire that is already developing:* In this case flame retardants cannot prevent the ignition of the material and it will eventually be thermally degraded or burn. However, flame retardants will reduce the rate of flame spread and heat release.

3.2 ज्वालारोधी सामग्री के प्रकार एवं उपयोग/TYPES AND USES OF FLAME RETARDANT MATERIALS

A variety of different chemicals, with different properties and structures, act as flame retardants and these chemicals are often combined for effectiveness. Bromine, phosphorus, nitrogen and chlorine are commonly used in flame retardants. Inorganic compounds are also used in flame retardants, either alone or as part of a flame retardant system in conjunction with bromine, phosphorus or nitrogen. They may be mixed with the base material (additive flame retardants) or chemically bonded to it (reactive flame retardants). Mineral flame retardants are typically additive while organohalogen and organophosphorus compounds can be either reactive or additive.

- *Reactive-type flame retardant materials* are preferable because they produce stable and more uniform products. Such materials are incorporated into the polymer structure of some plastics.

- *Additive-type flame retardant materials* are more versatile and economical. They can be applied as a coating to wood, woven fabrics, and composites, or as dispersed additives in bulk materials such as plastics and fibres.

Among the flame retardants, the most commonly used chemicals are 2,3 dibromophenyl phosphate and dichloroisopropyl phosphate, and Fyrol FR-2. Diethyl N, N-bis (hydroxyl) ethylaminomethyl phosphate (Fyrol 6) is used for flameproofing of rigid polyurethane foams. For flexible polyurethane foams, phosgard 2XC20, 2,2-bis chloromethyl-1-1, 3propanediol bis (chloroethyl-1) phosphate, and Fyrol FR-2 offer excellent flame retardation.

Flame retardant chemicals used for treatment of plywood (IS 5509:2000) shall generally be the following:

Type 1	Ammonium phosphates
Type 2	Ammonium sulphate
Type 3	Boron compounds
Type 4	Combination of ammonium phosphate and boron compounds
Type 5	Combination of ammonium sulphate and ammonium phosphate

Flame retardants are used predominantly in four major areas:

Electronics and Electrical Devices

- Television and other electronic device casings
- Computers and laptops, including monitors, keyboards and portable digital devices

- Telephones and cell phones
- Refrigerators
- Washers and dryers
- Vacuum cleaners
- Electronic circuit boards
- Electrical and optical wires and cables
- Small household appliances
- Battery chargers

Building and Construction Materials

- Electrical wires and cables, including those behind walls
- Insulation materials (e.g., polystyrene and polyurethane insulation foams)
- Paints and coatings which are applied to a variety of building materials, including steel structures, metal sheets, wood, plaster and concrete
- Structural and decorative wood products
- Roofing components
- Composite panels
- Decorative fixtures

Furnishings

- Natural and synthetic filling materials and textile fibers
- Foam upholstery
- Foam mattresses
- Curtains and fabric blinds
- Carpets

Transportation (Airplanes, Trains, Automobiles)

- Overhead compartments
- Seat covers and fillings
- Seats, headrests and armrests
- Roof liners
- Textile carpets
- Curtains
- Sidewall and ceiling panels
- Internal structures, including dashboards and instrument panels
- Insulation panels
- Electrical and electronic cable coverings
- Electrical and electronic equipment
- Battery cases and trays
- Car bumpers
- Stereo components
- GPS and other computer systems

4.0 अग्निरोधी / FIRE RETARDANTS

A fire retardant is a substance that reduces flammability of fuels or delays their combustion. This includes chemical agents, but may also include substances that work by physical action, such as cooling the fuels, such as fire-fighting foams and fire-retardant gels. Fire retardants may also be coatings applied to an object, such as a spray retardant. Fire retardants are commonly used in fire fighting. Because of the importance of prevention, fire retardation has become a very notable industry.

Several methods are employed to make building materials fire retardant. These are (a) chemical impregnation, (b) spraying, (c) surface treatment, and (d) incorporation of a chemical during the manufacturing stage.

In general, fire retardants reduce the flammability of materials by either blocking the fire physically or by initiating a chemical reaction that stops the fire.

4.1 भौतिक क्रिया द्वारा अग्निरोधन / FIRE RETARDATION BY PHYSICAL ACTION

There are several ways in which the combustion process can be retarded by **physical action**:

- *By cooling down the material through some chemical reactions* in which energy absorbing (endothermic) processes triggered by additives and/or the chemical release of water cool the substrate to a temperature below that required for sustaining the combustion process.

- *By forming a protective* layer that prevents or shields the underlying material with a solid or gaseous protective layer from heat and oxygen necessary for the combustion process.

- *By dilution process* through which some retardants release water and/or carbon dioxide while burning, resulting in dilution of the radicals in the flame enough for it to go out.

Commonly used fire retardant additives that include mixtures of huntite and hydromagnesite, aluminium trihydroxide, and magnesium hydroxide are discussed in brief:

Huntite - Huntite is a carbonate mineral occurring in combination with hydromagnesite. The mineral thermally decomposes over a temperature range of about 450–800°C, releasing carbon dioxide and leaving a residue of magnesium and calcium oxides. Its most common industrial use is in a natural mixture with hydromagnesite as a flame retardant or fire retardant additive for polymers. The release of carbon dioxide is endothermic, meaning that it takes in heat. This action helps to cool the burning material, again slowing the spread of the fire. These types of mixtures are used as alternatives to the more commonly used aluminium trihydroxide.

Hydromagnesite - Hydromagnesite is a hydrated magnesium carbonate mineral, which thermally decomposes, over a temperature range of approximately 220°C to 550°C, releasing water and carbon dioxide leaving a magnesium oxide residue. Its most common industrial use is as a mixture with huntite as a flame retardant or fire retardant additive for polymers. The initial decomposition begins at about 220°C making it ideal for use as a filler in polymers and giving it certain advantages over the most commonly used fire retardant, aluminium trihydroxide.

Aluminium trihydroxide - Aluminium trihydroxide finds use as a fire retardant filler for polymer applications. It decomposes at about 180°C, absorbing a considerable amount of heat in the process and giving off water vapour. In addition to behaving as a fire retardant, it is very effective as a smoke suppressant in a wide range of polymers, most especially in polyesters, acrylics, ethylene vinyl acetate, epoxies, PVC and rubber.

Magnesium hydroxide - Solid magnesium hydroxide has smoke suppressing and fire retarding properties. This is due to the endothermic decomposition it undergoes at 332°C. The heat absorbed by the reaction acts as a retardant by delaying ignition of the associated substance. The water released dilutes any combustible gases and inhibits oxygen from aiding the combustion. Common uses of magnesium hydroxide as a fire retardant include plastics, roofing, and coatings. Other mineral mixtures that are used in similar fire retardant applications are natural mixtures of huntite and hydromagnesite.

4.2 रासायनिक क्रिया द्वारा अग्निरोधन/FIRE RETARDATION BY CHEMICAL ACTION

The combustion process that can be retarded by **chemical action** may take place as:

- **Reactions in the gas phase:** Chemical reactions in the flame (i.e. gas phase) can be interrupted by fire retardants, resulting in cooling of the system, reducing and eventually suppressing the supply of flammable gases.

- **Reaction in the solid phase:** Some retardants break down polymers so they melt and flow away from the flame, resulting in building up a char layer and shielding the material against oxygen and providing a barrier against the heat source. For carbon-based fuels, solid phase flame retardants cause a layer of carbonaceous char to form on the fuel surface. This char layer is much harder to burn and prevents further burning.

- **Intumescents:** These types of retardant materials add chemicals which cause swelling up behind the protective char layer, providing much better insulation behind the protective barrier. In additions to being added to plastics, these are available as paints for protecting wooden buildings or steel structures.

5.0 अग्निरोधी रसायन/FIRE RETARDANT CHEMICALS

The chemicals largely employed as fire retardants are either chemical compounds or mixtures of compounds of phosphorus, nitrogen, sulphur, boron, halogens, antimony, aluminium, etc. For combating fire to cellulosic materials such as thatch and wooden roofing, diammonium hydrogen phosphate or ammonium sulphate mixed with thickening agents is most commonly used. It is believed that phosphorus compounds act as catalyst to produce non-combustible gas and char. Phosphoric acid, chlorine, bromine and iodine suppress glow reactions.

The type of chemical used as fire/flame-retardant determines how it works i.e.

- *Boron or aluminium* increases the amount of char, or burnt material, formed in the early stage of a fire. The char forms a protective layer that prevents oxygen from reaching the inner

layers of the material and thus sustaining the fire. Chemicals commonly used are borax, boric acid, and hydrated aluminium oxide.

- *Phosphorus* containing compounds such as phosphoric acid works by forming a surface layer of protective char. *Nitrogen* used with phosphorus is effective in cellulose, polyester, and polyurethane products.

- *Antimony* by itself is ineffective as a flame retardant and is used only in combination with *halogens*, especially bromine and chlorine.

- *Bromine* works as a flame retardant in its gaseous phase. When bromine compounds are exposed to flame, the bromine dissociates from the material and forms a heavy gas. This dissociation disperses heat, and the bromine gas forms an insulating layer around the material. The layer prevents flames from spreading by inhibiting access to oxygen and by slowing the transfer of heat.

- *Chlorine* works in a similar manner in both its liquid and gaseous phases. The most important fluorine-containing flame retardant materials are the chloro-fluoro-carbons, which are used as blowing agents in polyurethane and polystyrene foams.

6.0 अग्निरोधी भवन सामग्री/FIRE RETARDANT BUILDING MATERIALS

Reducing the surface spread of fire through material helps in evacuation of the occupants of the building and give time for fire-fighting personnel to reach the site before the fire goes out of control. This can be achieved by suitably treating the building material mainly wood, paper, plastic etc. by fire retardant and flame retardant compounds. These materials when added or applied increase the resistance of that product to fire. They are less flammable than the materials they protect, burn slowly, and do not propagate fire. Some flame-retardant materials prevent the spread of flame; others burn and thereby create a layer of char that inhibits further combustion.

6.1 जिप्सम बोर्डस्/GYPSUM BOARDS



Among many chemicals, gypsum possesses an unusual fire resistance property. When exposed to high temperatures gypsum releases its water of crystallization which evaporates due to heat from the fire. As long as the side of the gypsum plasters board facing the fire does not get completely decomposed the other face remains cool. Gypsum boards used in partition and ceilings are good thermal insulators and also absorb heat on dehydration at high temperatures reached by the fire.

6.2 पर्लाइट बोर्डस्/PERLITE BOARDS

Perlite is an amorphous volcanic glass that has relatively high water content, typically formed by the hydration of obsidian. It occurs naturally and has the unusual property of greatly expanding when heated sufficiently. It softens when it reaches temperatures of 850–900°C. Water trapped in

the structure of the material vaporizes and escapes, and this causes the expansion of the material to 7–16 times its original volume. The expanded material is a brilliant white, due to the reflectivity of the trapped bubbles.

In the construction and manufacturing fields, it is used in lightweight plasters and mortars, insulation and ceiling tiles. Small quantities of perlite are also used in foundries, cryogenic insulation, as a lightweight aggregate in mortar (firestop) and in ceramics as a clay additive. Expanded vermiculite and perlite, the lightweight materials used in boards or plaster possess thermal qualities which increase fire-resistance properties.

6.3 मेग्नेसियम ऑक्सीक्लोराइड सीमेंट/MAGNESIUM OXYCHLORIDE CEMENT

Magnesium oxychloride cement, a combination of magnesium oxide and magnesium chloride with inert fillers, is used in coatings, flooring, and in wood-wool boards as binder. Wood-wool boards are widely used to partitions and ceilings.

6.4 कैल्सियम सिलिकेट बोर्डस्/CALCIUM SILICATE BOARDS

One of the most successful materials in fireproofing is calcium silicate, which is commonly used as a safe alternative to asbestos for high temperature insulation materials. Industrial grade piping and equipment insulation is often fabricated from calcium silicate. Its fabrication is a routine part of the curriculum for insulation apprentices.



High performance calcium silicate boards retain their excellent dimensional stability even in damp and humid conditions and can be installed at an early stage in the construction program, before wet trades are completed and the building is weather-tight. Fabricators and installers of calcium silicate in passive fire protection often also install firestops.

6.5 ग्लास पैनल्स/GLASS PANELS

Fire retardant glass panels are used in skylights, windows, doors, etc. These panels are made with two or more sheets of tempered glass, with an interlayer of a gel of polymer salt, which crystallizes to a solid when heated. These fire retardant glass panels can delay the spread of fire by 30 to 90 minutes.

7.0 इमारती लकड़ी का उपचार/TREATMENT OF TIMBER

It is not possible to make timber fully fire-resistant, chemicals and paints only retard the action of fire. Timber can be rendered non-inflammable, which will not flame or glow but merely char, and will not, therefore, assist in the propagation of fire.

Fire resistance of timber: Timber is very inflammable. When it burns, the first step is the vaporization of moisture (118^0C) and the next is the volatilization of extraneous materials (110-

165^0C). As the temperature builds up, the evolution of gases is more rapid and the surface of the timber begins to char. Finally, the point is reached at which the wood itself begins to glow and to ignite (220-390^0C). Until this point is reached, the woody portion does not support its own combustion. Quick ignition of inflammable gases and glowing of charcoal occur at about 390-530^0C.

Chemical methods: These include the impregnation of timber with effective chemicals, or by coating the surface of timber with a layer of noncombustible paint.

- **Impregnation with chemicals:** The treated wood utilizes a fire retardant chemical that remains stable in high temperature environments. The treatment is done by pressure impregnation of the timber with large quantities of chemicals. The most common of which are aluminium di-phosphate and sulphate, borax and boric acid, zinc chloride and sodium tetra-borate. The treatment provides a physical barrier to flame spread. The treated wood chars but does not oxidize. Effectively, this creates a convective layer that transfers flame heat to the wood in a uniform way which significantly slows the progress of fire to the material.

  As chemicals are water soluble, they are leached out due to rain when applied on exposed structures. Therefore, a second shallow impregnation with a fire-retardant, water-repellent sealer or paints like flamex and bitulac fire-retardant paint is applied, which substantially retards leaching. Paints of asbestos, magnesium sulphate, ferrous oxide etc. also have been found to be very much effective. Fire retardant salts are impregnated by pressure process. White washing is effective to some extent in retarding the action of fire.

- **Surface coating:** The most commonly used flame retardant coatings are cement grouts, clay-sulphate paste; paints such as silicate, chloride, phosphate paints and; emulsions like chloro paraffin. Some fire retardants (chemicals) form a film on the surface of wood and decompose under heat yielding non-inflammable gases that dilute the inflammable gases and consequently retard the ignition of the latter. Some of the other fire retardants have low melting points. These melt under heat and form a barrier to the supply of oxygen to the inside.

  Some site-applied coatings as well as brominated fire retardants have lost favour due to safety concerns as well as concerns surrounding the consistency of application. Specialized treatments also exist for wood used in weather-exposed applications.

Structural Method: There is considerable difference between the burning of thin wooden members and that of large timbers. Timbers of substantial dimension offer high resistance to fire. Heavy timber on burning form a protective coating of charcoal, which being a heat insulator retards the penetration of heat to the interior. On the contrary, thin members quickly reach the ignition point and burn rapidly. Once the fire is started, flames rise upward in case of wood and hence, wood which is in vertical direction catches fire easily. That is why windows and doors burn more rapidly as compared to beams and floors.

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8.0 अग्निशमन फोम/FIRE FIGHTING FOAM

The foam used is obtained from a protein-based concentrate that is added to water to form a solution. The foam is formed from water-concentrate solution with compressed air. Fire-fighting foam is used for fire suppression by way of cooling the fire and coating the fuel, and further preventing its contact with oxygen. Other components of fire-retardant foams are organic solvents (e.g., trimethyltrimethylene glycol and hexylene glycol) and foam stabilizers (e.g., lauryl alcohol). They are suitable for enclosed spaces such as hangars, where quick filling is needed.

Alcohol-resistant foams contain a polymer that forms a protective layer between the burning surface and the foam, preventing foam breakdown by alcohols in the burning fuel. Alcohol-resistant foams should be used in fighting fires of fuels containing oxygenates, e.g. MTBE (Methyl tert-butyl ether), or fires of liquids based on or containing polar solvents.

9.0 अग्निशमन जैल/FIRE RETARDANT GELS

Fire retardant gels are made from super absorbent polymer slurries, which have a consistency almost like petroleum jelly. Polymers can occur either naturally or synthetically. They can be used as fire retardants for structure protection and in direct-attack applications against wildfires. Sodium polyacrylate, a super absorbent polymer, acts like a sponge soaking up to 800 times its weight in water.

- Fire retardant polymers when mixed with water become a sticky gel through a process known as hydration. During the hydration process, fire retardant polymers encase water droplets in a bubble-like shell.
- As the gel and water are sprayed onto an exposed surface, millions of tiny bubblets are stacked one on top of another. The stacking of the water bubblets forms a thermal protective blanket over the surface to which it is applied.
- In order for the heat of the fire to penetrate the protected surface, it must burn off each layer of the gel bubblets coating. Each layer holds the heat away from the next layer of bubblets beneath.
- The polymer shell of each bubblets and their stacking significantly prevent water evaporation. After the retained water is completely evaporated from a gel, fire resistance is lost, but can be restored by re-wetting the surface if gel material is still adherent.
- Gels can provide thermal protection from fire for extended periods. Depending on the fire conditions, applied fire retardant gels offer fire protection for periods of 6 to 36 hours.

10.0 अग्निरोधी कोटिंग्स/FIRE RETARDANT COATINGS

A fire retardant coating can be worth hundreds of times its cost in minimizing premise damage in the event of fire and the value cannot be calculated when the "intumescent paint" contains or delays fire spread long enough to save human life.

The application of fire retardant paints on combustible wood structures reduces the flammability as it forms an insulating layer on the surface. Paints based on polyvinyl acetate or other synthetic resins in which fire retarding components like ammonium phosphate (a nitrogen compound) or a

carbon-forming agent are incorporated, have properties to delay ignition by at least 10 minutes in case of fire.

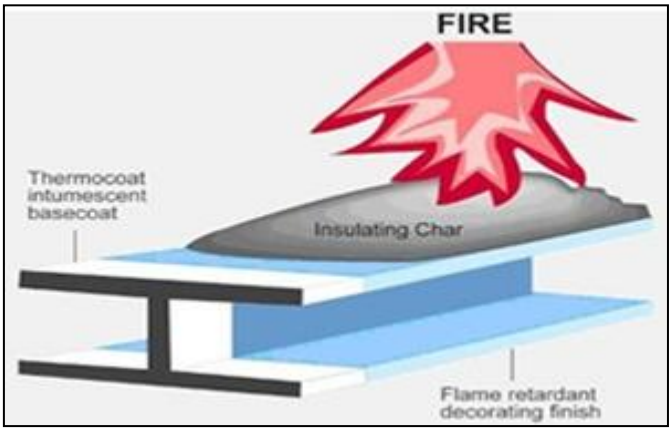
Calcium carbonate and calcium oxalate are used in formulations of organic coatings against fire. Heat is dissipated both in decomposition of inorganic compounds and in the intumescent fragmented particles detached from the surface by sudden gel formation. The interiors, therefore, could be treated by carbonates and oxalate containing paints which swell and decompose, and form foams, non-flammable gases, or form fragmented particles which, while leaving the surface, take the heat away, and thus cool the surface.

11.0 इन्ट्यूमसेंट (फूली हुई) कोटिंग्स/INTUMESCENT COATING

An intumescent coating or paint is the mixture of organic resins, binders, pigments, ceramics and refractory fillers that swell and char when exposed to fire. Intumescent coatings are sprayed on steel surfaces, and when temperature increases to a threshold point these coatings expand in the cellular form. The expansion is many times their original thickness thereby forming a protective barrier that protects the surface from heat.

Substances that actually produce expansion and char formation are known as blowing agents. The blowing agents are usually *dicyandiamide, melamine, guanidine, glycine, urea, chlorinated paraffin* etc. Epoxy or vinyl based intumescent paints are also available but they have limited interior applications due to their toxicity. A clear intumescent paint is based on polyurethane with halophosphate easter, asbestos, silica, fluorspar, dolomite, etc., or magnesia, fibre glass and foamed glass. These coatings are either water based with ammonium polyphosphate or oil based containing melamine phosphate with fibrous materials to increase toughness.

An intumescent paint applied at the manufacturer's recommended rate can make it possible to comply with a flame spread rating lower than what exists on an already-installed wall, ceiling or other surface. These paints can give an extra measure of fire protection to property and people. Architects, developers, building superintendents and home owners can use this simple safeguard in a number of strategic ways:



- As a fire retarding coating on roof timbers, floor rafters and support members.
- To protect corridors, stair wells between stories, and exits from buildings.
- On dividing walls around space heaters, furnaces, or heating plants in basements or compartmented in living areas.
- In working areas of a factory or process plant exposed to gas or oil-fired heaters, welding or brazing operations, handling of combustible materials.

When fire breaks out, whatever the source, in an area with surfaces properly coated with intumescent paint – here are the benefits it delivers that a conventional paint cannot:

- Upon first encroachment of the source flame, the film foams up as much as 200 times its thickness to make continuous insulating foam composed of tiny closed cells.

- The greatly expanded cellular foam delays the lateral spread of fire and helps protect the substrate beneath it. Occupant escape time is prolonged; destruction of property is delayed, reduced or avoided; restoration costs are minimized.

- On properly coated surfaces, the generation of combustible gasses and high temperatures that lead to flashover and the creation of lethal atmospheres is delayed or prevented.

- The thick, tightly-adhered foam coating thermally insulates the substrate walls, ceiling, or support member from excessive heat, thus postponing ignition.

- The insulation maintains the protection of the substrate for as long as hours, often long enough to prevent actual ignition.

- Even in severe fires that have been brought under control in reasonable time, the substrate wall, ceiling, support timber may often be scraped clean and found to be still in serviceable condition.

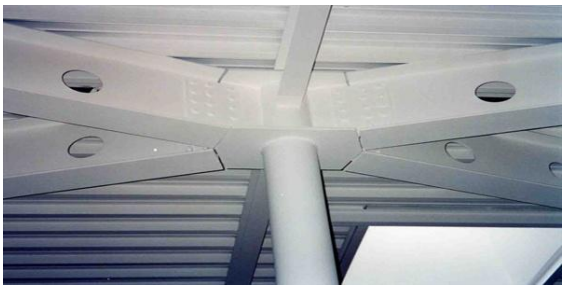
- Intumescent paints are not designed to prevent fires. They are designed to keep damage to a minimum and to "buy time" until help can arrive.



Fire Stop Doors



Fire retardant Structural Steel Paint



Fire Retardant Steel Structure Coating



Fire Retardant Coating for Electrical Cable

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Fire Proof Paint for Wood

12.0 कपड़ों में प्रयुक्त अग्निरोधी सामग्री/FIRE RETARDANT MATERIALS USED IN CLOTHING

- ***Wool fibers*** can readily absorb moisture almost one-third of its own weight. Wool ignites at a higher temperature than cotton and some synthetic fibers. It has a lower rate of flame spread, a lower rate of heat release, a lower heat of combustion, and does not melt or drip. When used in carpets, it forms a char which is insulating and self-extinguishing, and it contributes less to toxic gases and smoke than other flooring products. The carpets made of Wool are specified for high safety environments, such as trains and aircraft. Wool is usually specified for garments for firefighters, soldiers, and others in occupations where they are exposed to the likelihood of fire.

- ***Polybenzimidazole*** is a synthetic fiber, which has a very high melting point and does not readily ignite because of its exceptional thermal and chemical stability. It is used to fabricate high-performance protective apparel such as firefighter turnout coats and suits, astronaut space suits, high temperature protective gloves, welders' apparel, race driver suits, and aircraft wall fabrics.

- ***Nomex***, a flame-resistant material, which is used in electrical laminates such as circuit boards and transformer cores as well as fireproof honeycomb structures where it is saturated with a phenolic resin. Both the firefighting and vehicle racing industries use Nomex to create clothing and equipment that can withstand intense heat. Wild land firefighters wear Nomex shirts and trousers as part of their personal protective equipment during wildfire suppression activities.

- ***Twaron***, which is a heat-resistant and strong synthetic fibre is used as a protective gear in making of flame-resistant clothing, helmets, heat-hardy gloves, sporting goods, textiles, ballistic vests.

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10	**www.fire.tc.faa.gov**
11	**IS 5509:2000 (Reaffirmed 2006) Fire Retardant Plywood – Specification *(Second Edition)***
12	**IS 1642:1989 (Reaffirmed 1994) Fire Safety of Buildings (General): Details of Construction – Code of Practice *(first revision)***
13	**http://en.wikipedia.org**

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टिप्पणी/NOTES

गुणवत्ता नीति

रेलों में यात्री और माल यातायात की बढती माँग को पूरा करने के लिए गुणवत्ता प्रबंध प्रणाली में अनुसंधान, डिजाइनों और मानकों में उत्कृष्टता तथा सतत् सुधारों के माध्यम से सांविधिक और नियामक अपेक्षाओं को पूरा करते हुए सुरक्षित, आधुनिक और किफायती रेल प्रौद्योगिकी का विकास करना।

QUALITY POLICY

To develop safe, modern and cost effective Railway technology complying with Statutory and Regulatory requirements, through excellence in Research, Designs & Standards and Continual improvements in Quality Management System to cater to growing demand of passenger and freight traffic on the Railways.

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हमारा उद्देश्य

अनुरक्षण प्रौद्यौगिकी और कार्यप्रणाली को उन्नयन करना तथा उत्पादकता और रेल्वे की परिसम्पत्ति एवं जनशक्ति के निष्पादन में सुधार करना जिससे अन्तर्विषयों में विश्वसनीयता, उपयोगिता और दक्षता प्राप्त की जा सके।

यदि आप इस सन्दर्भ में कोई विचार और सुझाव देना चाहते हों तो कृपया हमें इस पते पर लिखें:

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Our Objective

To upgrade Maintenance Technologies and Methodologies and achieve improvement in productivity and performance of all Railway assets and manpower which inter-alia would cover Reliability, Availability, and Utilisation.

If you have any suggestion & comments, please write to us:

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