STANDARD NO. AERB/NF/SS/FPS (Rev. 1)

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GOVERNMENT OF INDIA

AERB SAFETY STANDARD

FIRE PROTECTION SYSTEMS FOR NUCLEAR FACILITIES

ATOMIC ENERGY REGULATORY BOARD

AERB SAFETY STANDARD NO. AERB/NF/SS/FPS (Rev. 1)

FIRE PROTECTION SYSTEMS FOR NUCLEAR FACILITIES

Atomic Energy Regulatory Board
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Order for this standard should be addressed to:

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FOREWORD

Activities concerning establishment and utilisation of nuclear facilities and use of radioactive sources are to be carried out in India in accordance with the provisions of the Atomic Energy Act, 1962. In pursuance of the objective of ensuring safety of members of the public and occupational workers, as well as protection of the environment, the Atomic Energy Regulatory Board (AERB) has been entrusted with the responsibility of laying down safety standards and enforcing rules and regulations for such activities. The Board has, therefore, undertaken a programme of developing safety codes, safety standards and related guides, guidelines and manuals for the purpose. While some of the documents cover aspects such as siting, design, construction, operation, quality assurance, decommissioning of the nuclear and radiation facilities, other documents cover the regulatory aspects of these facilities.

Safety codes and safety standards are formulated on the basis of nationally and internationally accepted safety criteria for design, construction and operation of specific equipment, structures, systems and components of nuclear and radiation facilities. Safety codes establish the objectives and set requirements that shall be fulfilled to provide adequate assurance for safety. Safety guides and guidelines elaborate various requirements and furnish approaches for their implementation. Safety manuals deal with specific topics and contain detailed scientific and technical information on the subject. These documents are prepared by experts in the relevant fields and are extensively reviewed by advisory committees of the Board before they are published. The documents are revised, when necessary, in the light of the experience and feedback from users as well as new developments in the field.

Fire protection in the nuclear facilities is accorded a very high priority and accordingly a standard for fire protection systems of nuclear facilities was developed and released by AERB in 1996. With rapid changes in technologies of fire prevention, detection and suppression and complexity of plant designs, the need for revision of the standard was felt.

The major changes brought out in the standard are reclassification of fire and portable fire extinguishers, provision of halon alternatives for fire suppression systems, additional requirements in building design and sprinkler systems as per the central electricity authority (CEA) guidelines, redefinition of fire crew, modifications in the fire equipment testing and maintenance practices as per operational feedback from plants. Certain chapters such as quality assurance programme, fire protection during construction and housekeeping etc have been recast with additional requirements as per present practices.

Consistent with the accepted practice, 'shall' and 'should' are used in the standard to distinguish between a firm requirement and a desirable option respectively. Appendices are an integral part of the document, whereas annexure, footnotes and bibliography are included to provide further information on the subject that might be helpful to the user.

For aspects not covered in this document, applicable national and international standards, codes and guidelines acceptable to AERB should be followed. Industrial safety is to be ensured through compliance with the applicable provisions of the Factories Act, 1948 and the Atomic Energy (Factories) Rules, 1996.

The standard applies to all nuclear facilities built after the issue of the document. For the existing facilities, the provisions of this standard shall be implemented to the extent acceptable to AERB.

The standard has been revised by a subcommittee constituted under the Advisory Committee on Industrial Fire and Safety (ACIFS) with specialists in the field drawn from Atomic Energy Regulatory Board, Bhabha Atomic Research Centre, Nuclear Power Corporation of India Limited, Nuclear Fuel Complex and Heavy Water Board. Advisory Committee on Industrial Fire and Safety has reviewed the final draft and vetted it before issue.

AERB wishes to thank all individuals and organizations, who have prepared and reviewed the document and helped in its finalisation. The list of persons, who have participated in this task, along with their affiliations, is included for information.

(S.S. Bajaj)
Chairman, AERB

DEFINITIONS

Combustible Liquid

A liquid having a flash point at/or above 38^{0}C.

Combustible Material

Any material used in a particular form in which it is used and under the conditions anticipated will ignite and burn, generally accompanied by flames, glow or emission of smoke or a combination thereof.

Commissioning

The process during which structures, systems and components of a nuclear or radiation facility, on being constructed, are made functional and verified in accordance with design specifications and found to have met the performance criteria..

Common Mode Failure

Failure of two or more structures, systems or components in the same manner or mode due to a single event or cause. It is a type of common cause failure.

Primary Containment

The principal structure of a reactor unit that acts as a pressure retaining barrier, after the fuel cladding and reactor coolant pressure boundary, for controlling the release of radioactive material into the environment. It includes containment structure, its access openings, penetrations and other associated components used to effect isolation of the containment atmosphere.

Secondary Containment

The structure surrounding the primary containment that acts as a further barrier to limit the release of radioactive materials and also protects the primary containment from external effects. It includes secondary containment structure and its access openings, penetrations and those systems or portions thereof, which are connected to the containment structure.

Contamination

The presence of radioactive substances in or on a material/the human body or other places in excess of quantities specified by the competent authority.

Criticality

The 'stage' or 'state' of a fissile material system where a self-sustained nuclear chain reaction is just maintained.

Decay Heat

The heat produced by the decay of radioactive nuclides.

Decommissioning

The process by which a nuclear or radiation facility is finally taken out of operation in a manner that provides adequate protection to the health and safety of the workers, the public and the environment.

Decontamination

The removal or reduction of contamination by physical or chemical means.

Defence-in-Depth

Provision of multiple levels of protection for ensuring safety of workers, the public or the environment.

Deluge System

A fire control or extinguishing installation with open sprinkler heads used where it is desired to deliver water through all sprinklers simultaneously and to wet the entire area to be protected.

Design

The process and results of developing the concept, detailed plans, supporting calculations and specifications for a nuclear or radiation facility.

Design Basis Fire

A hypothetical fire, which is assumed for the purpose of fire protection design or analysis. Fire is assumed to be one that would lead to the most severe damage in the area under consideration in the absence of fire protection systems.

Diversity

The presence of two or more different components or systems to perform an identified function, where the different components or systems have different attributes, so as to reduce the possibility of common cause failure.

Dosimeter

A device, instrument or system, which can be used to measure or evaluate any quantity related to the determination of either absorbed dose or equivalent dose.

Explosion

An abrupt oxidation or decomposition reaction producing an increase in temperature or pressure, or in both simultaneously.

Fail Safe Design

A concept in which, if a system or a component fails, then the plant/component/system will pass into a safe state without the requirement to initiate any operator action.

Fire Barrier

A structural barrier, partially or completely limiting the spread and thus the consequences of a fire.

Note: Unless otherwise specified 'adequate' barrier rating means, rating as calculated as per fire hazard analysis (FHA), or a minimum of 1 hour rating, whichever is more. Wherever FHA is not performed, the specified barrier rating shall be installed, subject to approval of regulatory authority. In such case where FHA is not performed the rating shall not be less than 3 hours for safety related items and 1 hour for non-safety related items.

Fire Cell

A sub-division of a larger fire compartment of concentrated fire load within a fire area (e.g. lubricating oil tank within turbine building) (see also 'Fire Compartment').

Fire Compartment

An area or compartment of a building or a building itself bounded by a fire resistive enclosure (walls, floor, ceiling or openings, if any) of a defined fire rating (see also 'Fire Cell').

Fire Damper

A device, which is designed for automatic and/or manual operation to prevent propagation of fire through a duct in a given condition.

Fire Detector

Devices designed to automatically detect and indicate the presence of fire.

Fire Load

The calorific potential of combustible materials contained in a space, including the facings of the walls, partitions, floors and ceilings.

Fire Prevention

Measures directed towards avoiding the inception of fire and spread of fire to other areas/zones.

Fire Protection

Measures directed towards prevention, detection and suppression of fire.

Fire Resistance/Rating (F)

The ability of an element of a stracture to maintain against fire for a stated period of time the required stability, integrity and/or thermal insulation as specified in the standard fire resistance tests.

Fire Retardant

The quality of a substance as a means of suppressing, reducing or delaying markedly the combustion of certain materials.

Fire Stop

Physical barrier designed to restrict the spread of fire in cavities within or between the elements of installation.

Fire Suppression

Measures directed towards control or extinguishment, or both, of fire through an automatic or fixed (manual) system, utilising an appropriate agent (such as water, carbon dioxide, foam or dry chemical powder).

Flammable

Any medium which is capable of undergoing combustion in the gaseous phase, with emission of light during or after the application of igniting source.

Flammable Liquid

A liquid having a flash point of 38^0 C or less and having a vapour pressure not exceeding 1.8 kg/cm^2 (g) at 38^0 C.

Flame Detector

A device which detects the infra-red, the ultra-violet or visible radiation produced by a fire.

Heat Detectors

A device, which detects and/or indicates a temperature or rate of temperature rise.

Line Type Detector

A device in which detection is continuous along a path.

Non-restorable Detector

A device, whose sensing element is designed to be destroyed by the process of detecting a fire.

Protection System

A part of the safety critical system which encompasses all those electrical, mechanical devices and circuitry, from and (including the sensors) up to the input terminals of the safety actuation system and the safety support features, involved in generating the signals associated with the safety tasks.

Quality

The totality of features and characteristics of an item or service that have the ability to satisfy stated or implied needs.

Quality Assurance (QA)

Planned and systematic actions necessary to provide the confidence that an item or service will satisfy given requirements for quality.

Raceway

Any channel that is designed and used expressly for supporting or enclosing wires, cable or bus-bars. Raceways consist primarily of cable trays and bus-ducts.

Redundancy

Provision of alternative structures, systems, components of identical attributes, so that any one can perform the required function, regardless of the state of operation or failure of the other.

Restorable Detector

A device, whose sensing element is not ordinarily destroyed by the process of detecting a fire. Restoration may be manual or automatic.

Sensitivity (Detector)

Relative degree of response of a detector to the parameter to be detected.

Smoke Detector

A device, which detects the visible or invisible particles of combustion.

Spot-type Detector

A device whose detecting element is concentrated at a particular location.

SPECIAL DEFINITIONS
(Specific for the Present Standard)

Air Sampling Type Detector

A sampling type detector consisting of piping or tubing distribution from the detector unit to the area(s) to be protected. An air pump draws air from the protected area back to the detector through the air sampling ports and piping or tubing. At the detector the air is analysed for fire products.

Automatic Sprinkler System

A fire control or extinguishing installation with normally closed sprinkler heads, whereby the closing bulb of those exposed to the heat at preset temperatures is shattered, thus releasing automatically, the sprinkler water.

Balance of Plant (BOP)

Those items of plant (also referred to as 'the conventional part') other than the 'nuclear island', in an operable nuclear power station.

Boundary

The external walls, floor and closing passages such as doors, hatches, pipes and cable entry ways that enclose the fire zone.

Cable Vault/Cable Gallery

The space or spaces adjacent or below electrical switchgear rooms through which interface electrical power cables are routed largely on cable trays.

Class 1E

The safety classification of electrical equipment and systems, which are essential to emergency reactor shut down, containment isolation, reactor core cooling and containment and reactor heat removal, or are otherwise essential in preventing significant release of radioactive material to the environment.

Coded Signal

Signal pulsed in a prescribed form in each round of transmission.

Control Equipment Rooms/Control and Instrumentation Cables Spreading Area

The space or spaces within, adjacent or below main control room where instrumentation and control cables to and from main control room/field converge on termination or instrumentation panels.

Critical Area

Those areas, which contain nuclear safety related structures, systems or components.

Critical Assembly or Mass

The minimum mass or volume of a stated arrangement of fissile material, which can become critical.

Criticality Incident

Inadvertent accumulation of fissile material into a critical assembly leading to criticality and the sudden and dangerous emission of neutrons, gamma rays and heat.

Delinquency Signal

A signal indicating the need of action in connection with the supervision of guards or system attendants.

Division

The designation applied to a given system or set of components that enables the establishment and maintenance of physical, electrical and functional independence from other redundant sets of components.

Dual Detector

A device that either responds to more than one fire phenomena or employs more than one operating principle to sense one of these phenomena.

Fire

(i) A process of combustion characterised by the emission of heat accompanied by smoke or flame or both.

(ii) Rapid combustion spreading uncontrolled in time and space.

Fire Classification

For all practical purpose, the basic types of fires can be grouped into following classes of fires:

Class 'A' Fire

Fires involving solid combustible materials of organic nature such as wood, paper, rubber, plastics, etc., where the cooling effect of water is essential for extinction of fires.

Class 'B' Fire

Fires involving flammable liquids or liquefiable solids or the like where a blanketing effect is essential.

Class 'C' Fire

Fires involving flammable gases under pressure including liquefied gases, where it is necessary to inhibit the burning gas at a fast rate with an inert gas, powder or vaporizing liquid for extinguishments.

Class 'D' Fire

Fires involving combustible metals, such as magnesium, aluminium, zinc, sodium, potassium etc., where the burning metals are reactive to water and water containing agents and in some cases also with Carbon dioxide, halogenated hydrocarbons and ordinary dry powders. These fires require special media and techniques to extinguish.

Fires (Electrical)

Where energised electrical equipment is involved in a fire, non-conductivity of the extinguishing media is of utmost importance, and only extinguishers expelling dry powder, Carbon dioxide (without metal horn) or vaporising liquids should be used. Once the electrical equipment is de-energised, extinguishers suitable for the class of fire involved can be used safely.

Fission Products

Nuclei (fission fragments) formed by the fission of heavy elements (Uranium, Plutonium) plus the nuclides formed by the radioactive decay of these fission fragments. Most of them are highly radioactive beta, gamma emitters.

Indicating Device Circuit

A circuit to which indicating devices are connected e.g. bells, horns, lamps etc.

Initiating Device Circuit

A circuit to which automatic or manual signal initiating devices are connected.

Hazards

Non-hazard Area

An area meeting the following requirements is designated as a non-hazard area.

(a) The area shall not contain high-energy equipment such as switchgear, transformers, rotating equipment, or potential sources of missiles or pipe failure hazards or fire hazards.

(b) Circuits in this area shall be limited to control and instrument functions and those power supply circuit cables and equipment located within the area.

(c) Power circuit cables in this area shall be installed in enclosed raceways.

(d) Administrative control of operations and maintenance activities shall control and limit introduction of potential hazards into the area.

Limited Hazard Areas

Limited hazard areas are those plant areas from which potential hazards such as missiles, exposure fires and pipe whip are excluded.

Note: In both limited hazard area and a non-hazard area, the only energy available to damage electrical circuits is that energy associated with failure or faults internal to electrical equipment or cables within the area. The primary difference between a limited hazard area and a non-hazard area is that power circuits and equipment are restricted in the non-hazard area.

Hazard Areas

(a) Pipe Failure Hazard Area:

An area, which contains piping normally operating at high or moderate energies.

(b) Missile Hazard Area:

An area containing missile source having sufficient kinetic energy under design basis event conditions to damage redundant class 1E circuits routed through the area.

(c) Fire Hazard Area:

An area shall be designated as a fire hazard area if it contains any of the following potential hazards:

(i) Liquids which are classified as flammable or combustible as per NFPA-321 - Basic classification of flammable and combustible liquids.

(ii) Solids exhibiting a flame spread classification of 26 or higher as per ASTM E 84-80 Test for surface burning characteristics of building materials.

(iii) Coatings exhibiting a flame spread classification of 50 or higher as per ASTM 84-80.

Note: An area need not be designated as a fire hazard area if administrative control provides suppression measures for temporary ignition source; use or the introduction of the above hazards is temporary or limited to an acceptable quantity.

Mimic Diagram

A topographic representation of the protected premises and their subdivision, such that the indications of the fire alarm system can be rapidly related to the layout of the premises.

Non-coded Signal

Signal from an indicating device, which is energised continuously.

Nuclear Island

Essentially, the nuclear steam supply system, or the nuclear installations comprising of an operable nuclear power station.

Nuclear Safety Related System

That part of the reactor installation which is essential for preventing, in any condition, the accidental release of the radioactive fission products from the reactor core, i.e. systems provided to assure the safe shut-down of the reactor and the heat removal from the core under shut-down conditions.

Off-gas Systems

System for treating gaseous effluents, other than normal ventilation, prior to release to the atmosphere.

Physical Separation

(a) Separation by geometry (distance, orientation etc.), or

(b) Separation by appropriate barrier, or

(c) Separation by a combination thereof.

Repeatability

Ability of a device to maintain a constant set-point characteristic.

Restart

A manually initiated start-up.

Safe State

Plant is considered to be in a safe state, when it is in all respects within those limits, which have been identified and specified for the purpose of limiting the risk due to that plant at any time.

Safety Related Systems and Components

Systems and components required to shut down the plant, mitigate the consequences of postulated accidents or maintain the plant in a safe shutdown condition.

Shall, Should or May

The word 'shall' is used to denote a mandatory requirement; the word 'should' to denote a recommendation; and the word 'may' to denote permission, neither a requirement nor a recommendation.

Smoke

Particulate and aerosol products of combustion generated by fire, whether this is of the smoldering or open flame type.

Spacing (detectors)

A horizontally measured dimension relating to the allowable coverage of fire detectors.

Standpipe and Hose Systems

A fixed piping system with hose outlets, hose, and nozzles connected to a reliable water supply to provide effective fire hose streams to specific areas inside the building.

Supervisory Signal

Signal indicating the need of action in connection with supervision of guards, sprinkler and other extinguishing systems or equipment or with the maintenance features of other protective systems.

Water Spray System

A fire control or extinguishing installation with open sprinkler heads used where it is desired to deliver water simultaneously through all sprinklers of that particular group of interconnected heads and to engulf the equipment to be protected in a fog like atmosphere of finely subdivided droplets.

CONTENTS

1. INTRODUCTION

1.1 General

Fire protection in the nuclear facilities is accorded a very high priority. The consequences of fire can be more severe in a nuclear installation due to the added risk of release of radioactivity. Hence there is a need for regulating the fire protection system in nuclear facilities and strengthen the fire safety aspects to ensure nuclear and radiological safety in addition to industrial safety.

1.2 Objective

The primary objective of this standard is to set forth fire protection guidelines for nuclear facilities to ensure a fire safe design. Plant management and designer should note that other considerations such as personnel safety, environmental safety and property protection might indicate a need for fire protection in the areas not specifically covered by this standard. Qualified personnel should be made responsible for engineering, design and maintenance of fire protection system and also for establishing and maintaining fire prevention, training and manual fire fighting activities. Implementation of this standard requires communication between the fire protection designer and the plant designer such that they are both aware of the system and the limitations of equipment.

1.3 Scope

1.3.1 The provisions of this standard shall apply to the fire protection systems of the following nuclear facilities:

(i) Pressurised heavy water reactors

(ii) Boiling water reactors

(iii) Pressurised water reactors

(iv) Fast reactors

(v) Spent fuel reprocessing plants

(vi) Heavy water plants

(vii) Fuel fabrication plants

(viii) Solvent production facilities and miscellaneous process plants

(ix) Other facilities such as IREL/RRCAT/VECC/UCIL and ECIL

1.3.2 This Standard provides criteria for fire prevention, detection and suppression systems of appropriate capacities and capability to minimise the adverse effect of fires on structures, systems and components important to plant safety. Requirements relating to conventional fire safety should generally be based on the national regulations and practices.

1.3.3 Fire protection requirements given in section 1 to 9 in this standard are generally applicable to all nuclear facilities. The requirements for a few specific facilities are covered in section 10. The requirements given in section 10 may be made applicable suitably for other nuclear facilities also.

2. BASIC APPROACH TO FIRE PROTECTION PROGRAMME

2.1 General

The aim of the fire protection programme is to minimise the probability and consequences of postulated fires. Means are needed to detect and suppress fires with particular emphasis on providing passive and active fire protection of appropriate capability and adequate capacity for the systems necessary to achieve and maintain safe plant shut down with or without off-site power. Fire protection system shall be designed to ensure that a failure, rupture or an inadvertent operation does not significantly impair the safety capability of the structures, systems and components.

The fire protection programme shall not only address the direct effects of flame, radiant heat and explosion but also the potential for the release of hazardous materials and hazardous combustion products in the event of fire and the potential for the release of water and other fire fighting media contaminated during fire fighting.

2.2 Defence-in-depth

Nuclear facilities use the concept of defence-in-depth to achieve the required high degree of safety. With respect to the fire protection programme also, the defence-in-depth principle shall be applied to achieve an adequate balance in:

(a) preventing fire from starting,

(b) detecting fires quickly, suppressing those fires which occur, putting them out quickly and limiting the damage, and

(c) designing plant safety systems, so that a fire that starts in spite of prevention programme shall not prevent essential plant safety functions from being performed.

The first objective requires that the design and operation of the plant be such that the probability of initiation of a fire is minimised. The second objective concerns the early detection and extinguishment of fires by a combination of automatic and/or manual fire fighting techniques and therefore relies upon active systems. For the implementation of third objective, particular emphasis shall be given to the use of passive systems, which would be the last line of defence, if the first two objectives were not effective.

2.3 Programme Implementation

The planning for fire protection programme is to normally start at the plant design stage itself and carried through construction, commissioning and operation phases. During the implementation stages, adequate emphasis be laid on the quality assurance of the fire prevention, installation of detection and suppression systems, to ensure that the programme's objectives are fully and satisfactorily met.

In the case of nuclear power plants, the applicable fire protection system shall be fully operational before the initial fuel loading in the reactor unit.

Likewise, in the case of nuclear installations other than reactors, the applicable fire protection system shall be fully operational before the facility is commissioned. However during pre-commissioning stage, when supplies of hazardous materials arrive at plant site, adequate interim arrangement for fire protection shall be provided for the same.

At sites, where operating nuclear installations exist and fresh construction work (of other units) is undertaken in close proximity, means shall be provided to protect the operating unit/installation against fire hazards at the unit/ installation under construction/ commissioning.

2.4 Fire Protection System Reliability

To achieve high reliability, the fire protection system shall utilise an inherent fire safe design to minimise fire hazards and the effects of a fire and include fire prevention programme, detection and rapid extinguishment of fires to limit the damage. An optimum combination of these three aspects should be selected to obtain a reliable fire protection system. Fixed fire protection systems (automatically or manually initiated) are considered the 'primary' means of fire suppression for areas in which they are installed. In these areas the standpipe and hose fire protection system is considered a 'back-up' system. In this context any single impairment of the fire protection system or direct support systems shall not incapacitate both the primary and back-up fire protection capability. Fire protection systems shall be designed to assure that an initiating failure such as break in fire protection lines or a single inadvertent actuation of the fire protection system cannot:

(a) damage the safety related system of plant, and

(b) prevent the habitability of the main control room or other areas requiring access for safe plant shut down.

2.5 Fire Hazard Analysis

2.5.1 A detailed fire hazard analysis (refer Appendix-A of this document for additional guidance) shall be made during initial plant design and shall include the proposed construction arrangements, materials and facilities. This analysis shall be revised periodically as design and construction progresses and before and during major plant modifications.

2.5.2 The fire hazard analysis should be a systematic study of (a) all elements of the fire protection programme being proposed to ensure that the plant design has included adequate identification and analysis of potential fire hazards (b) the effect of postulated fires relative to maintaining the ability to perform safe shutdown functions and minimising toxic and radioactive releases to the environment and (c) suggest remedial measures.

2.5.3 The fire hazard analysis should separately identify hazards and provide appropriate protection in locations where safety related losses can occur as a result of:

(a) concentrations of combustible contents, including transient fire loads due to combustibles expected to be used in normal operation such as refueling, maintenance and modifications,

(b) continuity of combustible contents, furnishings, building materials, or combinations thereof in configurations conducive to fire spread,

(c) exposure of fire, heat, smoke, steam and including those, which may necessitate evacuation from areas that are required to be attended for safe shutdown,

(d) fire in control rooms or other locations having critical safety related functions,

(e) lack of adequate access or smoke removal facilities that impede fire extinguishment in safety related areas,

(f) lack of explosion prevention measures,

(g) loss of electric power or control circuits, and

(h) inadvertent operation of fire suppression systems.

2.5.4 The fire hazard analysis should demonstrate that a design basis fire need not be postulated to be concurrent with some low probability non-fire related failures in safety systems, or with unlikely plant accident that would not in themselves cause fires. An example of such a low probability event is a fire and an independently occurring loss of coolant accident in a nuclear power plant. Also, for multi-unit plants, simultaneous unrelated fires in more than one unit need not be considered in the design of fire protection systems, but the possibility of a fire spreading from one unit to the other unit should be taken into account in the fire hazard analysis.

2.5.5 Persons trained and experienced in plant safety should perform the analysis of consequences of postulated fire on safety of the plant. The fire hazard analysis should be conducted for industrial fire prevention and control and in fire phenomena from fire initiation through its development to propagation into adjoining spaces. It should be done in consultation with the fire protection engineer.

2.6 Management Responsibility

2.6.1 The management shall establish and implement a fire protection programme, which complies with this standard. The responsibility for implementation of the fire protection programme shall be ensured through the design, construction, commissioning, operation and decommissioning phases.

2.6.2 The feasibility of mutual aid scheme with neighbouring industries may be worked out by the management for effective mitigation of fire emergencies.

2.6.3 The construction and commissioning phases are very critical with respect to fire potential in view of simultaneous working of many agencies at the site, difficulty in controlling the transient fire loads, volume of cutting and welding works, absence of a fully operable fire protection system and trained work force etc. Adequate supervision shall be ensured during these phases.

2.6.4 The management shall ensure:

(a) coordination of fire protection programme requirements, including consideration of potential hazards associated with building layout and system design,

(b) design, testing and maintenance of fire detection and suppression systems,

(c) fire prevention activities, including the preparation of plant procedures and administrative controls,

(d) training of plant personnel and fire brigade personnel on fire fighting activities,

(e) pre-fire planning,

(f) effective implementation of the overall fire protection quality assurance programme, and

(g) analysis of proposed changes in existing fire protection systems and approval prior to implementation of the change.

3. DESIGN REQUIREMENTS FOR FIRE PREVENTION

3.1 General

3.1.1 Design requirements to minimise the consequences of fire shall be specified in the early stage of design. The concept of defence-in-depth against fire and its consequences as it applies to fire prevention requires:

(a) Limiting the inventory of combustibles to the minimum extent practicable.

(b) Separation of redundant safety related divisions such that a single fire cannot prevent the performance of a required nuclear safety function.

(c) Separation of critical areas from non-critical areas such that a single fire in any non-critical area cannot prevent the performance of safety function for either of the divisions.

(d) Establishing administrative procedures to control hazardous operations and introduction of combustible material.

(e) Ventilation system to control the spread of fire and smoke.

3.2 Building Design

3.2.1 The plant shall be divided into several individual fire areas to reduce the risk of spread of fire and consequent damage and to prevent common mode failures of redundant safety related systems.

The division of fire areas should take into consideration:

(a) Restricted and non-restricted areas

(b) Essential plant items for safety purposes

(c) High fire loads

(d) Areas with a high value density (such as control room, plant computer, instrument room)

(e) Access, escape routes and fire exits.

All the buildings and working areas (each floor) of the facility shall be provided with adequate numbers of fire escape stairs/exits. These shall meet following requirements:

(a) The access to the exits shall never be blocked.

(b) The exits shall also be marked in language/s understood by majority of the workers.

(c) Exits shall be so located that the travel distance on the floor shall not exceed 30 m.

(d) Opening from staircase to any portion of the building shall be fitted with fireproof door. Iron rung ladders or spiral staircases shall not be used as exit staircases.

(e) Hollow combustible construction shall not be adopted for staircases.

(f) Basement areas shall be provided with staircase/ramps for access from basement to outside of the building at ground floor level. Normally two such staircases/ramps having width of 1 m for each basement shall be provided.

3.2.2 Interior wall and structural components, thermal insulation materials, radiation shielding materials, and soundproofing materials shall be non-combustible.

3.2.3 Interior finishes shall in general, be non-combustible or of tested and listed by a nationally recognised testing laboratory for

(a) Surface spread of flame rating of 50 or less when tested under ASTM E-84, and

(b) Potential heat release of 8141 kJ/kg or less when tested under ASTM D-3286 or NFPA 259.

Materials, which are acceptable for use as interior finish without evidence of test and listing by a nationally recognised laboratory are the following:

(a) Plaster, acoustic plaster, gypsum plaster board (gypsum wall-board).

(b) Any of the above, plain, wall papered, or painted with oil or waterbase paint.

(c) Ceramic tile, ceramic panels.

(d) Glass, glass blocks.

(e) Brick, stone, concrete blocks, plain or painted.

(f) Steel and aluminium panels, plain, painted or enameled.

(g) Vinyl tile, vinyl-asbestos tile, linoleum, or asphalt tile on concrete floors.

3.2.4 Floors, walls, and ceilings separating fire areas shall have ‘adequate’ (see definition under fire barrier) fire rating. Openings through fire barriers around conduit or piping shall be sealed or closed to provide a fire resistance rating of at least equal to that required of the barrier itself. Door openings shall be protected with equivalent fire rated doors with frames and hardware that have been tested and approved by a nationally recognised laboratory. Such doors shall be normally closed and should be equipped with automatic self-closing devices with doors opening outside the fire area. Fire barrier openings for ventilation systems shall be protected by a fire damper actuated by fire detection system having a rating equivalent to that required for the barrier.

3.2.5 For fire areas housing special safety systems/equipment or high value densities within a building, a further separation of fire zones within that fire area with appropriate fire rating as specified should be provided.

3.2.6 Fire barriers of adequate rating, shall be provided to

(a) Isolate safety-related systems from any potential fires in non-safety related areas that could affect their ability to perform safety function.

(b) Separate redundant divisions or trains of safety-related systems from each other so that both are not subjected to damage from a single fire hazard

(c) Separate individual units on a multi-unit site.

3.2.7 Buildings containing safety related systems shall be protected from exposure or spill fires involving out door oil-filled transformers by providing oil spill confinement or drainage away from the buildings and

(a) Locating such transformers at least 15 m away from the buildings.

(b) Ensuring that such building walls within 15 m of oil-filled transformers are without openings and have adequate fire resistance rating.

3.2.8 Transformers installed inside fire areas containing safety related systems shall be of the dry type or insulated and cooled with non-combustible liquid. Where transformers filled with combustible fluid are located in non-safety related areas, there shall be no openings in the fire barriers separating such transformers from areas containing safety related systems or equipment.

3.2.9 Personnel access and escape routes shall be provided for each fire area. These routes should consider the risks, such as smoke, toxic gases, radiation doses, scalding, electrical injuries etc. and the requirements arising from plant incidents such as confinement of radioactive matter.

3.2.10 Fire exit routes shall be clearly marked.

3.2.11 Staircases serving as escape routes shall be separated from the rest of the building by construction with adequate fire rating.

3.2.12 Cable spreading rooms shall not be shared between units on a multi-unit site.

3.2.13 The main and the emergency control rooms shall not be housed in the same fire compartment/area.

3.2.14 Floor drains sized to remove expected fire fighting water flow without flooding safety related equipment shall be provided in those areas where fixed water fire suppression systems are installed. Floor drains shall also be provided in other areas where hand hose lines may be used, if such fire fighting water could cause unacceptable damage to safety-related equipment in the area.

Suitable pumping arrangements shall be made in basement and other areas where fire water may accumulate. Where gas suppression systems are installed, the drains shall be provided with adequate seals or the gas suppression system shall be sized to compensate for the loss of the suppression agent through the drains. Drains in areas containing combustible liquids shall have provisions for preventing the spread of the fire throughout the drain system. Water drainage from areas that may contain radioactivity/toxicity shall have provision for sampling for analysis before discharge as per the approved procedures for discharge of such effluents.

3.3 Control of Combustibles

3.3.1 As far as practicable, use of noncombustible materials shall be specified for the construction of structure and systems. Where this cannot be achieved, efforts shall be made to reduce the quantity of combustible materials or to reduce the combustibility of the materials by using fire-retardant additives or fire resistant coatings.

3.3.2 In selecting materials with low contribution to fire load:

(a) Preference should be given to cable materials containing low halogens.

(b) Use of combustible materials in air filters and their frames shall be minimised.

(c) Preference should be given to less flammable hydraulic control fluid for the control system of steam turbines and other machines.

(d) Dry type transformers should be used indoors wherever appropriate.

(e) As a minimum, all buildings shall be of noncombustible material construction as per National Building Code of India 2005-Part IV.

3.3.3 Structures and equipment installed indoors shall be made of non-combustible materials to the extent practicable. Items such as penetration sealing materials, structural finishes such as painting and surface layers, adhesives, linings, ducts, and suspended ceilings and their supports should be of approved noncombustible materials. Use of plastics which produce corrosive combustion products including smoke shall be kept as low as practicable, especially in areas of high concentration for electronic instruments and control installations, which are susceptible to corrosion by gases liberated during a fire. Precautions should be taken to prevent insulating materials, which have the capability of absorbing oil or other fluid combustibles from accumulating the same.

3.3.4 In case, where a floor covering is required, non-flammable compound should be used and laid directly on a non-combustible surface, e.g. a concrete floor. In particular, halogenated plastics that are not fire-retardant shall not be used.

3.3.5 The amount of combustible materials stored indoors and normally exposed to the danger of fire should be reduced by having the supply of materials (such as oil) kept to the minimum, consistent with the operational requirements, whereas the bulk supply should be kept outside the buildings containing items important to safety. Use and storage of compressed gases (especially oxygen and flammable gases) inside buildings housing safety related equipment should be controlled. Bulk storage of flammable gas should not be permitted inside the structures housing safety related equipment and should be kept at a sufficiently remote location, such that a fire or explosion will not adversely affect any safety related system or equipment.

3.3.6 The supply cylinders or special containers of hydrogen and their distribution manifold should be kept in a well ventilated and sheltered location, preferably not inside such buildings containing items important to safety. Where mechanical ventilation is necessary, the system should be designed to maintain hydrogen concentration below 1% by volume. Each station electrical battery room containing batteries which may generate hydrogen during operation shall be provided with a separate ventilation exhaust arranged to discharge directly to outside, so that the hydrogen concentration is kept below 1%. Attention should be given to the availability of the system by means of redundant components.

3.3.7 Systems containing combustible or flammable liquids or gases should have a high degree of integrity and should be protected from vibrations or other destructive effects to prevent leakage of such materials. Similarly, collection facilities should be provided for combustible or flammable liquids in case they leak.

3.3.8 Safety related systems should be isolated or separated from combustible materials. When this is not possible because of the nature of the safety system or the combustible material, automatic fire suppression should be provided to limit the consequences of a fire.

3.3.9 Insulating and jacketing materials for cables should be chosen to have a high flame resistance and low smoke and off gas characteristics without degrading the required electrical and physical properties.

3.3.10 Storage and usage of flammable materials should, as a minimum, comply with the following requirements of Factories Act 1948, Petroleum Act 1934, Explosive Act 1884 and their rules.

(a) Packing materials, combustible liquids and explosive substances shall be stored at a safe distance from plants and stores.

(b) Materials like timber shall be stored in such a way that there may not be any possibility of fire hazards.

(c) The storeroom, where plastic and rubber sheets are stored, shall be well ventilated.

(d) All containers of paints, thinners and allied materials shall preferably be stored in a separate room, which is well ventilated and free from excessive heat, sparks of flame or direct rays of sun. The containers of paint shall be kept covered or properly fitted with lid and shall not be kept open.

(e) Oil filled drums shall be transported in drums carriers and shall not be allowed to be rolled while shifting. Oil drums shall be stored in separate enclosures with lock and key.

3.3.11 Gas Cylinders

(a) Whenever the leakage of dangerous gases/vapour is sensed/felt, all the persons working in the area shall be withdrawn and no electrical device shall be switched on/off within the premises so as to prevent spark, which may initiate fire.

(b) A well-ventilated storeroom shall be provided for handling and storage of cylinders. Empty cylinders shall be stacked away from filled cylinders. 'Full' or 'Empty' notices shall be displayed on each relevant stack.

(c) All compressed gas cylinders must be properly secured to prevent toppling. When stacking vertically, it shall be ensured that they are properly secured so that they do not fall.

(d) The cylinders shall be protected from extreme temperature, physical damage and electricity.

(e) Oxygen, acetylene and other fuel gas cylinders shall be stored in upright position.

(f) Cylinders shall not be kept in a battery charging room or in oil storage room or in places where there is a likelihood of oil, acid or any other corrosive liquid being splashed on them.

(g) During unloading, cylinders shall not be dropped from a height and should also be protected from impact of each other.

(h) Loading, unloading and transportation of gas cylinders should be done in a safe manner.

(i) While handling hydrogen gas, care shall be taken so that hydrogen gas does not come in direct contact with oxygen/air to avoid any explosion.

(j) Regular checks shall be made to ensure that there is no leakage of gases from cylinders and associated fittings.

(k) All the places wherever hydrogen is being handled shall be guarded by suitable enclosure and the entry should be restricted to authorised person only. Proper ‘Caution Boards’ in English as well as in local language shall be displayed at appropriate places. The stubs where the hydrogen cylinders are fitted to fill the hydrogen gas shall be capped when not in use.

(l) All cylinders shall have protective caps over the valve at all the times except when in use.

(m) Cylinders containing compressed gas may only be exposed in open if they are protected against excessive variation of temperature, direct rays of sun or continuous dampness. Such cylinders shall never be stored near highly inflammable substances. The room where such cylinders are stored shall have adequate ventilation.

(n) In addition to above provisions, the Gas Cylinder Rules shall also be strictly adhered to.

3.3.12 Hazardous Chemicals

Handling of hazardous chemicals should be done as per material safety data sheet (MSDS) under the supervision of competent person.

(a) The persons engaged with the work shall be trained for the safe handling of hazardous chemicals. They should know the action to be taken in case of a fire, spillage and any mishap.

(b) All chemicals should be properly identified before relocation, observing material safety guidelines and regulations. Incompatible chemicals shall be properly separated in storage, such as oxidisers separated from flammables.

(c) All chemical processes shall be carried out in well-ventilated locations.

(d) Absorbing spilled acid with saw dust, waste cloth or other organic material shall be prohibited. It shall always be flushed out with water or neutralised with chalk or lime.

(e) Overfilling of tanks storing chemicals shall be avoided. Precautions shall be taken to avoid the breakage of hoses and failure of joints.

(f) Caution boards in English as well in local language shall be displayed near the site where hazardous chemicals are being used/stored in the plant. The boards shall indicate important properties of the chemicals along with necessary precautions.

(g) Eye wash fountains and showers shall be provided where hazardous chemicals are handled/stored.

3.4 Ventilation

3.4.1 Products of combustion from all postulated fires shall be controlled and removed to reduce the extent of fire damage and hazards to personnel.

3.4.2 Where an area is vented into another area (e.g. from a low radioactive contamination area to a higher radioactive contamination area), and ventilation control cannot be determined on fire protection reasons alone, the consequence of heat and smoke spread shall be assessed. Wherever necessary, manual, remote controlled fire dampers shall be provided in exhaust openings of the upstream room.

3.4.3 Each fire area containing a redundant division of a safety system should preferably have an independent and fully separated ventilation system. The portions of this ventilation system (e.g. connecting ducts, fan rooms, filters) situated outside the fire area shall either have the same fire resistance as the area or, alternatively, the fire area shall be isolated by fire dampers with the same fire resistance rating; in which case those portions of the ventilation system outside the area may not require any fire resistance.

3.4.4 If a ventilation system serves more than one fire area, the portions of the ventilation systems located outside each fire area shall also have the same fire resistance as of the fire areas. Means shall be provided to minimise the spread of smoke between the fire areas by natural ventilation, limited pressurisation or by smoke prevention flaps. Alternatively, fire dampers shall be fitted at appropriate locations on the plant to isolate the affected fire area to prevent the spread of fire, heat or smoke to another fire area. For such systems, the change of pressure within the ventilation system and the affected fire area due to temperature rise, smoke production or equipment failure caused by the fire shall also be taken into account; even a separate fire venting system/smoke extraction system may be necessary.

3.4.5 Supplementary smoke control methods shall be provided when the fire hazard evaluation dictates that such measures are necessary to permit accessibility for fire fighting; maintain a safe environment for personnel access in areas containing nuclear safety related systems; and control damage to nuclear safety related components from the spread of corrosive gases.

3.4.6 The products of combustion, which need to be removed from a specific fire area shall be evaluated to determine the methods of control. In addition, any ventilation system designed to exhaust smoke or corrosive gases shall be evaluated to ensure that inadvertent operation or single failure cannot violate the isolation requirements for the radioactive controlled areas in the plant design or compromise redundant safety functions. This requirement includes containment functions for protection of the public and maintaining habitability for operation personnel.

3.4.7 In areas that contain or may potentially contain radioactive materials, venting of smoke and gases shall be monitored and controlled consistent with other safety considerations. Some acceptable methods to comply with the above are to:

(a) Contain the smoke in the fire area.

(b) Reduce the contamination prior to release from the plant. Some acceptable methods are: release at a controlled rate; process through existing plant filter trains; provide a system for smoke clean up prior to release.

3.4.8 Fresh air supply intakes to all areas shall be located remotely from the exhaust air outlets and smoke vents of other fire areas and away from any exterior fire hazards to minimise the possibility of contaminating the intake air with the products of combustion.

3.4.9 Special protection for ventilation power and control cables should be considered. The power supply and controls for mechanical ventilation systems should be run outside the fire area served by the system where practicable.

3.4.10 The main and the supplementary control areas shall be on separate ventilation systems.

3.4.11 Continuous ventilation shall be provided in areas where flammable gases or vapours may be present.

3.4.12 Enclosed stairwells that serve as fire exits shall be designed to minimise smoke infiltration during a fire.

3.4.13 Ducts and Fire Dampers

Duct system shall be designed to limit the number of fire barrier penetrations to those essential for safe operation. Ventilation ducts penetrating or serving critical areas shall be non-combustible.

Dampers required by this standard are for the purpose of maintaining the integrity of a fire barrier or controlling combustion products.

Air duct penetrations in fire barriers shall be provided with approved automatic fire dampers with a fire rating equivalent to the designated fire rating of the fire enclosure penetrated. Closure of fire dampers may be initiated by several diverse means based on the hazard involved.

3.4.14 Air Filters

Where combustible air filters have to be used in ventilating systems posing a fire hazard that could affect the nuclear safety-related components, the filters shall be protected as determined by a fire hazard analysis.

High-efficiency particulate air filters used in nuclear safety-related ventilating systems shall conform to the requirements of underwriters laboratory, inc., ‘Standard for Test Performance of High-efficiency, Particulate, Air Filter Units’, UL 586-1977.

Where charcoal adsorbed beds are required in nuclear safety-related ventilating systems, each redundant charcoal bed assembly shall be separated by adequate fire barrier. Fixed fire protection need not be provided for charcoal adsorber beds containing less than one hundred pounds (45 kg) of charcoal. Fixed fire protection shall be provided for larger charcoal filters, except when a temperature monitoring system, filter train isolation dampers and decay heat removal capability are provided.

3.4.15 Where natural convection ventilation is used, a minimum ratio of vent area to floor area shall be 1 to 200 except in oil hazard areas where a 1 to 100 ratio shall be provided.

3.4.16 Where total flooding gas extinguishing systems are used, area intake and exhaust ventilation dampers should be controlled in accordance with NFPA 12, 'Carbon Dioxide Systems' to maintain the necessary gas concentration for fire suppression.

3.5 Electric Circuits and Equipment

3.5.1 Fire survival cables shall be used for safety circuits where redundancy of safety circuits cannot be ensured due to various constraints.

3.5.2 In closed ventilated areas, where smoke/heat venting is not possible, for power cables (415 V and below) and control and instrumentation cables, halogen-free, fire-retardant, low smoke materials shall be used for sheathing.

3.5.3 Electric cable constructions shall pass the flame test as per IS : 10810:1984 (PT53) 'Method of Test for Cables : Part 53 Flammability Test'.

3.5.4 Oil impregnated cables shall not be used indoors.

3.5.5 Metallic cable trays and tubing for conduits shall be used. Flexible metallic tubing should be used only in short lengths for connections to equipment. Wherever cable tray covers are specified, they shall be constructed of the same material as that of the cable tray.

3.5.6 Cable trays are separated into power cable trays and control and instrumentation cable trays.

3.5.7 Segregation of cable trays shall be followed in the following order from top to bottom:

EHV power cables

HV power cables

MV power cables

Instrumentation and control cables

3.5.8 Percentage fill for power and control cable trays shall be as per NFPA code Vol-6 (national electric code)

3.5.9 Routing should be so chosen to avoid passing close to the equipment such as steam pipelines, oil pipelines, resistor grids and process equipment which are capable of producing heat. Where cables are required to be routed for loads located close to such systems, protection shall be provided to these cables. The cables shall be protected against oil spillages.

3.5.10 When routed under grid type walkways or similar structures, additional physical protection shall be provided in the form of solid covers or barriers located above the cable tray.

3.5.11 In long run of horizontal cables, fire stops at suitable intervals shall be provided to check the spread of fire.

3.5.12 Cable and cable tray penetration fire barriers (vertical and horizontal) shall be sealed to give protection at least equal to that of fire barrier. The design of the fire barriers for horizontal and vertical cable trays shall, as a minimum meet the requirements of IS : 12459-1993 'Code of Practice for Fire Protection of Cable Runs'.

3.5.13 Water based fire protection systems shall be provided as primary fire suppression for the cable fires.

3.5.14 Potential fires due to lightning shall be considered. Lightning protection shall be made as per IS-2309.

3.5.15 Cable trays shall be used for cables only.

3.5.16 Miscellaneous storage and piping for flammable or combustible liquids or gases should not create any potential exposure hazard to important cable systems.

3.5.17 Transformers

(a) All transformers shall meet the requirements of 'The Indian Electricity Rules, 1956' (Amended in 2000).

(b) Transformers installed inside fire areas containing systems important to safety should be of the dry type or insulated and cooled with noncombustible liquid. Transformers filled with combustible fluid, which are located indoors, should be enclosed in a transformer vault. (see NFPA 70).

(c) Outdoor oil-filled transformers should have oil spill confinement features or drainage away from the buildings. Such transformers should be located at least 15 m (50 feet) away from the building, or building walls within 15 m (50 feet) of oil-filled transformers should be without openings and have a fire rating of at least 3 hours.

(d) Transformers shall be provided with a danger notice permanently in a conspicuous position in Hindi or English and local language with sign of skull and bones as specified in respective Indian Standard.

(e) The frame of every transformer shall be earthed by two separate and distinct connections to the earth pit.

(f) All the transformers shall be maintained in accordance with the maintenance schedule given in the relevant code of practice of BIS and the authorised person shall keep a record thereof.

(g) Dry type of transformers shall be used for installations inside buildings in future installations.

(h) The transformers shall be protected by an automatic high velocity water spray system or by carbon dioxide or Halon alternatives fixed installation system or nitrogen injection and drain method.

(i) Gas pressure type protection to give alarm and tripping shall be provided on all transformers of rating 1000 KVA and above.

(j) The building housing the oil-filled transformer having an individual or aggregate oil capacity of 2000 litres or more shall be separated by a distance of not less than 6 m from all other buildings. If the building housing the transformer is within 6 m of the surrounding building, there shall be adequate fire rating barriers and fire suppression means.

(k) Oil-filled transformers or other apparatus, having an individual or aggregate oil capacity of 2000 liters, shall be segregated by 355 mm thick fire resisting brick wall or 230 mm thick RCC. The separating wall shall be carried up to a height at least 600 mm above the top of the equipment or up to the roof level of the equipment vault so separated.

(l) Each building housing oil filled apparatus containing 2000 litres or more of oil shall be provided with oil drains of at least 150 mm in diameter and soak pits, the latter being not less than 2.5 m away from the building. Floors shall be sloped not less than 1 in 96 towards oil drains. The soak pits shall be of sufficient capacity to take the entire oil content of the equipment and designed to provide for drainage of liquids to a safe location.

(m) A minimum clearance of 750 mm shall be provided between the transformer or other apparatus and enclosing or separating walls.

(n) All transformers shall have suitable isolating equipment on both high and low/medium tension side.

(o) It is essential in all transformer houses and in places of similar applications that an efficient and distinctive indicating device be provided to show clearly whether the supply in the main incoming cable is 'On' or 'Off' for the safety of fire-fighting personnel in the event of an outbreak of fire.

(p) Transformers and equipment installed outdoors, having an individual or aggregate oil content of 2000 litres or more shall be located in a suitably fenced enclosure separated on all sides by at least 6 m.

(q) Separating walls shall not be necessary in case of transformers having an aggregate oil capacity exceeding 2000 litres but individual oil capacity of less than 5000 litres if the distance between transformers and other apparatus is more than 6 m or if the transformers are protected by an approved high velocity water spray system.

(r) However, where oil capacity of individual transformer is larger than 5000 litres separating walls shall be provided unless all equipment/ building/plant are located at a clear distance of not less than the following:

Oil Capacity of Individual Transformer (litres)	Clear Separating Distance (m)
5000 - 20 000	8
Over 20 000	15

3.5.18 Cable Trenches

Trenches shall be lined with suitable plaster and always be kept clean. Trenches shall be provided with trench covers.

(a) The trench elevation shall be envisaged so as to prevent entry of rainwater or any undesired liquid.

(b) Suitable arrangement shall be made for dewatering the trenches and periodical dewatering shall be ensured. Provision to drain firewater shall also be made.

(c) Adequate space shall be provided in trenches for carrying out maintenance works.

(d) All cable outlet points in the trench shall be insulated/sealed with fire resistant materials/fiber wools or light PCC to prevent spreading of fire.

(e) Fire barriers shall be provided in cable trenches at periodic intervals.

(f) Cable trenches inside the substations and switch stations containing cables shall be completely covered with non-flammable slabs, or filled with sand, pebbles or similar non-inflammable material.

(g) The metallic covering or sheathing of every cable shall be electrically and mechanically continuous and protected against corrosion.

4. DESIGN REQUIREMENTS FOR FIRE DETECTION AND SUPPRESSION SYSTEMS

4.1 General

4.1.1 Fire detection and suppression systems are one of the three echelons of the defence-in-depth to achieve the degree of fire safety necessary in nuclear facilities. Fire detection devices provide early warning for implementation of emergency action and may be used to actuate fire extinguishing systems ensuring prompt and effective application of extinguishing agents to gain maximum freedom from risks and hazards due to problems such as inaccessibility, delayed discovery, delayed response, manpower deficiencies and erroneous operation.

4.2 Fire Detection and Alarm System

4.2.1 In designing fire detection and alarm systems, it is important to consider the reliability of the system and individual components to always perform their required functions. For fire detection systems, this reliability may be affected by the reduction in sensitivity or of sensing devices leading to non-detection or late detection of a fire, or the spurious operation of an alarm system when no smoke or fire hazard exists.

4.2.2 Each fire area shall be equipped with reliable fire detection and specifically engineered alarm systems.

4.2.3 The detection system shall annunciate by audible and visual alarms in the control room and in-house fire station. Local audible and visual alarms, as appropriate, shall also be provided in areas normally manned at other specific locations. For the purpose of providing a warning to personnel who may enter or who may be working in an area equipped with potentially hazardous automatic fire extinguishing systems (e.g. carbon dioxide), suitable audible and visual alarms shall be provided within and also at each entrance of the area and there shall be adequate written procedures to ensure the safety of the personnel entering such areas. Fire alarms shall be distinctive and shall not be capable of being confused with any other plant alarm.

4.2.4 Reliable power supply shall be ensured for the fire detection and alarm system. To take care of failure of main supply, emergency power from diesel generating set and backup supply from battery system should be provided.

4.2.5 The selection of detectors shall be based on the nature of products released by the heating up, carbonization, or the initial bursting into flame of the materials present in the fire hazard area. The appropriateness of the detection system shall be confirmed by fire hazard analysis. Fire detectors and detection system shall be as per the guidelines provided in the Appendix-B.

4.2.6 The individual detectors shall be placed within a fire area such that the flow of air due to ventilation or pressure differences dictated by contamination control would not cause smoke or heat to flow away from the detectors and thus cause undue delay in actuation of the detector alarm. Fire detectors should also be placed in such a way as to avoid spurious signals due to air currents generated by the operation of the ventilation system. Suitability of the location of the detectors shall be verified by in situ testing for prompt detection.

4.2.7 Selection of fire detection equipment shall take into account the environment in which it functions, e.g. radiation fields, humidity, temperature and air flow. Where the environment (e.g. higher radiation level, high temperature etc.) does not allow detectors to be placed immediately in the area to be protected, alternative methods, such as sampling of the gaseous atmosphere from the protected area should be considered for analysis by remote detectors with an automatic operation.

4.2.8 Where necessary, certain equipment such as fire pumps, spray systems, ventilation equipment and fire dampers shall be controlled and activated by the detection systems. Where spurious operation is detrimental to the plant, activation shall be by two lines of protection system.

4.2.9 Provision for manually activated fire alarms shall also be made.

4.3 Fire Suppression System

In selecting the type of suppression system for installation, consideration shall be given to response time, type of combustible material/s present as indicated in the fire hazard analysis, possibility of thermal shock, its effect on human beings (e.g. asphyxiation) and on items important to safety (e.g. reaching criticality condition during water or foam flooding in the nuclear fuel storage area). Reliable power supply shall be ensured for electrically operated control valves meant for automatic suppression systems.

4.3.1 Water Systems

4.3.1.1 Fire suppression systems, which employ water as means for suppression of fire, could be principally categorised under fixed water extinguishing systems as follows:

(a) Sprinkler and other water spray systems.

(b) Fire hydrant or standpipe and hose systems.

4.3.1.1.1 Sprinkler and Other Water Spray Systems

Complete automatically initiated water sprinkler protection should be provided as a conservative measure in all those locations of the plant or facility where, significant amounts of combustible material might be present, which would result in unacceptable fire damage in the event of an uncontrolled fire. Such a design measure may also take into account aspects other than safety (for example: spread of contamination). Generally, water systems are preferred in areas containing a high fire load of class-A materials including electrical cable material and other combustibles where the possibility of deep-seated fires exist. Water sprinklers may also be used for installations with large quantities of oil (for lubrication or transformer cooling). Further, in cases where gas or other extinguishing systems are provided for primary fire protection, water systems serve as a good backup fire protection.

Sprinkler/spray extinguishing systems shall, as a minimum, conform to requirements of appropriate standards such as NFPA 13, 'Standard for the Installation of Sprinkler Systems' and NFPA 15, 'Standard for Water Spray System' and IS : 9972-1981 : 'Specification for Automatic Sprinkler Heads'.

The type of sprinkler/spray system to be used and the arrangement of the sprinkler/spray system need to be designed specifically for the hazard. In addition to the expected fire exposure as determined in the fire hazard analysis, various factors should be addressed in the design of sprinkler systems. Among these factors are:

(a) Spacing and location of sprinkler heads.

(b) Temperature rating and thermal response time of the sprinkler heads.

(c) Water discharge rate or discharge density necessary for extinguishment.

To provide proper response to fire emergencies, sprinkler/spray systems should preferably be automatically actuated. Manually operated sprinkler systems should only be used in cases where it has been clearly demonstrated in the fire hazard analysis that delayed operation of the sprinkler system during a fire emergency will not compromise plant safety and other considerations.

4.3.1.1.2 Water Spray Systems

Two types of water spray systems shall be provided in a facility depending upon their application viz. high velocity water spray system and medium velocity water spray system. Both the systems shall be provided with automatic detection for immediate automatic/manual activation in case of fire. The detection could be by quartzoid bulb detector network, linear heat sensing cable, smoke detector etc.

 High Velocity Water Spray System (HVWS)

HVWS system should be provided at the following areas:

- Transformers, oil filled equipment.
- Oil burners, turbine lube oil tanks, oil purification unit.

- Hydrogen cooling and seal oil equipment.
- Storage tanks of flammable liquids.

Water application rate (discharge density) should not be less than 10.2 lpm/m^2 of surface area.

The hydraulic design of the system should be such that water pressure inside the system should be 3.5 kg/cm^2 to 5.0 kg/cm^2.

- Medium Velocity Water Spray System (MVWS)

MVWS system should be provided at cable galleries, cable shafts and storage of solid combustibles.

Water application rate (discharge density) should not be less than 10.2 lpm/m^2.

The hydraulic design of the system should be such that water pressure inside the system should be 1.4 kg/cm^2 to 3.5 kg/cm^2.

For cable galleries and tunnels, water application rate (discharge density) should not be less than 12.2 lpm/m^2 at a minimum pressure of 2.8 kg/cm^2. For efficient control of fire in long cable galleries, area should be divided into multiple zones of fire detection and suppression. Suitable drainage of cable gallery floors shall also be made.

4.3.1.1.3 Sprinkler System

The sprinklers operate automatically at pre-determined temperatures to discharge water over the affected part of the area below the installation. The flow of water through the valve initiates a fire alarm. The application of this system should be made at stores, buildings and other areas, which remain normally unoccupied.

4.3.1.1.4 Fire Hydrant or Standpipe Hose Systems

Standpipes with hose connections equipped with approved fire hose and nozzles shall be provided for areas containing or exposing nuclear safety-related structures, systems or components and shall be spaced so that these areas are accessible to at least one hose stream. Water supply (continuous) and hoses (appropriate) shall be provided for the containment. Fire hose stations shall be conspicuously located as dictated by fire hazard analysis and shall not be blocked. The fire hose standpipe system shall be used for fire-fighting only. Alternative hose stations shall be provided for an area if the fire hazard could block access to a single hose station serving that area.

Fire hydrant or standpipe hose system, should, as a minimum, conform to requirement of appropriate standards such as NFPA 14, ‘Standpipe and Hose

Systems' or IS : 5714-1981 or the latest amendment 'Hydrant Standpipe for Fire Fighting' for sizing, spacing and pipe support requirements. While designing the system, the following factors shall be considered.

(a) Provision shall be made to supply water to standpipes and hose connections for fire fighting in areas within hose stream reach of equipment required to provide and maintain safe plant shut down in the event of a safe shutdown earthquake (SSE).

(b) Outside hose installations shall be sufficient to reach any external portion of nuclear safety-related structures, systems or components with an effective hose stream. To accomplish this, hydrants should be installed on the yard loop system in areas adjacent to nuclear safety related structures.

(c) Selection of proper type of hose nozzle shall be based on the fire hazard analysis. The usual combination spray/straight stream nozzle shall not be used in areas where the straight stream can cause unacceptable mechanical damage.

(d) Each hydrant hose and standpipe riser shall have connections, which are compatible with fire tenders and other mobile fire fighting equipment.

(e) Each branch line to a separate building shall have at least two independent connections to the fire water main loop such that the water supply is assured even in the event of failure of one connection.

(f) Sprinkler systems and manual hose station standpipes shall have connections to the plant underground water main so that no single active failure can impair both the primary and backup fire suppression systems. Alternatively, headers fed from each end are permitted inside the buildings to supply both sprinkler and standpipe systems, provided steel piping and fittings meeting the requirements of ANSI B31.1, 'Power Piping' are used for the headers up to and including the first valve supplying the sprinkler systems where headers are part of the seismically analysed hose standpipe system. When provided, such headers are considered to be an extension of the yard main system. Hose standpipe and automatic water suppression systems serving a single fire area shall have redundant independent connections to the yard main system. Each sprinkler and standpipe system shall be equipped with outside screw and yoke type gate valve or other approved shutoff valves. Audible water flow alarms shall be provided on sprinkler deluge valves. Safety related equipment that does not require sprinkler water for fire protection and where fire water can cause unacceptable damage shall be protected by water shields or baffles.

(g) Internal and external hydrants shall be provided for complete plant including all its buildings. Hydrant system shall meet the following requirements:

- The main hydrant line shall be in ring form with isolating arrangement and the ring-main of the hydrant system should be either below the ground level in suitable trenches or above ground or a combination of the two.
- Hydrant outlets shall be located within 2 m - 15 m distance from the building/block to be protected and 15 m away from fuel oil storage tanks.
- Distance between two hydrant outlets should be either 45 m or 30 m depending upon the hazard classification of the plant.
- The hydrant post outlet shall be situated 1m above the ground/ floor level and shall be of 80 mm diameter.
- The entire fire hydrant system shall be painted in signal red colour.

4.3.1.1.5 Small Bore (First-Aid) Hose Reels

(a) Provision of hose reels shall be made in buildings such as reactor building, reactor auxiliary building, service building, administrative building and canteen building. Hose reel is not deemed suitable for buildings/compartments containing electrical apparatus only or buildings/compartments in which flammable liquids are stored.

(b) The number and distribution of hose reels shall be such that the whole of each floor is protected and that no part of the floor is more than 6 m from a hose nozzle when the hose is fully extended.

(c) The hose reel shall be such that it will enable not less than 22.5 litres of water to be discharged per minute through a nozzle of not more than 6.35 mm internal diameter.

(d) Hose shall be of reinforced rubber not less than 19 mm and not more than 32 mm internal diameter.

(e) Hose lengths shall not exceed 36.50 m.

4.3.1.1.6 Fire Water Supply System

The fire water supply should be designed to furnish anticipated fire water requirements. The pump heads shall be such as to give a minimum residual pressure of 3.5 kg/cm^2 at the hydraulically farthest point while delivering required full flow. However, the maximum operating pressure at the nozzle shall be limited to 4.5 kg/cm^2. Distribution of water supply to fire equipment shall be through a main loop such that water can reach each connection from two directions.

Valves shall be provided to isolate portions of the fire water main loop. They shall provide visual local indications as to whether the valves are open or closed. Valves on the main loop shall be so arranged that closure of a single valve shall not cause the complete loss of the fire extinguishing system's capability in any given fire area.

The fire water main loop shall not be connected with service or sanitary water system piping.

The fire water main loop may serve more than one facility at a multi-facility site. For such facilities common water supplies may be utilised.

At sites where pumping is required to provide the necessary amount of water, redundancy and diversity in fire pumps shall be provided to ensure availability of fire water supply system. The pumps shall be capable of delivering the required quantity of water, even with one pump removed for maintenance and under blackout conditions. This may be achieved by having independent controls and diverse power supplies provided by the plant emergency power supply system and independent prime movers. Alarms, indicating running of pumps, power failure and failure to start, shall be provided in the control room

The fire water supply system shall be designed on the basis of the largest flow rate at the required pressure for a minimum of 2 hours. The flow rate, derived from the fire hazard analysis, should be based on the operation of the sprinkler system with the largest water demand plus an adequate allowance for manual fire fighting. Design of the fire water supply system should take the minimum pressure requirements at the highest outlet in the plant into account .

Two separate reliable water sources should normally be provided. If only one water source is provided, then it shall be large (e.g. lake, pond, river) and at least two independent intakes should be provided. If only tanks are used, two 100% system capacity tanks shall be installed. The main plant water supply capacity shall be capable of refilling either tank within 8 hours. Tanks shall be capable of being interconnected such that pumps can take suction from either or both tanks. Each tank shall be capable of being isolated in the event of a leak. Tanks shall be fitted with an attachment enabling fire engines to be connected to them.

The water supply for sprinkler systems may require chemical treatment and additional filtration to ensure that blockage of sprinklers does not occur from the effects of debris and corrosion products.

Provision should be made for the inspection of sprinkler heads, and valve operability should be regularly tested to provide confidence in the continued ability of the system to perform its duty throughout the lifetime of the plant.

4.3.2 Carbon Dioxide Suppression System

4.3.2.1 Carbon dioxide extinguishing systems shall, as a minimum, comply with the requirements of IS-6382 : 1984 titled ‘Code of Practice for Design and Installation of Fixed CO_2 Fire Extinguishing System’.

4.3.2.2 Carbon dioxide systems are normally used for fires involving electrical equipment such as switchgear, control consoles etc., since the gas is clean, does not leave any significant deposits and does not conduct electricity. However, since concentration of the gas greater than 5% in air can be a hazard to personnel, due consideration shall be given to this aspect in the design and specification of the system.

Some of the most important types of hazards and equipment, which carbon dioxide systems may satisfactorily protect include:

(a) Gaseous and liquid flammable materials.

(b) Electrical hazards such as transformers, oil switches and circuit breakers and rotating equipment.

(c) Engines utilising gasoline and other flammable fuels.

(d) Ordinary combustibles such as paper, wood and textiles.

Carbon dioxide shall not be used to extinguish fires involving the following:

(a) Chemicals containing their own supply of oxygen such as cellulose nitrate.

(b) Reactive metals such as sodium, potassium, magnesium, titanium and zirconium.

(c) Metal hydrides.

4.3.2.3 In determining the need for a carbon dioxide extinguishing system, consideration shall be given to the type of fire, reaction with other materials (including those chemicals present, which may contain their own oxygen or materials which, when burning, can extract oxygen from carbon dioxide), effects on charcoal filters, and toxic and corrosive characteristics of thermal decomposition products of gases.

4.3.2.4 Carbon dioxide extinguishing systems should not be used where cooling is needed to extinguish a deep-seated fire such as in areas containing a high fire load of electrical cable material.

4.3.2.5 Carbon dioxide extinguishing systems shall only be used in areas where the required concentration can be ensured for a period necessary to extinguish the fire.

4.3.2.6 In designing the CO_2 suppression system, consideration should also be given to:

(a) The minimum required CO_2 concentration, distribution, soak time and ventilation control

(b) Anoxia and toxicity of CO_2

(c) Possibility of secondary thermal shock damage due to sudden cooling

(d) Conflicting requirements for venting during CO_2 injection to prevent over-pressurisation versus sealing to prevent loss of agent

(e) Location and selection of the activating detectors.

4.3.2.7 For enclosures housing electrical equipment, a total flooding system is recommended. A total flooding system consists of a fixed supply of carbon dioxide normally connected to fixed piping with nozzles arranged to discharge carbon dioxide into an enclosed space or enclosure around the hazard. The requirements and recommendations for a total flooding system are as follows:

(a) The total quantity of carbon dioxide required shall be sufficient to ensure that the oxygen content of the enclosure is reduced to a point, where combustion can no longer be sustained. For total flooding systems minimum design concentration of 30 to 50% in the area is required to suppress the fire. In determining this, account shall be taken for the leak tightness of the enclosure, the required extinguishing concentration for the particular hazard, the rate of application and the period for which the design concentration is to be held.

(b) The possible structural effects of the pressure buildup, which may occur within the enclosure as a result of the discharge of carbon dioxide, shall be evaluated and provision shall be made for special venting, if considered necessary. Where such venting is necessary, attention shall also be given to the space into which the excess pressure (which may also contain flammable vapours) is to be relieved.

4.3.2.8 The minimum design rate of application shall be based on the quantity of carbon dioxide and the maximum time to achieve design concentration.

For surface fires the design concentration shall be achieved within 1 minute.

The design concentration shall be achieved within 7 minutes but the rate shall not be less than that required to develop a concentration of 30% in 2 minutes for deep-seated fires.

4.3.2.9 Where automatic carbon dioxide systems are used, they shall be equipped with a pre-discharge alarm system and a discharge delay to permit personnel evacuation.

4.3.2.10 Time delay shall be used only where discharge delay is required for personnel evacuation or to prepare the hazard area for discharge. Time delays shall not be used as a means of confirming operation of a detection device before automatic actuation occurs.

4.3.2.11 Provisions for locally disarming automatic carbon dioxide systems shall be key locked and under strict administrative control. Automatic carbon dioxide extinguishing systems shall not be disarmed unless controls as described in 7.1.2 are provided.

4.3.2.12 Adequate reserve supply shall be maintained to restore systems to operating condition on the same day. Permanent connection of both the primary and reserve supplies and the arrangement for easy change over should be considered.

4.3.2.13 The system shall be installed, thoroughly inspected and tested periodically by competent personnel as per relevant Indian Standard.

4.3.3 Other Suppression Systems

Other suppression systems include :

(a) Halon shall not be used as a fire extinguishing medium in new facilities, due to its deleterious effect on the earth's environment.

The various alternatives to Halon 1301 are as follows:

Total flooding gaseous alternatives

Halocarbons-hydro Fluorocarbons (HFC), Perfluorocarbons (PFC), Fluoroiodocarbons (FIC).

(b) Inert gases- nitrogen, argon, nitrogen/argon blend, nitrogen/argon/ CO_2 blend.

(c) Water mist.

(d) Fine particulate aerosols or fine powdered aerosols.

(e) Foam system.

Automatic foam system shall be used for fuel oil facilities and fuel oil storage tanks.

(f) Inert gas system/other suitable system.

Any system of the above type may be used for protection of control rooms, control equipment rooms, computer rooms, and rooms containing motor control centers etc.

For all the above alternatives, the latest Indian Standards shall be followed.

4.3.4 Portable Fire Extinguishers:

Class of Fire	Description	Suitable Appliances
A	Fire in ordinary combustibles (e.g. wood, paper, cloth, vegetable fibers, rubber etc.)	Gas expelled water type and anti-freeze type extinguishers, water buckets
B	Fires in flammable liquids, paints, grease, solvents etc.	Mechanical foam, CO_2 and dry chemical powder (DCP) types of extinguishers, sand buckets
C	Fire in gases including liquefied gases	CO_2 and DCP types of extinguisher
D	Fire in metals	Special type of dry chemical powder extinguishers such as ternary eutectic chloride (TEC) /graphite based and sand buckets

Note: Where energised electrical equipment is involved in a fire, the non-conductivity of the extinguishing media is of utmost importance and only CO_2 and dry chemical powder shall be used. Once the electrical equipment is de-energised, extinguishers suitable for class A, B or C type may be used safely.

- 10% spare fire extinguishers of each type should always be maintained as a standby stock in the store-room for use in emergencies.
- The fire extinguishers shall be distributed over the entire area in such a manner that it shall be within 15 m from any point of area. As far as possible, the fire extinguishers should be located at the entrances of the blocks if the travel distance is less/around 15 m.
- Portable fire extinguishers should preferably be fixed on the wall at a height of 1m from the floor level to the bottom of the fire extinguisher.
- Extinguishers removed from the premises for recharge shall be replaced with spare extinguishers.
- All the fire extinguishers shall be numbered and list of fire extinguishers shall be available with fire officer who will look after upkeep and proper functioning of all fire fighting devices. It is suggested to maintain the history record of individual fire extinguisher in a register, which would be easy in placing them back in original position if at all taken away for any use or maintenance. A history card for individual extinguishers should be made as per IS : 2190 - 1992 and these records should be pasted on the respective fire extinguisher.

- The access to all the fire extinguishers shall be kept free at all the times without any obstruction and fire extinguishers shall not be covered/blocked with any stacking of material/equipment.
- All the employees shall be trained adequately in the operation of fire extinguishers to tackle/quench the fire effectively at the initial stage.

4.3.4.1 Adequate number of fire extinguishers shall be provided in various plant areas and particularly in areas, which contain or could present a fire exposure hazard to safety related equipment in accordance with guidelines as per IS : 940-1989, 2171-1999, 2878-1986 and 10204-2001.

4.4 Personnel Support System

4.4.1 Emergency Breathing Apparatus

Adequate numbers of self-contained positive pressure breathing apparatus with full-face positive pressure mask shall be provided and maintained for the operating personnel in addition to those maintained by the fire brigade. At least two self-contained breathing air apparatus with spare cylinders having operating life of 30 minutes shall be located on-site. In addition, an on-site six-hour supply of reserve air should be provided to permit quick and complete replenishment of empty cylinders, unless alternative arrangement exists for getting filled cylinders expeditiously.

Control room personnel may be provided with breathing air either from self-contained breathing apparatus or from manifold system (hose mask or airline respirator) piped from a storage reservoir. If compressors are used as a source of breathing air, only equipment approved for breathing air shall be used. Compressor shall be operable assuming a loss of off-site power. Special care must be taken to locate the compressor in areas free of dust and contaminants.

4.4.2 Communication

Requirements for the reporting of fires and the communication during fire fighting shall be provided in the design of the plant communication system. Emergency communication equipment shall be readily accessible, located in the normal path of access to critical areas. Fixed emergency communication systems independent of the normal plant communication system should be installed at pre-selected stations to communicate to the control room and from control room to fire station.

In addition, portable communication devices shall be provided and reserved for direct communication amongst the different agencies coordinating the fire fighting operations. This system shall not interfere with the communications capabilities of the plant. Fixed repeaters installed to permit use of portable radio communication units shall be protected from exposure to fire. Pre-operational and periodic testing shall demonstrate that the frequencies used for portable radio communication will not affect the actuation of protective relays.

4.4.3 Emergency Lighting

The plant emergency lighting system shall illuminate fire escape routes with light having an intensity of not less than 1.0 foot-candle (11 lux) measured at floor level. The illumination shall be so arranged that the failure of any single lighting unit does not leave a fire access route in darkness. The emergency lighting system shall provide the required illumination automatically for a period of at least eight hours in the event of an interruption to the normal lighting system. The emergency lighting system may be powered by batteries or diesel generator(s). At least six battery-powered portable hand lights should be provided and maintained for emergency use by the fire brigade and other operation personnel required to achieve safe plant shutdown.

5. FIRE PROTECTION REQUIREMENTS DURING CONSTRUCTION

Provision shall be made to ensure fire prevention during all phases of construction of the plant. Particular attention shall be paid to reduce the amount of combustibles through regular inspections made by fire and safety personnel. As welding operations tend to be a frequent cause of fires, adequate precautions shall be taken to prevent fires due to these operations. Steps shall be taken to ensure that possible consequences of fire during construction will not have a significant effect on the capability of items important to safety. Appropriate action for inculcating basic fire protection concepts among construction workers should be taken.

Additional fire barriers, fire protection measures and administrative controls shall be provided on the unit under construction in close proximity to other existing units under commissioning/operation to safeguard against construction fire hazards.

Fire safety is to be built up progressively from construction phase of a project. During construction phase, a fire brigade organisation, equivalent to at least that of Class-III (Appendix-C) shall be made functional. This shall be upgraded to the required Class before operation phase.

General guidelines for fire safety:

(a) It shall be ensured that for fire safety, IS 3034 : 1961 'Fire Safety of Industrial Buildings, Electrical Generating and Distribution Station - Code of Practice' is followed.

(b) The management of the facility should clearly spell out the responsibility for preventing the fire accident during construction/erection stage. The facility shall take necessary measures to prevent/extinguish fire in the area of work/ activity during construction/erection and all necessary facilities shall be arranged.

(c) The management of the facility shall ensure compliance to the fire prevention measures taken/provided through structured procedures.

(d) The management of the facility shall explore and keep liaison with the nearby fire fighting facilities like municipality etc. from where fire tenders can be called in case of fire. The contact numbers shall be displayed at conspicuous locations.

(e) Flammable material should not be stored near or below the place where operations such as cutting/welding are carried out.

(f) As far as possible, inflammable material such as hydrogen cylinders etc. should not be brought/stored during erection unless otherwise unavoidable.

(g) Fencing shall be constructed around storage area meant for flammable material storage.

(h) Temporary buildings (offices, material stores, rest room etc.) shall be made of non-combustible materials only. Adequate safe distances shall be kept between temporary buildings (particularly between material stores). Temporary sheds should preferably be located at least 15 m from the main buildings and 9 m from each other.

(i) The use of combustible material for scaffoldings etc. shall be avoided, as far as possible. If such material is used, it shall be stored at a safe distance from the construction site, offices, material and equipment stores.

(j) 'No smoking' shall be enforced in areas exposed to fire hazard and in the vicinity of hazardous operation.

(k) Construction schedule shall be co-coordinated so that requisite fire fighting systems are installed and placed into service as soon as possible, at least prior to starting any activity involving any major fire hazard.

(l) Adequate fire extinguishing measures shall be provided for all locations where fire hazards are present, like storage of construction material, storage of flammable material, in the proximity of welding and cutting operations.

(m) Where practical, the permanent fire hydrant system for the plant shall be installed well ahead of the completion of the project so that the fire fighting water supplies are available even during construction work. Where this is not practicable, a minimum number of water tanks of not less than 1.25 lakh litres capacity with replenishing arrangements shall be provided at strategic locations in the plant area which may be utilised as emergency water supply for fire fighting even after commissioning of the plant. A minimum of 2 hours duration water supply for fire fighting shall be available at the construction site.

(n) In addition to the fixed water extinguishing systems, sufficient number of portable fire fighting equipment e.g. different types of fire extinguishers shall be available for deployment at various fire risk areas as per latest IS-2190-1992. The fire extinguishers shall be inspected and maintained in accordance with IS-2190-1992.

(o) While selecting location of installation of portable fire extinguishers, due consideration shall be given to the nature of risk to be covered.

(p) The extinguishers with proper labeling shall be placed in conspicuous positions and shall be readily accessible for putting into immediate use.

(q) If extinguishers intended for different classes of fires are required to be grouped, their intended use shall be marked conspicuously to help choice of proper extinguisher at the time of fire.

(r) Allocation of spaces to different contractors for storage of materials shall be such that high fire risks materials shall be segregated/isolated and shall not be scattered all over the site in order to contain the spread of fire.

(s) Appropriate water spray and sprinkler system should be provided for transformers, turbine oil tanks, seal oil units, fuel oil storage tanks, cable vaults, cable galleries, cable spreading room etc. before commencement of commissioning activities. Appropriate alternatives like fire safety personnel with fire tender should be provided for commissioning of transformers.

(t) Effective communication systems such as telephones, mobile phones, walkie-talkie etc. shall be established.

(u) Safe access to and means of escape from all site locations shall be ensured.

(v) Appropriate fire prevention and control measures shall be ensured for all construction activity areas where more than one agency might be engaged by the facility.

(w) Watch and ward services should be provided at construction sites during holidays and nights.

(x) Approach roads for fire fighting should be planned, properly maintained and kept free from blockage. Width of approach road should be not less than 5 m to facilitate fire fighting operations.

(y) Where the building plan requires installation of fixed fire fighting equipment such as hydrants, standpipes, sprinklers and underground water mains or other suitable arrangements for provision of water, the same shall be installed, completed and made available for permanent use as soon as possible, but in any case not later than the date at which the hydrants, etc. are required for use as specified.

(z) All works waste, such as scrap timber, wood shavings, sawdust, paper packing materials and oily waste shall be collected and disposed of safely at the end of each day's work. Particular care shall be taken to remove all waste accumulation in or near vertical shaft openings like stairways, lift-shaft etc.

(aa) An independent water storage facility shall be provided before the commencement of construction operations for fire fighting purposes. It shall be maintained and be available for use at all times.

(bb) Firewalls and exit stairways required for a building should be given construction priority. Where fire doors, with or without automatic closing devices, are stipulated in the building plans they should be hung as soon as practicable and before any significant quantity of combustible material is introduced in the building.

(cc) As the work progresses, the provision of permanent stairways, stairway enclosures, firewalls and other features of the completed structure which will prevent the horizontal and vertical spread of fire should be ensured.

(dd) Access for fire fighting equipment such as fire tenders, shall be provided to the construction site at the start of construction and maintained until all construction work is completed.

(ee) Free access to fire hydrants/static water tanks, where available, shall be provided and maintained at all times.

(ff) No materials for construction shall be placed within 3 m of hydrants/static water tanks.

(gg) During building constructions, free access to permanent, temporary or portable fire fighting equipment shall be maintained at all times.

(hh) In all buildings over two storeys high, at least one stairway shall be provided in usable condition at all times. This stairway shall be extended upward as each floor is completed. There shall be a handrail on the staircase.

(ii) Sources of ignition hazards like electrical wiring and equipment for light, heat or power purposes shall be installed in compliance with the requirements of Atomic Energy (Factories) Rules, 1996.

6. FIRE PROTECTION REQUIREMENTS DURING DECOMMISSIONING

During the decommissioning phase of the plant, combustible materials shall be removed from the plant as far as possible. The fire hazard analysis shall be revised to reflect the latest changes in the type and quantity of radioactive and hazardous materials on the site, and to justify removal of fire barriers and parts of the fire detection and extinguishment systems, which are no longer, needed. Adequate fire protection systems, based on the above fire hazard analysis, shall remain functional until all radioactive or contaminated materials are stored in a safe manner or have been removed from the site.

7. ADMINISTRATIVE PROCEDURES, CONTROLS AND FIRE BRIGADES

7.1 Administrative Procedures and Controls

7.1.1 Fire Hazard Control

7.1.1.1 Housekeeping

Appropriate housekeeping requirements shall be specified in plant administrative procedures. As a minimum, these shall include storage of combustible materials in specifically designated areas, checking for obstruction of access to fire hazard areas and fire protection equipment, cleaning of floor drains and sumps, and delegation of responsibility for inspections.

Adequate attention should be paid to ensure cleaning of area of all combustible /flammable materials, including wooden planks etc. before sealing of area for start up.

A system shall be implemented, wherein employees are made responsible for good housekeeping. Periodic and surprise checks shall be conducted to monitor observance of housekeeping and apply corrective measures as necessary.

Housekeeping shall be promoted by posters and displays at various locations and observance of cleanliness week etc.

The following precautions shall be observed/adhered to by all employees of the facility:

(a) 'A place for everything and everything in its place' principle shall be followed. The materials, tools, equipment etc. shall be placed at their designated places.

(b) Stairs, fire escapes and passages shall be kept clear of all obstructions. No material shall be stored at such places.

(c) All floors, passages, stairs shall be kept in clean, dry and non-slippery condition.

(d) Spilled oil, chemical etc. shall be immediately cleaned and measures shall be taken to modify procedures/work practices that cause spillage.

(e) The unwanted materials shall be disposed off as promptly as possible.

(f) Rags, oily waste, etc. shall be deposited in designated metal containers and disposed off as soon as possible.

(g) Air/water hoses, electrical wires should not be run across the floor. These should preferably be taken along the wall or else should be fixed up at a height of at least 2.5 m above ground level. Also, if any projected conduit pipes are found running on the floor, action should be taken for its embedment in the floor.

(h) Adequate no. of suitable scrap/waste disposal bins shall be provided at different locations. Scrap shall not be allowed to accumulate, but removed regularly from the work area to identified areas.

(i) Construction material (combustible/flammable materials), wooden waste, cotton waste and waste paper shall be kept away from welding area.

(ii) Work permit(s) issued for carrying out the work shall specifically include the cleanliness of that area.

7.1.1.2 Storage, Use and Handling of Flammable Materials

(a) Plant administrative procedures shall specify appropriate requirements governing the storage, use and handling of flammable materials.

(b) Bulk storage of combustible materials inside or adjacent to safety-related buildings or systems shall be prohibited. Use of combustible materials in safety related areas shall be controlled. Use of wood inside buildings containing safety related systems or equipment should be permitted only when, suitable non-combustible substitutes are not available. If wood must be used, only fire retardant treated wood shall be used.

(c) Refueling (off-line as in fast reactors and boiling water reactors) and maintenance operations may introduce additional hazards such as contamination control materials, decontamination agents, wood planking, temporary wiring, welding and flame cutting. Possible fires would not necessarily be in the vicinity of fixed detection and suppression systems. These special operations could result in breaches of fire barriers or fire stops, impairment of fire detection and suppression systems. These operations shall be reviewed at appropriate levels of management.

(d) Appropriate special actions and procedures such as fire observers or temporary fire barriers shall be implemented to ensure adequate fire protection and plant safety during such operations.

7.1.1.3 Control of Cutting, Welding and Open Flame Work

Work involving ignition sources such as welding and flame cutting shall be done under closely monitored conditions. Such works in an operating plant shall be controlled by a work permit system. Procedures governing such work shall be reviewed and approved by persons trained and experienced in fire protection. Persons performing and directly assisting in such work shall be trained and equipped to prevent and combat fires. If possible, a person from the fire fighting organisation should directly monitor the work and function as a fire observer.

Prior to the issuance of the work permit, a responsible person shall physically survey the area where the work is to be performed and shall establish the following safeguards.

- Remove all combustible materials from the vicinity of the work area or non-combustible barriers shall protect them.
- Adequately cover the floor or wall openings near the work area.
- Provide additional fire extinguishers, hose and other fire fighting equipment as deemed necessary and ensure that existing fire fighting equipment in the work area is operable.
- Provide a fire observer to be present throughout any operations, which involve breached fire barriers or in which there is a potential for fire exposure to a safety-related equipment.
- Assure that the work to be performed is confined to the permitted area.
- Assure that all equipment to be used are in safe working condition.
- Provide additional protective equipment as necessary.

7.1.1.4 Open flames or combustion generated smoke shall not be used for detector testing or establishing flow pattern. Instead, a cold smoke generated should be used for the same.

7.1.1.5 Smoking

Smoking shall be prohibited in designated areas and ‘no smoking’ signs shall be appropriately displayed.

7.1.2 Control of Fire Protection System

Disarming of fire detection or suppression systems shall be controlled by a work permit system. Impairments shall be as short in duration as possible and every effort shall be made to rapidly restore the fire protection system to operation. Procedures for improved supervision shall be established in areas where systems are so impaired.

7.2 Personnel Training, Fire Brigades and Standing Fire Order

7.2.1 Personnel Training

The plant shall be self-sufficient with respect to fire fighting activities to protect critical areas. Therefore, the plant personnel shall be given adequate training in fire fighting practices.

In an emergency due to fire, the shift-charge-engineer shall assume overall responsibility of the plant. The fire officer shall assume the responsibility of controlling the fire under the overall guidance of the shift-charge-engineer.

A plant fire protection training programme shall be developed and documented which as a minimum shall provide the following:

(a) A course in fire fighting and fire prevention for all plant personnel and fire brigade personnel.

(b) A course covering the radiological aspects/hazards specific to the facility and the plant layout for all fire brigade personnel.

(c) Re-training or refresher training for all personnel at least once in 5 years.

(d) Fire drills shall be conducted at least once in 2 months and their effectiveness shall be reviewed.

7.2.2 Fire Brigade

The organisation of the fire brigades shall be as per Appendix-C.

7.2.3 Standing Fire Order

A standing fire order shall be established and documented for both plant and fire brigade personnel. It shall outline the communication/responsibilities/responses of the various agencies like the plant operating personnel, plant health physicists, plant management, medical, fire brigade personnel etc. It shall also contain the specific hazards of the plant and the type and locations of the fire suppression equipment/system provided. It shall specify the emergency equipment to be maintained at the plant and the procedures to assign responsibility for inventory, inspection and replacements of the same. The standing fire order shall also have procedures for assessing the effectiveness of the periodic drills. The format for the standing fire order is shown in Appendix-D.

8. QUALITY ASSURANCE PROGRAMME

Quality assurance programme (QAP) shall be in effect for fire prevention and protection elements of the plant from the inception of design through construction of the plant and during its operating life and decommissioning. Fire protection program shall include the organisational aspect in the QAP. It should satisfy the other specific criteria listed below:

(a) Manuals/Documents : All manuals/documents highlighting the requirements of fire prevention and protection aspects shall be included.

(b) Design control : Measures shall be established to ensure that regulatory requirements and design bases are translated into specifications, drawings, procedures etc. The specifications of quality standards and methods to control deviations shall be established. The aspects of design verification interfaces and changes control should also be highlighted.

(c) Instructions, procedures and drawings : Inspections, tests, administrative controls, fire drills and training that govern the fire protection programme should be documented.

(d) Control of purchased material, equipment and services : Measures shall be established to ensure that purchased material, equipment and services conform to the specifications.

(e) Inspection : The programme for independent inspection of activities effecting fire protection shall be established.

(f) Handling and storage : The handling and storage of all equipment shall be carried out by proper established procedures. Proper methods of preservation shall be adopted for the equipment requiring the same.

(g) Test and test control : A test programme shall be established and implemented to ensure that testing is performed to meet the design intent.

(h) Inspection, test and operating status : Measures shall be established to provide the identification of items, which have passed, required tests.

(i) Non-conforming items : Measures shall be established to control items which do not conform to specified requirements.

(j) Corrective action : Measures shall be established to ensure that conditions adverse to fire protection are corrected.

(k) Records : Records shall be prepared to furnish evidence that the criteria enumerated above are being met.

(l) Audits : Periodic auditing shall be carried out and the observations shall be documented and reviewed.

9. TESTING AND SURVEILLANCE

9.1 Introduction

Verification of pre-operational design performance and surveillance test programmes is necessary to assure the operational readiness of the fire protection systems and components. These tests shall be so conducted as not to adversely affect the fire safety and functional availability and operability of the various plant systems/equipment.

9.2 Pre-operational Testing

All fire protection related systems shall be tested in accordance with the documented procedures to verify that the design performance requirements are met. Procedures shall be prepared for each pre-operational test. These test procedures shall as a minimum specify appropriate test objectives, prerequisites, initial system and environmental conditions, acceptance criteria, data to be collected, special precautions, step-by-step instructions, and documentation requirements. At the completion of each test, the results shall be evaluated against the documented acceptance criteria. Deficiencies or exceptions to the procedures/requirements shall be documented and evaluated to determine the effect upon the test and to make appropriate corrective action including system re-test, if required.

Those systems or components requiring preoperational testing shall include, but not be limited to, the following:

(a) All manual and automatic fire water protection systems.

(b) All automatic and manual gas, chemical, and foam systems.

(c) All detection and alarm systems.

(d) All ventilation systems required to operate in a fire emergency.

(e) All fire doors and dampers.

(f) All control circuitry related to fire protection systems.

(g) All communications systems related to fire protection.

(h) All lighting systems related to fire protection.

(i) All portable fire extinguishers.

9.3 Periodic Inspection, Testing and Maintenance

In order to ensure that all fire protection related systems and components function properly and meet design requirements, a formal inspection, testing and maintenance programme and written procedures, which specify the necessary inspection, testing, and maintenance requirements shall be established and documented. Plant administrative procedures shall identify an officer responsible for overall coordination of equipment testing and maintenance.

Approval for testing any fire protection related system shall be obtained from appropriate plant authorities in accordance with specified administrative procedures. If test procedures require the deactivation of a system, the procedure shall also require a signoff that the system has been returned to its normal operating condition. A record shall be maintained of all tests including date, abnormalities or failures, and corrective actions taken.

The various elements of the inspection, testing, and maintenance programme shall be conducted in accordance with the schedule given in Table-9.1. The following specific tests or inspections shall be performed at the intervals indicated:

(a) A complete performance test of all fire pumps shall be conducted once in every two years to verify their design flow and pressure capability.

(b) Compressors and other equipment associated with breathing air systems shall be operationally tested annually and serviced in accordance with the manufacturer's instructions.

(c) Instrumentation associated with fire protection systems shall be inspected and calibrated annually.

(d) If the plant telephone system is used as a portion of the fire alarm system, it shall be tested semiannually.

(e) All self-contained breathing units to be used for fire emergencies shall be inspected monthly and after each usage.

TABLE-9.1 FIRE EQUIPMENT INSPECTION, TESTING AND MAINTENANCE

S.No.	Item		Weekly	Monthly	Quarterly	Semi Annual	Annual	Others
1	Alarm and detection circuitry				--	--	C	T-daily
2	Fire and smoke detectors	Conventional		A		M/T[vii b]		
		Addressable					M/T[vii b]	
3	Building evacuation alarms			T		M		
4	Manual fire alarms	Conventional				M/T[vii b]		
		Addressable					M/T[vii b]	
5	Sprinkler and water spray systems including alarms		V	A			M/T[i,vii a, vii b]	
6	High expansion foam systems		V	A		M	T[i]	
7	Carbon dioxide systems		V	A		M[v]	T[i]	
8	Fixed fire pumps (main/jockey) including DG battery		T[ii]	M				V-daily P-biennially
9	Water including Hydro pneumatic tank alarms			A		M/T		
10	Isolation valves			V[iii]		M/T		
11	Fire hydrants						T	
12	Fire hose					T[iv]		
13	Portable fire extinguishers				V, M[v]			H[vi]
14	Fire brigade equipment			V			T	
15	Fire doors			V/T/M				
16	Dampers						M/T[viii]	
17	Exit signs						V/M	
18	Penetration fire seals						V	
19	Deluge and pre-action valves						Tr	

SCHEDULE

Code: V = Visual inspection — M = Preventive maintenance

T = Operational test — A = Alarm test only

H = Hydro test — P = Performance test

C = Calibration — Tr = Trip testing.

V = Visual inspection includes checking for leakage and any deterioration to the system e.g. for pump: leakages from glands, bearing oil level, pump foundation/ supports etc.

M = Preventive maintenance e.g. for pumps include; bearing oil top up, setting of only permitted gland leakage, vibration check, coupling check, megger value check, motor cooling fan check, motor bearing check, motor terminal box check

P = Pump performance check e.g. checking the pump head with current drawn by the motor and correlate with the characteristic curves given by the manufacturer to evaluate flow of the pump.

Wherever fire equipment are in areas not accessible during normal operation, the operational tests shall be done during major shutdown.

Notes:

(i) Test of activation mechanism only for dry chemical, carbon dioxide systems and for spray or foam systems where water or foam could damage electrical equipment.

(ii) This test is to verify pump operability only.

(iii) Valves, which are accessible to the general public, shall be inspected weekly, unless electrically supervised or locked. Valves which would not affect the required water flow shall be inspected quarterly. Valves which are locked or electrically supervised shall be inspected semiannually.

(iv) Hose for outdoor use shall be hydrostatically tested annually. Hose for inside use shall be refolded annually and hydrostatically tested after the fifth and eighth year of service, and every second year thereafter.

(v) Weighing of CO_2 cylinders.

(vi) Hydro test as required by respective Indian Standard.

(vii) (a) Where flow testing of fixed systems is not permitted a representative number of water spray system nozzles shall be removed and checked for signs of blockage and any adjustable nozzle shall be checked for proper setting annually.

(b) Fire and smoke detectors/alarm/sprinkler/nozzle which are not accessible during operation shall be tested during any available longer shutdown or biennially which ever is earliest.

(viii) Operational test based on random sampling for fusible link dampers shall be carried out. For pneumatic dampers annual maintenance and testing is to be carried out as recommended.

10. FIRE PROTECTION REQUIREMENTS FOR SPECIFIC FACILITIES

10.1 Pressurised Heavy Water Reactors

10.1.1 General

The fire protection programme in a pressurised heavy water reactor (PHWR) aims at limiting the fires through minimizing use of combustibles as construction material, early detection of fires that emanate in spite of all precautions, suppress the fires early to limit the damage due to the fire and ensure no/minimum damage to safety systems/equipment from fires in order to maintain the reactor in safe shut down condition. The specific guidelines for the design of the capacity, storage etc. of fire water system to ensure its adequacy for fire fighting, layout of electrical cables/cable trays and specific requirements for certain important areas like reactor building, boiler room, fueling machine vaults, control rooms, cable spreading room, switchgear rooms, diesel generator rooms etc., have been brought out in the following paragraphs.

10.1.1.1 Fire Water System

The system shall be designed to safe shutdown earthquake (SSE) category for the safety related nuclear systems. The storage for the fire fighting water shall be estimated for continuous operation of 2 hours of hydrants @ 171m^3 /hr and 2 hours of largest sprinkler, both operating simultaneously. The pump head shall be estimated to give a minimum residual pressure of 3.5 kg/cm^2 at the hydraulically farthest point while delivering required full flow. Provision shall be made for suitable number of independently powered pumps to cater to the fire protection requirement during station black out (on- site and off-site power failure) condition.

10.1.2 Additional Requirements for Nuclear Power Plants

10.1.2.1 Safety-related Electric Circuits

Class 1E circuits and equipment shall be arranged to maintain the independence of equipment assigned to different safety divisions and to prevent the spread of fire from one safety division to the other. Where fire barriers are not provided due to overriding design features, the location and installation of Class 1E circuits and equipment shall meet the separation requirements of 'Standard Criteria for Independence of Class 1E Equipment and Circuits', IEEE Std.-384-1977. A fire hazard analysis shall be performed to determine any additional requirements for fire protection necessary to ensure that nuclear safety functions are maintained in the event of a fire.

10.1.2.2 Guidelines for Specific Plant Areas

Fire protection in some of the areas within the reactor building, inaccessible during normal operation, need specific consideration.

10.1.2.2.1 Reactor Building Containment

Fire protection requirements for containment areas should be provided for hazards identified by the fire hazard analysis. Because of the general inaccessibility of certain areas of the containment during normal plant operation, protection shall be provided by automatic/remote, or manually operated fixed systems. Operation of the fire protection systems should not compromise the integrity of the containment or other safety related systems. Cable trays having high cable densities should be provided with fire detection system and remote, or manually operated sprinkler systems. In view of difficulty in purging out CO_2 from the various areas of reactor building, use of fixed CO_2 system is not recommended within the building.

10.1.2.2.2 Boiler Room/Pump Room

All high enthalpy, high temperature and high pressure fluid process systems are located in this area. Minimising the heavy water inventory in pipelines/ system results in cramped pipe layout and criss-crossing of pipelines and support systems. In general, approach to pumps with oil-lubricated motor is normally congested. There are a large number of power and control cables in this area in different cable trays. The leakage of oil from the lubrication system of primary coolant pump motor bearings over hot piping could also be a source of fire.

The background radiation level in this area during operation is high and hence normally inaccessible.

Based on the above problems, the selection and location of the detectors shall be decided to make fire detection system in the area effective e.g. in the proximity of motors.

Remotely operated sprinkler system should be considered for fire suppression in the area. Fire suppression system using chloride free dry powder/water, applied locally, should be employed with utmost care.

10.1.2.2.3 Fueling Machine Vaults

Use of hydraulic oil for fueling machine and cables in the area pose fire hazard. End fittings and feeders are the areas having higher temperatures. This area also has high radiation levels. The ceiling heights are high with large air currents due to vault coolers. Use of appropriate detectors at suitable location should be provided for this area. It should be ensured that no additional fire load is kept in this area.

10.1.2.2.4 Moderator Room

Moderator room may house oil-lubricated motors for the moderator pumps. Operators are alerted about oil leakages from the lubricating system of moderator pumps by low-level alarms of oil chambers of motors. But because of low operating temperature of system, the fire potential is very low. The provision of hose reels to minimise the use of light water and linear heat detection along the cable trays as well as smoke detectors and use of localised sprays of water over the cable trays is recommended. The ceiling height being over 10 m, ceiling mounted detectors face a constraint in this regard. The radiation level also could be very high. Smoke detectors along with heat/ flame detectors could be considered. However, the frequency of replacement for smoke detectors should be looked into because of the high radiation levels and consequent reduction in sensitivity.

10.1.2.2.5 Other Areas Housing Safety Related Systems/Equipment

10.1.2.2.5.1 Control Room

The control room including galleys, office spaces etc. shall be protected against disabling fire damage and shall be separated from other areas of the plant by floors, walls, and roof having adequate fire resistance ratings. Peripheral rooms of the control room shall be separated from the control room by noncombustible construction with adequate fire resistance rating. Ventilation system shall be designed to avoid ingress of smoke from peripheral areas to control room. If a carbon dioxide flooding system is used for fire suppression, these dampers shall be strong enough to support the pressure rise accompanying carbon dioxide discharge and seal tightly against infiltration of carbon dioxide into the control room.

Manual firefighting capability shall be provided for:

(a) Fire originating within a cabinet, console, or connecting cables

(b) Exposure fires involving combustibles in the general room area.

Portable Class A and Class C fire extinguishers shall be located in the control room. A hose station shall be installed immediately outside the control room.

Smoke detectors shall be provided in the control room and main control panels. If redundant safe shutdown equipment is located in the same control room cabinet or console, additional fire protection measure shall be provided for the respective cabinet/consoles.

Breathing air, either from self contained breathing apparatus or a manifold system for control room operators shall be readily available.

The outside air intake(s) for the control room ventilation system shall be provided with detection capability for smoke/toxic substances (as applicable) to alarm in the control room to enable isolation of the control room ventilation system and thus prevent smoke/chlorine/toxic substances from entering the control room.

Provision shall be made to permit isolation of the re-circulating portion of the normal ventilation system. Manually operated venting of the control room shall be available.

All cables that enter the control room shall terminate in the control room i.e. no cable shall be simply routed through the control room from one area to another.

Cables in under floor and ceiling spaces shall meet the separation criteria as outlined in Para 3.5. Air-handling functions should be ducted separately from cable runs in such spaces; i.e. if cables are routed in under floor or ceiling spaces, these spaces should not be used as air plenums for ventilation of the control room.

Fire detection and suppression shall be provided for under floor and ceiling spaces if used for cable runs unless,

(a) all cables are run in 10 cm or smaller steel conduit, or

(b) the cables are in fully enclosed raceways internally protected by automatic fire suppression.

10.1.2.2.5.2 Cable Gallery/Cable Vault

The primary fire suppression in the cable gallery/cable vault shall be a manual/automatic water sprinkler system. The sprinkler systems shall have provision for manual operation at a remote station. Sprinkler/spray systems may be zoned.

Cable gallery/cable vault should have

(a) Two separate entrances for fire fighting access for fire brigade personnel.

(b) An aisle separation between cable tray stacks at least 90 cm wide and 240 cm high.

(c) Hose stations out side the room/gallery/vault. Adequate numbers of portable extinguishers installed both inside and immediately outside the room/gallery/vault.

(d) Area smoke detection.

(e) Linear heat sensing cables for cable trays.

Floor drains with proper slope shall be provided to remove fire fighting water.

Physically separate routes maintaining distances in accordance with the provisions of IEEE-384 shall be provided for each redundant division. Manually actuated smoke venting that is operable from outside the room should be provided.

10.1.2.2.5.3 Control Equipment Rooms/Control and Instrumentation Cable Spreading Area

The primary fire suppression in the control equipment room shall be by portable extinguishers.

Control equipment rooms/control and instrumentation cables spreading area should have:

- At least two remote and separate entrances for access by fire brigade personnel.
- An aisle separation between tray stacks at least 90 cm wide and 240 cm high.
- Hose stations out side the room.
- Area smoke detection.
- Linear heat sensing cables for cable trays.

Floor drains with proper slope shall be provided to remove fire fighting water.

Physically separate routes maintaining distances in accordance with the provisions of IEEE-384 shall be provided for each redundant division. Manually actuated smoke venting operable from outside the room should be provided.

Cable spreading/control equipment rooms should not be shared between reactors. Cable spreading room shall be separated from other areas of the plant by barriers of adequate fire rating.

10.1.2.2.5.4 Plant Computer Room

Rooms for computers performing safety related functions, which are not a part of the control room complex shall be separated from other areas of the plant by barriers having adequate fire resistance rating and by fire detection/protection system. Computers, which are part of the control room complex, but not in the control room shall be separated and protected as described in requirement 10.1.2.2.5.1. Computer cabinets located in the control room shall be protected as other control room equipment and cable runs therein.

10.1.2.2.5.5 Switchgear Rooms

Switchgear rooms containing safety-related equipment shall be separated from the remainder of the plant by barriers with adequate fire rating. Redundant switchgear safety divisions shall be separated from each other by barriers of adequate fire rating. Automatic fire detectors should alarm and annunciate in the control room. In addition to the ionisation type of smoke detectors, optical type of smoke detectors on cross zoning principle shall be used. Cables entering the switchgear room, which do not terminate or perform any function there should be kept to a minimum. These rooms should not be used for any other purpose. Fire hose stations and portable fire extinguishers shall be readily available outside the area.

Equipment shall be located to facilitate access for manual firefighting. Drains shall be provided to prevent water accumulation. Manually actuated remote ventilation system should be provided for venting smoke. All cable terminations shall be preceded by fire stops/seals as protection against propaga-tion of fire.

10.1.2.2.5.6 Remote Safety Related Panels

Redundant safety related panels remote from the control room complex shall be separated from each other by barriers having adequate fire rating. Similarly, panels providing remote hot shutdown capability e.g. supplementary control room shall be separated from the control room complex by fire barriers having adequate fire rating. The general area housing remote safety related panels shall be provided with automatic fire detectors, which alarm locally and also alarm and annunciate in the control room. Combustible materials should be controlled and limited to those required for operation. Portable extinguishers and manual hose stations shall be readily available in the general area.

10.1.2.2.5.7 Battery Rooms

Battery rooms shall be separated from each other and other areas of the plant by barriers having adequate fire rating inclusive of all penetrations and openings. D.C. switchgear and inverters shall not be located in these rooms. Automatic fire detection shall be provided to alarm and annunciate in the control room and alarm locally. Ventilation systems in the battery rooms shall be capable of maintaining hydrogen concentration below 1% by volume. Loss of ventilation shall be alarmed in the control room. Standpipe, hose and portable extinguishers shall be readily available outside the room.

10.1.2.2.5.8 Diesel Generator Area

Diesel generators shall be separated from each other and from other areas of the plant by fire barriers having adequate fire resistance rating.

Automatic fire suppression shall be installed to combat fires of any diesel generator or lubricating oil. Such systems shall be designed for operation when the diesel generator is running without affecting the safety of the plant.

Automatic fire detection shall be provided to alarm and annunciate in the control room and alarm locally. Hose stations and portable extinguishers shall be readily available outside the area. Drainage for fire fighting water, means for local manual venting of smoke shall be provided.

Day tanks with total capacity up to 4.2 m^3 (1100 gallons) are permitted in the diesel generator area under the following conditions:

(a) The day tank is located in a separate enclosure with an adequate fire resistance rating, including doors or penetrations. These enclosures shall be capable of containing the entire contents of the day tanks and should be protected by an automatic fire suppression system, or

(b) It is located inside the diesel generator room in a dyked enclosure that has a capacity to hold 110% of the contents of the day tank or is drained to a safe location.

10.1.2.2.5.9 Diesel Fuel Oil Storage Area

Diesel fuel oil tanks with a capacity greater than 4.2 m^3 (1100 gallons) shall not be located inside buildings containing safety related equipment. If aboveground tanks are used, they should be located at least 15 m from any building containing safety related equipment or, if located within 15 m, they should be housed in separate buildings with construction having adequate fire resistance rating. Potential oil spills should be confined or directed away from buildings containing safety related equipment. Totally buried tanks are acceptable outside or under the buildings. Requirement under explosives/flammable liquids acts shall be adhered to.

Above ground tanks (capacity greater than 4.2 m^3) should be protected by a fire suppression system and kept under visual monitoring.

10.1.2.2.5.10 Safety Related Pumps

Pump houses and rooms housing redundant safety related pumps shall be separated from each other and also from other areas of the plant by fire barriers having adequate fire ratings or adequately separated. These rooms shall be protected by automatic fire detection and suppression systems unless a fire hazard analysis can demonstrate that a fire will not endanger other safety related equipment required for safe plant shutdown. Fire detection shall alarm and annunciate in the control room and alarm locally. Hose stations and portable extinguishers shall be readily accessible.

Floor drains shall be provided to prevent water accumulation and damage to safety related equipment.

Provisions should be also made for manual control of the ventilation system to facilitate smoke removal if required for manual fire fighting operation.

10.1.2.2.5.11 Fresh Fuel Storage Area

Portable extinguishers shall be located within this area. Also, hose stations should be located outside this area. Automatic fire detection shall alarm and annunciate in the control room. Combustibles should be limited to a minimum in the new fuel storage area. The storage area shall be provided with a drainage system to preclude accumulation of water.

10.1.2.2.5.12 Spent Fuel Pool Area

Protection for the spent fuel pool area shall be provided by local hose stations and portable extinguishers. Automatic fire detection shall be provided to alarm and annunciate in the control room.

10.1.2.2.5.13 Rad-waste and Decontamination Areas

Fire barriers, fire detection and suppression and ventilation controls should be provided as considered necessary depending upon the combustibles present in the area.

10.1.2.2.5.14 Cooling Towers

Cooling towers should be of noncombustible construction or so located and protected that a fire will not adversely affect any safety related systems or equipment in the neighbourhood. When the basins are used for the ultimate heat sink or for the fire protection water supply, cooling towers shall be of noncombustible construction.

10.1.2.2.5.15 Turbine Building

The turbine building shall be separated from adjacent structures containing safety-related equipment by a fire barrier with adequate fire rating. Openings and penetrations shall not be located where the turbine oil system or generator hydrogen cooling system creates a direct fire exposure hazard to the barrier. Considering the severity of the fire hazards, additional protection may be considered to ensure integrity of the barrier.

Hydrogen leak detection system should be provided around the generator, inside the bus-ducts and in the hydrogen charging station area. The ventilation should be such that the hydrogen concentration in air is less than 1% by volume.

The electrical fittings in the area shall be of flameproof type.

Since, oil in main oil tank and turbine oil tank form a very high fire load, due consideration shall be given for location of these tanks with suitable embankments around the tank, proper fire barrier and fire protection system.

10.1.2.2.5.16 Miscellaneous Areas

Miscellaneous areas such as records storage areas, shops, warehouses, auxiliary boiler rooms, fuel oil tanks, and flammable and combustible liquid storage tanks should be so located and protected that a fire or effects of a fire (including smoke) will not adversely affect any safety related system or equipment.

10.1.3 Special Protection Guidelines

10.1.3.1 Storage of Acetylene-Oxygen Fuel Gases

Gas cylinder storage locations shall not be in areas that contain or expose safety related equipment or the fire protection systems that serve those safety related areas. A permit system shall be required to use this equipment in safety related areas of the plant.

10.1.3.2 Storage Areas for Ion Exchange Resins

Unused ion exchange resins shall not be stored in areas that contain or expose safety-related equipment.

10.1.3.3 Hazardous Chemicals

Hazardous chemicals shall not be stored in areas that contain or expose safety related equipment.

10.1.3.4 Materials Containing Radioactivity

Materials, which collect and contain radioactivity such as spent ion exchange resins, charcoal and high efficiency particulate air (HEPA) filters shall be stored in closed metal tanks or containers, which are located in areas free from ignition sources or combustibles. These materials shall be protected from exposure to fires in adjacent areas as well. Consideration shall be given to requirements for removal of decay heat from entrained radioactive materials.

10.2 Fast Reactors

10.2.1 General

This subsection outlines fire protection requirements specific to reactors using sodium. High temperature sodium leaking out from the systems reacts violently with the atmospheric air and burns. The consequences are more severe with the primary sodium as it is also radioactive and hence the safe guards must be more stringent.

From the safety aspect, the main consequences of a sodium fire are threat to the structural integrity of the building, the effect of fire on the other systems and the toxic hazards of oxides released to the atmosphere. In the case of primary sodium, the hazards of radioactivity are additional.

10.2.2 Requirements of Specific Systems

10.2.2.1 Building Design

10.2.2.1.1 The following buildings shall be designed as separate fire areas of adequate fire rating.

(a) Reactor containment building.

(b) Control room.

(c) Supplementary control room.

(d) Cable spreading room.

(e) Electrical switchgear room.

(f) Battery room.

(g) Emergency diesel generator area (each).

(h) Steam generator building (each).

(i) Turbine building.

All other areas shall be analysed by FHA to determine the ratings required.

10.2.2.1.2 Direct contact of leaking sodium with the concrete shall be avoided by providing liners of steel or sodium compatible concrete. The thermal effect of sodium on the concrete shall also be considered.

10.2.2.2 Electrical Circuits and Equipment

(As given in 10.1.2.1.)

10.2.2.3 Ventilation

S.G. buildings having sodium systems shall have a venting system with filtration to remove smoke and aerosols to prevent settling of the aerosols and to enable fire fighting personnel to enter the affected area.

10.2.2.4 Fire Detector and Alarm System (Sodium Leak Detection System)

10.2.2.4.1 Diverse types of leak detectors should be provided for detecting sodium leaks to improve reliability.

10.2.2.4.2 All the sodium tanks, equipment, pipelines and leak collection devices shall be provided with leak detectors.

10.2.2.4.3 The sensitivity and response time of the sodium leak detectors shall be as per ASME section XI, Div. 3.

10.2.2.5 Fire Suppression Systems

10.2.2.5.1 Various fire extinguishing powders based on graphite and chlorides are being used for extinguishing sodium fires. Taking into consideration the following factors, suitable dry powder extinguishers shall be selected.

(a) The quantity of powder required should not be more than twice the weight of sodium to put out the fire.

(b) Ease of application.

(c) Availability and cost.

(d) Cooling rate/blanketing effect/lower density than sodium.

(e) Ease of disposal.

(f) Ease of storage.

(g) Non-corrosive nature of powder.

10.2.2.5.2 CO_2 or water based extinguishers shall not be used for putting out sodium fires.

10.2.2.5.3 The plant shall have in its operating area, adequate quantity of powder (at least 25% more than the actual requirement) that would be required to fight the maximum postulated sodium fire.

10.2.2.5.4 For fighting small fires, the extinguishing powder shall be kept in small capacity containers/bags in strategically chosen locations.

10.2.2.5.5 Small capacity cartridge type portable extinguishers shall also be kept at strategic locations for fighting small fires.

10.2.2.5.6 For fighting moderate to large sodium fires, adequate number of trolley mounted pressurised extinguishers shall be kept at strategic locations.

10.2.2.5.7 A fixed installation of pressurised container with flexible hoses of sufficient length, which can reach any part of the building, may also be considered for fighting moderate to large sodium fires.

10.2.2.5.8 The extinguishing powders shall be periodically checked as per the manufacturer's recommendations for their quality and self-life.

10.2.3 Requirements of Specific Plant Areas

10.2.3.1 Buildings Housing Sodium Systems

10.2.3.1.1 The design leak criteria for sodium shall also take into account the errors during the maintenance and special operational activities. The system design shall also be evaluated for protection against failures by dropped loads or missiles.

10.2.3.1.2 Water shall not be used in these buildings for fire protection system.

10.2.3.1.3 Fire protection requirements shall be provided for hazards identified by the fire hazard analysis.

10.2.3.1.4 An analysis of the potential for sodium leak and fire in the different areas shall be made. Suitable and adequate fire fighting capability shall be permanently installed in different areas, if found necessary. Portable fire extinguishers shall be installed at strategic locations. The quantity of fire extinguishers provided should take into consideration that water system and water based fire hydrant are not to be used.

10.2.3.1.5 All power and control cables (safety or non-safety related) shall be covered/ coated by a fire resistant material. As compensation for the impaired capabilities of fire fighting operations, with the preclusion of use of water for fire suppression, the cables should generally be of higher rating so as to enable a more liberal use of fire resistant enclosure without undue heating of cables. In special circumstances, cables with either mineral insulation or other fire resistant insulation materials shall be used.

10.2.3.1.6 Adequate self-contained breathing apparatus shall be provided near the entrances for fire fighting and rescue personnel. These units shall be independent of any breathing apparatus or air supply systems provided for general plant activities and shall be clearly marked as emergency equipment.

10.2.3.2 Reactor Containment Building

10.2.3.2.1 The effects of postulated fires within the reactor building shall be evaluated to ensure that the integrity of the shutdown system, primary coolant system, the decay heat removal system and the containment is not jeopardised assuming no action is taken to fight the fire.

10.2.3.2.2 Operation of the fire protection system shall not compromise the integrity of the containment including ventilation and gaseous activity release or other safety related systems.

10.2.3.2.3 Penetrations in the containment, if any, for the piped powder systems shall meet the isolation requirements of containment and meet seismic category-II.

10.2.3.2.4 All sodium lines in the reactor containment building, the primary and secondary sodium lines, the decay heat removal system lines and the primary sodium purification lines shall be double-walled and the annular space filled with inert gas. Single wall for small line will be acceptable provided they are housed in inerted steel cabins or in inerted cells lined with steel or sodium compatible concrete.

10.2.3.2.5 Concrete cells housing both the primary sodium system and components are a specific feature of fast reactors. Considering the inaccessibility to fight the fire, all combustible materials should be avoided. In view of the possible interaction between sodium and concrete, the cell walls shall be suitably lined. Only mineral insulated or fire survival cables shall be used inside the cells.

10.2.3.2.6 In fast reactors, the attic (the volume above the reactor vault) is an important location which houses several safety-related components/equipment like control and safety rod drive mechanisms (CSRDMs), the primary sodium pumps, portion of secondary sodium pipelines, the decay heat removal systems and the associated cables and other safety related systems. In view of these, the attic area shall be considered to be a separate fire zone. All sodium pipelines in the attic shall be double-walled and shall be provided with leak collection trays. No valves are to be provided for these lines in the attic. Use of combustible materials should be avoided to the extent possible in the attic. From the cable fire hazard point of view, use of fire survival or mineral insulated (MI) cables should be considered. Barrier concept shall be adopted to separate all safety-related equipment, sodium lines and cables. A complete fire hazard analysis shall be performed for the attic area considering the fire loads and suitable fire suppression system shall be provided in the area. Diverse fire detection systems shall be installed in the attic. A remotely operated manual fire suppression system shall be provided. CO_2 systems should be considered and a reasonably leak tight containment for the attic should also be provided. For sodium fires in the attic, a manually operated inert gas flooding system shall be provided to bring down the concentration of oxygen to less than 5% within a reasonable time as established by the fire hazard analysis. A separate exhaust with appropriate filters to handle radioactive sodium aerosols shall also be provided for the attic area.

10.2.3.2.7 A general area fire detection capability shall be provided in the containment as a backup for the fire detectors provided for specific fire hazards in these areas. To accomplish this, suitable detectors compatible with the radiation environment shall be installed.

10.2.3.3 Steam Generator Building

10.2.3.3.1 Each steam generator building shall be separated from each other and also from other buildings by a fire barrier of adequate rating.

10.2.3.3.2 Operation for the fire protection system shall not compromise the integrity of the safety-related systems. Fire protection activities in these areas shall function in conjunction with requirements such as ventilation.

10.2.3.3.3 If the sodium carrying pipelines are single-walled, they shall be provided with leak collection devices to passively accommodate the leaks and terminate sodium burning with a limited release of sodium aerosols (such as tray system with very small oxygen inlet).

Provision for fast dumping of sodium shall be made to limit the leaking sodium. In case of tanks, provision shall be made for transferring the sodium from the leaking tank to another storage tank.

10.2.3.3.4 Necessary and adequate stock of protective wear (like laboratory coat or coverall, asbestos coat and apron, leather safety shoes, leg guard, helmet with face shield, asbestos or leather gloves) for work on sodium systems shall be provided at the entrance of each steam generator building. Instructions on use of appropriate protective wear should be prominently displayed in these areas.

10.2.3.3.5 Each steam generator building shall have areas earmarked for eye and body wash and cleaning for personnel for first aid treatment against sodium burns and injuries. Eye wash and deluge shower shall be located at a place, which shall be easily accessible even during an emergency.

10.2.3.3.6 First aid for sodium burns shall be given as per approved instructions. First aid box containing paraffin oil, acetic acid (2%) or boric acid (2%) in addition to the normal applicators shall be provided. Acetic acid must NEVER be used for eyewash.

10.2.3.4 Control Room Complex

(As in 10.1.2.2.5.1)

10.2.3.5 Cable Spreading Room

(As in 10.1.2.2.5.2)

10.2.3.6 Cable Galleries

10.2.3.6.1 The routing of the cables in this area shall be in accordance with the provisions of section 10.1.2.2.5.2.

10.2.3.6.2 Fire detection systems shall be provided in the cable galleries. Air sampling type detectors shall be provided for the cables in this area.

10.2.3.6.3 Cable galleries carrying safety-related cables and which are not accessible shall be provided with a zoned automatic water system such as sprinklers, deluge or water spray system. Deluge and open spray systems shall have provisions for manual actuation from a remote station; however, there shall be provisions to preclude inadvertent operation. Location of sprinkler heads of spray nozzles shall consider cable tray arrangements and possible transient combustibles to ensure adequate water coverage for areas that could present exposure hazards to the cable system. Cables shall be designed to allow wetting down with water supplied by the fire suppression system without causing electrical faults.

10.2.3.6.4 The use of foam is acceptable.

10.2.3.6.5 Automatic CO_2 system may be used for primary fire suppression if they are backed up by a fixed water spray system.

10.2.3.6.6 Cable galleries shall have:

(a) At least two remote and separate entrances for access by fire brigade personnel.

(b) An aisle separation between tray stacks at least 1 m wide and 2.5 m high.

(c) Hose stations and portable extinguishers installed immediately outside these areas.

10.2.3.7 Plant Computer Rooms

(As in 10.1.2.2.5.4)

10.2.3.8 Switchgear Rooms

(As in 10.1.2.2.5.5)

10.2.3.9 Remote Safety Related Panels

(As in 10.1.2.2.5.6)

10.2.3.10 Battery Room

(As in 10.1.2.2.5.7)

10.2.3.11 Diesel Generator Area

(As in 10.1.2.2.5.8)

10.2.3.12 Diesel Fuel Oil Storage Area

(As in 10.1.2.2.5.9)

10.2.3.13 Fresh Fuel Storage Area

The storage configuration of the fresh fuel shall always be so maintained as to preclude criticality for any water dousing that might occur during firewater application.

Storage of combustibles shall be avoided in this area and fire loads shall be limited to the absolute minimum.

10.2.3.13.1 The ventilation system of the area shall be capable of being isolated with suitable dampers rated for the fire hazard.

10.2.3.13.2 General area fire detection system shall be provided for this area. This system shall alarm and annunciate in the control room and locally.

10.2.3.13.3 Hose stations shall be located outside but within hose reach of this area.

10.2.3.13.4 The storage area shall be provided with a drainage system to preclude accumulation of water and flooding.

10.2.3.13.5 Portable extinguishers shall be located within this area.

10.2.3.13.6 Adequate quantities of dry chemical powder shall be available for fighting plutonium fires.

10.2.3.14 Spent Fuel Storage Area

10.2.3.14.1 For dry storage of the irradiated fuel, the configuration shall always be so maintained to preclude criticality for any water density that might occur during fire water application.

10.2.3.14.2 Storage of combustibles shall be avoided in this area and fire loads shall be limited to the absolute minimum.

10.2.3.14.3 The ventilation system of the area shall be capable of being isolated with suitable dampers rated for the fire hazard.

10.2.3.14.4 General area fire detection system shall be provided for this area. This system shall alarm and annunciate in the control room and locally.

10.2.3.14.5 Hose stations shall be located outside of this area but within hose reach.

10.2.3.14.6 The storage area shall be provided with a drainage system to preclude accumulation of water and flooding.

10.2.3.14.7 Portable extinguishers shall be located within this area.

10.2.3.15 Rad-waste and Decontamination Areas

(As in 10.1.2.2.5.13)

10.2.3.16 Cooling Towers

(As in 10.1.2.2.5.14)

10.2.3.17 Turbine Building

(As in 10.1.2.2.5.15)

10.2.3.18 Miscellaneous Areas

(As in 10.1.2.2.5.16)

10.3 Light Water Reactors

10.3.1 General

This subsection describes the fire protection requirements in a light water reactor station (both Pressurised water reactor and Boiling water reactor). The reactor systems shall be designed against a postulated fire in any zones within the plant so that the hot shutdown of the reactor may be achieved when the fire brings about a disturbance to the reactor and requires the operation of the reactor protection systems and the reactor shutdown systems even if a single failure is assumed. The systems required for cold shutdown of the reactor shall be designed not to lose its functions by a postulated fire in any zones within the plant.

10.3.2 Fire Water System

The system shall be designed to safe shutdown earthquake (SSE) category for the safety related nuclear systems. The storage for the fire fighting water shall be estimated for continuous operation of 2 hours of hydrants @ $171m^3$/hr and 2 hours of largest sprinkler, both operating simultaneously. The pump head shall be estimated to give a minimum residual pressure of 3.5 kg/cm^2 at the hydraulically farthest point while delivering required full flow. Provision shall be made for suitable number of independently powered pumps to cater to the fire protection requirement during station black out (on- site and off-site power failure) condition.

10.3.3 Additional Requirements for Fire Protection

10.3.3.1 Safety Related Electrical Circuits.

Class-1E circuits and equipment shall be arranged to maintain the independence of equipment assigned to different safety divisions and to prevent the spread of fire from one safety division to the other. Where fire barriers are not provided due to overriding design features, the location and installation of Class 1E circuits and equipment shall meet the separation requirements of 'Standard Criteria for Independence of Class 1E Equipment and Circuits,' IEEE Std.-384-1977. A fire hazard analysis shall be performed to determine any additional requirements for fire protection necessary to ensure that nuclear safety functions are maintained in the event of a fire.

10.3.4 Reactor Building Containment

Fire protection requirements for containment areas should be provided for hazards identified by the fire hazard analysis. Because of the general inaccessibility of certain areas of the containment during normal plant operation, protection shall be provided by automatic/remote, or manually operated fixed systems. Operation of the fire protection systems should not compromise the integrity of the containment or other safety related systems. Cable trays having high cable densities should be provided with fire detection system and remote, or manually operated sprinkler systems. In view of difficulty in purging out CO_2 from the various areas of reactor building, use of fixed CO_2 system is not recommended within the building.

10.3.5 Boiler Room/Pump Room

All high enthalpy, high temperature and high pressure fluid process systems are located in this area. The most vulnerable area is the primary coolant pump with its oil-lubrication system. There are a large number of power and control cables in this area in different cable trays.

The background radiation level in this area during operation is high and hence normally inaccessible.

Based on the above problems, the selection and location of the detectors shall be decided to make fire detection system in the area effective e.g. in the proximity of motors.

Remotely operated sprinkler system should be considered for fire suppression in the area. Fire suppression system using chloride free dry powder/water, applied locally, should be employed with utmost care.

10.3.6 Other Areas Housing Safety Related Systems/Equipment

10.3.6.1 Control Room

(As in 10.1.2.2.5.1)

10.3.6.2 Cable Gallery/Cable Vault

(As in 10.1.2.2.5.2)

10.3.6.3 Control Equipment Rooms/Control and Instrumentation Cable Spreading Area

(As in 10.1.2.2.5.3)

10.3.6.4 Plant Computer Room

(As in 10.1.2.2.5.4)

10.3.6.5 Switchgear Rooms

(As in 10.1.2.2.5.5)

10.3.6.6 Remote Safety Related Panels

(As in 10.1.2.2.5.6)

10.3.6.7 Battery Rooms

(As in 10.1.2.2.5.7)

10.3.6.8 Diesel Generator Area

(As in 10.1.2.2.5.8)

10.3.6.9 Diesel Fuel Oil Storage Area

(As in 10.1.2.2.5.9)

10.3.6.10 Safety Related Pumps

(As in 10.1.2.2.5.10)

10.3.6.11 Fresh Fuel Storage Area

The storage configuration of the fresh fuel shall always be so maintained as to preclude criticality for any water dousing that might occur during firewater application by use oa a geometrical safety layout or other appropriate means.

Storage of combustibles shall be avoided in this area and fire loads shall be limited to the absolute minimum.

The ventilation system of the area shall be capable of being isolated with suitable dampers rated for the fire hazard.

General area fire detection system shall be provided for this area. This system shall alarm and annunciate in the control room and locally.

Hose stations shall be located outside but within hose reach of this area.

The storage area shall be provided with a drainage system to preclude accumulation of water and flooding.

Portable extinguishers shall be located within this area.

10.3.6.12 Spent Fuel Pool Area

(As in 10.1.2.2.5.12)

10.3.6.13 Rad-waste and Decontamination Areas

(As in 10.1.2.2.5.13)

10.3.6.14 Cooling Towers

(As in 10.1.2.2.5.14)

10.3.6.15 Turbine Building

(As in 10.1.2.2.5.15)

10.3.6.16 Miscellaneous Areas

(As in 10.1.2.2.5.16)

10.4 Spent Fuel Reprocessing Plants

10.4.1 General

A potential risk to the health and safety of the plant personnel and general public at a fuel reprocessing plant is the release and dispersal of radioactive materials due to a fire or explosion. The principal purpose of a fire protection programme for a reprocessing plant, therefore, is the protection of the plant personnel, general public and the environment from the adverse radiological consequences due to fire. The fire protection programme for these plants shall be designed to prevent, detect, extinguish, limit or control fires and explosions and their hazards and damaging effects. This section discusses the basis and criteria for such a programme and provides guidelines for implementation during the design and construction stage of the plants.

Major fire hazards in a PUREX process based reprocessing plant could be due to bulk handling of tri-butyl phosphate, n-dodecane, hydrazine, formaldehyde and furnace oil. Zirconium fines fire during fuel chopping is also likely. Glove boxes, fume hoods and enclosures with perspex panels, neoprene gloves (in case of glove boxes) and combustibles present inside them, are also potentially hazardous. Loss of coolant for prolonged periods for waste storage tanks in the underground vault could result in considerable heating of the wastes.

10.4.2 Requirements of Specific Plant Areas/Systems

10.4.2.1 Buildings

The fuel reprocessing plant shall be designed and constructed using building components of heat resistant and noncombustible material wherever practicable, particularly in locations vital to the functioning of confinement barriers and systems.

All plutonium handling areas or highly radioactive areas should be protected by an isolating wall of adequate rating to prevent the spread of contamination in the event of fire in those areas. (For further details see subsection 3.2 on building design)

10.4.2.2 Hot Cells

In the construction of hot cells, use of combustible materials shall be minimised. Hot cells shall contain the minimum amount of combustible materials consistent with operational requirements. Construction and processing materials shall be so selected that they will not be degraded by exposure to high radiation fields or corrosive atmosphere to the point where they will present a fire hazard. Materials and equipment in a hot cell shall not be arranged in such a way as to contribute to the ignition or the spread of the fire or hinder the detection or suppression of a fire.

Hot cells and enclosures for glove box trains handling plutonium shall have proper water collection trays with drains for allowing flow of water used in fire fighting to a special holdup tank.

Adequate fire fighting arrangement shall be provided in/near hot cells. Provision of water sprinkler system should also be made in this area with adequate arrangement for collection and drainage of water.

Explosion-proof electrical fittings shall be used inside the hot cells.

10.4.2.3 Glove Boxes and Enclosures

Glove boxes and process enclosures should be provided with fire stops in connecting tunnels to prevent the spread of fire. The fire stops between enclosures should normally be closed. Where operations require that the fire stops be in the open position, they should be designed to close whenever required. Provision should also be made for the manual operation of fire stops. Combustible materials, which are an integral part of a glove box, should be held to a minimum.

Use of fixed extinguishing system with an appropriate media such as CO_2, dry chemical powder etc. should be provided for the glove boxes.

The design of enclosures should be such that the ventilation flow minimizes spread of fire. Heat detectors and combustible gas and vapour detection meters should be provided on glove boxes or enclosures, where fire or explosion hazards exist. Automatic systems are preferred; manual systems are also acceptable with appropriate provisions for manual fire fighting.

10.4.2.4 Fume Hoods

Chemical fume or particulate exhaust hoods shall be equipped with partly closing sashes to maintain ventilation balance and shall be provided with fire detectors. Provisions shall be made for manual fire suppression where fire or explosion hazards exist i.e. a small portable or trolley-mounted inert gas cylinder shall be made available nearby for ready use. If the cylinder is kept inside, then the material of construction of these cylinders shall be corrosion resistant.

10.4.2.5 Ventilation

The ventilation and exhaust system of main process areas, laboratory areas, process off-gas system, glove boxes etc. shall be designed to withstand any credible fire accident and continue to act as confinement barrier. The ventilation system shall be constructed of fire-resistant material and shall include fire resistant filters, heat and smoke detectors, alarms, fire suppression equipment and fire doors and dampers to restrict the spread of fire.

The filter bank area shall be isolated with adequate fire barriers to ensure the availability of filter banks in case of fire in an adjoining area. Two stages (minimum) of adequately designed filter banks should be installed between the stack and plutonium handling glove boxes, The filters should be tested for the specified temperature of at least 300^0 C.

Ventilation system shall basically be capable of operating during fire in the areas they ventilate and safely handle products of combustion by effectively exhausting and thus taking due care of the abnormal dust load. Fire and smoke suppression equipment shall be so located as to ensure that the integrity of final high efficiency filters or filter systems is not degraded. Spark and flame arresters and isolation valves shall be used at appropriate locations.

10.4.2.6 Sprinkler System

Automatic water sprinklers should be provided for outdoor transformer systems. Nonaqueous systems shall be used in areas not protected by automatic water sprinklers or for other special applications. Automatic water-type extinguishing systems include wet pipe, pre-action sprinkler, open head deluge, water spray, and systems utilising automatic 'on-off' flow control. Selection of a specific type of system shall take into account, the system characteristics such as response time, ambient temperature, and required volumes and optimum use of water.

Where used in process areas, the sprinkler systems selected shall use minimum quantity of water, to prevent the un-intentional operation of sprinkler heads and the spread of contamination by water, reduce the extent of cleanup operations, and the possibility of criticality. Adequate provision shall be made to ensure that water so used for fire fighting enters neither the zones having high radiation levels nor active drains in the plant. Adequate underground holdup storage capacity shall be provided to collect water if used for fire fighting in areas having contamination or radioactivity as an extreme emergency step.

10.4.2.7 Fire Protection Water System

Potable and process water systems shall normally be independent of the fire water supply. Fire water supply for the permanent fire protection installation shall have a minimum of two reliable independent sources of sufficient capacity for firefighting until the other sources of water are also made available. Water supplies containing salt or other materials deleterious to the fire protection system shall be avoided wherever possible.

Water for fire protection systems shall be furnished to the site by a loop distribution system encircling the site building. Hydrants served by this system shall be strategically located around the loop. Valves or valve assemblies shall be provided for proper sectional control of the loop.

Firewater pumps shall be equipped with automatic starting features for fire service. There shall be a minimum of two pumps, at least one of which shall be driven by non electrical means, preferably diesel engine. Emergency power shall be supplied to an electric driven fire pump in the event of failure of the normal power supply.

Water shall be supplied to each water spray extinguishing system from the main water loop around the facility. A water spray system may be used for heat removal for the high efficiency filtration system serving as a final means of effluent cleaning for the ventilation systems. This water spray systems shall have a dedicated water supply, in addition to the normal water supply, sized to operate the system during a credible fire accident even if all other water supplies fail.

10.4.2.8 Fire Detection and Alarm System

Provision shall be made for fire detection and alarm systems in the plant. These systems shall consist of fire/smoke detectors, signaling devices, audible and visual indicators in constantly attended locations, as well as in appropriate locations in the plant. Fires shall be indicated audibly by alarms, which are initiated by fire detection systems. A means shall be provided to monitor the status and functioning of the fire detection, signal, and alarm systems as well as other fire protection system components located throughout the plant. Provision shall also be made for periodic testing and checking of these systems.

A plant-wide public address and telephone systems shall be provided. Manual fire alarm stations shall be installed throughout the facility at readily accessible locations. These stations shall be connected to the plant-wide alarm system.

The inlet duct to a multistage high efficiency filter plenum serving as a final means of effluent cleaning for the ventilation systems shall be provided with heat and smoke detectors, which actuate a local alarm and an automatic fire alarm station on the plant-wide alarm system.

10.4.2.9 Fuel Handling Area

Inert gas purging facility shall be made available during fuel chopping. The system shall be kept in poised condition, so that inert gas purging is started immediately on detecting a spark.

10.4.2.10 Flammable Materials

Special control shall be exercised over the handling of flammable, toxic and explosive gases, chemicals, and materials admitted to or produced in the process areas. Solvents (TBP) and other flammable liquids, other than small quantities in use, shall be stored in a separate building or unexposed storage area. Covered noncombustible containers shall be provided for combustible waste.

The preparation of the solvent shall be done in a well ventilated separate enclosure.

Provisions shall be made for isolation between incompatible chemicals, materials, and processes/areas such as solvent extraction, ammonium diuranate precipitation, electrolyser room, chemical make-up area etc.

Flammable and combustible materials shall not be stored in finished product storage areas or transit waste storage areas.

10.4.2.11 Control Room

(As in 10.1.2.2.5.1)

10.4.2.12 Switchgear Room

(As in 10.1.2.2.5.5)

10.4.2.13 Diesel Generator Area

(As in 10.1.2.2.5.8)

10.4.2.14 Diesel Fuel Oil Storage Area

(As in 10.1.2.2.5.9)

10.4.2.15 Rad-waste and Decontamination Area

(As in 10.1.2.2.5.13)

10.5 Heavy Water Plants

10.5.1 General

The scope of this section covers heavy water plants (HWP) based on ammonia-hydrogen exchange and hydrogen sulphide-water exchange processes. The plants based on ammonia-hydrogen exchange process are integrated with the neighbouring fertilizer plants from which feed synthesis gas and other utilities are obtained, whereas the hydrogen sulphide-water exchange process based plants are independent in nature. In all these plants, toxic, inflammable and explosive materials like hydrogen sulphide, ammonia, and hydrogen under high pressure are handled in bulk quantities both as dynamic and static storages. Apart from these, the plants also have a sizable inventory of chemicals like naphtha, natural gas, n-hexane, liquefied petroleum gas, coal, furnace oil, chlorine, calcium carbide, sulphuric and hydrochloric acids, sodium hydroxide etc. The main objective of the fire prevention measures in the HWPs is in the strict avoidance of release of flammable materials and prevention and containment of fire by proper design, construction, well defined operation and maintenance, and administrative controls etc. The above shall also ensure that in the event of a fire, the resulting damage is to be kept to the barest minimum and the fullest protection is given to the plant personnel, general public, environment and the plant machinery.

10.5.2 Requirement of Specific Systems

10.5.2.1 Ammonia-Hydrogen System and H_2S System

In ammonia-hydrogen and hydrogen sulphide system, the main consequences of fire/explosion are:

(a) Danger to the persons due to the toxic fumes released to the environment.

(b) Danger to the building structural integrity.

(c) Danger of the fire spreading to other plant systems/area.

10.5.2.1.1 For minimising danger due to ammonia, hydrogen and hydrogen sulphide, integrity of the equipment, piping and components shall be ensured by relevant design codes, established quality control and good engineering practice in fabrication and erection. The piping design shall ensure no rupture in pipe due to extremes in pressure and temperature, by proper material selection, fracture mechanics calculations and use of well-validated pipe work code.

10.5.2.1.2 Provision shall exist for safe dumping/venting/draining of the system fluid on detection of a leak. There shall be adequate leak detection system. In case of a leak, there shall be a provision for the complete isolation of the affected system in H_2S system and quench it.

10.5.2.1.3 High temperature piping shall be properly insulated to exclude it as an ignition source.

10.5.2.1.4 A closed drain and vent system should be provided for hazardous process fluids such as hydrogen sulphide, to contain such leaks/discharges/emissions from plant systems which can spread to various areas of the plant.

10.5.2.1.5 There shall be provision for transferring liquid H_2S from a storage tank to another in the event of a leak.

10.5.2.2 Building Design for the Plant

10.5.2.2.1 The following parts of plant shall be protected against fire suitably as indicated by fire hazard analysis:

(a) Electrical switchgear/substation.

(b) Battery room.

(c) Emergency diesel generator room.

(d) Control room.

The following areas are more prone to fire hazards and FHA shall be carried out:

Ammonia Based Plants	**Sulphide Based Plants**
High Pressure System:	
Ammonia converters	Hydrogen sulphide generation and storage units
Isotopic exchange towers	
Purifiers	
Medium Pressure System:	
Enrichment towers	LPG storage and handling unit
Crackers	

Catalyst recuperation unit	Furnace oil storage area
Final enrichment unit	Captive power plant

Low Pressure System:

Mini cracker

Potassium and potassium amide handling unit.

10.5.2.2.2 The plant layout shall be finalised with regard to major fires, which may arise in the main plant.

(a) The space between the two operating units shall be adequate for easy movement of cranes and accessibility for maintenance. However, if the operating units, equipment and machine handle explosive and hazardous materials, then their layout shall be as per the American Petroleum Institute (API) guidelines.

(b) Adequate fire water hydrant system with riser pipes to cope up with fire risks at any height in the operating plant shall be installed. The minimum quantities required shall be as per the requirements given in the National Fire Code 1989.

(c) The design of plant layout shall be as per national electric code classification (zone 0, 1 or 2). Plant layout shall be finalised based on consequence analysis and also taking predominant wind direction into consideration.

10.5.2.3 Electrical circuit/equipment

(a) Electrical equipment installed in areas containing flammable gases or vapours shall be governed by IS : 5572(Part-I)-1978 and IS : 5571-1979.

(b) Any hazardous locations where flameproof electrical equipment and fittings are required to be installed, such installations shall be located in a separate building. Only rigid metal conduits and armoured cable wiring shall be used in areas containing flammable gases or vapours.

(c) The cables shall not be routed near hot steam pipe, turbine, hot gas ducts etc. Wherever such routing is to be carried out, fireproof cables shall be used. Power and control cables shall run in separate cable trays wherever possible.

(d) Mineral insulated metal sheathed cables shall not be permitted

(i) where they would be exposed to destructive and corrosive conditions,

(ii) where they would be put directly underground without protection against mechanical damage and corrosive conditions, and

(iii) where they would be used in wet locations unless the metallic sheath is impervious to moisture, or a lead sheath or waterproof jacket is provided under the sheath are approved for use in wet locations.

Armoured cables shall not be permitted in commercial garages, storage battery rooms and in locations where they would be exposed to corrosive fumes or gases and the atmosphere is likely to contain flammable or explosive vapours.

10.5.2.4 Ventilation

10.5.2.4.1 The plant design shall ensure sufficient air circulation so that there is no concentration of hazardous/flammable gases. Minimum 20 air charges per hour shall be maintained in the control room, while in the compressor house of ammonia based plants, minimum 6 air charges per hour shall be maintained.

10.5.2.4.2 In case of heavy leak of H_2S gas in the plant area, the air entering the central control room shall be water washed and its H_2S content shall be continuously monitored. In case of an emergency, air intake to this building is cut off and stored air in the building shall be used.

10.5.2.4.3 Sufficient number of shelters shall be provided at different locations in the plant and area identified for the shelters, so that persons working in that area assemble at the designated shelters. Each shelter shall have a provision for stored breathing air with face masks to meet the breathing air requirement for at least 2 hours for all the personnel assembling in that shelter.

10.5.2.5 Fire Detection and Alarm System

10.5.2.5.1 For detection of fire in the plant, fire detectors along with the alarm system shall be installed. The fire alarm shall be initiated based on feedback from the various fire sensors located in the plant. Heat and smoke detectors, heat-sensing cables, manual call point etc., shall be installed as per the area specific requirements. On critical locations, sensors with automatic initiation of alarm shall be used, while for other noncritical locations manual action sensors can be installed. For informing neighbourhood public, fire warning sirens shall be installed.

10.5.2.5.2 The location shall be such that the sensors placed are able to pick up immediately on initiation of fire. Prevalent wind direction and obstructions to the sensors shall be kept in mind, while selecting the location of sensors.

10.5.2.5.3 Construction and installation of the detectors shall be as per ISA-Code 12.1 'Electrical Instruments in Hazardous Areas'.

10.5.2.6 Fire Suppression System

10.5.2.6.1 To prevent over heating of equipment in case of fire, deluge system coupled with hydrants system shall be provided to all the liquid hydrogen sulphide storage tanks. Provision shall be made for remote operation of the deluge system. LPG bullets shall be provided with continuous water spray system.

10.5.2.6.2 Various types of fire extinguishers will also be located in adequate numbers at scheduled places, for fighting minor fires. For the purpose of fire fighting, types of fire extinguishers shall be as follows:

(a) Dry chemical powder.

(b) Carbon dioxide.

(c) Water-CO_2.

(d) For extinguishing potassium fires, dry sand filled in buckets shall be kept at scheduled places besides special DCP.

(e) CO_2 or water-based extinguishers shall not be used for putting out potassium fire.

10.5.2.6.3 The capacity of pump for the fire hydrant system shall be such that it is able to meet the requirements of minimum 4 hydrants of 250 gpm and 1 largest jet monitor/riser in the plant. The storage capacity of the fire water storage tank should be able to sustain the above requirements for a minimum of 2 hours.

10.5.3 Requirement of Specific Plant Areas

10.5.3.1 Storage Areas

10.5.3.1.1 Potassium Storage Area

Potassium shall always be stored in paraffin oil free from moisture. No water hydrant or water source shall be present in these areas. Adequate amount of dry sand and special dry chemical powder like tertiary eutectic chloride (TEC) powder shall be made available. Storage of other combustibles shall be avoided.

10.5.3.1.2 Calcium Carbide Storage Area

The calcium carbide shall always be stored in such a way so as to preclude moisture. No water hydrant or water source shall be present in these areas. Adequate amount of dry sand and special dry chemical powder shall be made available. Storage of other combustibles shall be avoided.

10.5.3.1.3 Storage of Acetylene and Oxygen Gas Cylinders

The storage of acetylene and oxygen gas cylinders shall be as per the requirements of the gas cylinder rules 2004 and shall be approved from the Chief Controller of Explosives, Nagpur. Generally acetylene and oxygen cylinders shall be stored separately and away from the other hazardous materials. A permit system shall be required to use these cylinders in hazardous areas of the plant.

10.5.3.1.4 N-Hexane Storage

Being highly volatile and flammable (flash point - 21.5^0 C), no other material should be stored in n-hexane storage area.

The storage area of n-hexane shall be designed as per statutory requirement under the Petroleum Act-1934 and the Petroleum Rules, 2002.

Installation of electrical equipment in the storage area shall be in accordance with the National Electrical Code IS 5572, NFPA-70 (ANSI Standard C1)

10.5.3.1.5 LPG Storage

LPG is highly flammable and its explosive range is 2% to 10% in air. All types of open flame and ignition sources in the LPG area shall be avoided. In case of high ambient temperature, the water spray on to the bullets shall be started. In case of high ambient temperature of about 50^0 C, the water spray on the LPG bullet shall be started automatically for non insulated LPG bullets. However, in case of fire, heat sensors shall be provided on the LPG bullets and pipelines, so that water spray system starts automatically and also isolates the LPG bullets. For any maintenance work, nonsparking tools shall be used. The fire protection in the areas mentioned under 10.4.3.1.3 to 10.4.3.1.5 shall be as per static mobile pressure vessels rule under Indian Explosive Act, 1923.

10.5.3.2 Compressor House Building

The compressor house building shall be separated from the adjacent structure by providing safe distance. Fire detection systems and fire protection shall be provided at suitable place for detecting and fighting the fire. Portable fire extinguishers shall be provided for fighting minor fires. Fire fighting capability for major fire from the combustibles shall be provided adequately.

10.5.3.3 Diesel Generator Area

(As in 10.1.2.2.5.8)

10.5.3.4 Control Room

(As in 10.1.2.2.5.1)

10.5.3.5 Plant Computer Room

(As in 10.1.2.2.5.4)

10.5.3.6 Switch Gear Rooms

(As in 10.1.2.2.5.5)

10.5.3.7 Waste Disposal/Incineration Areas

Combustibles should be minimized and adequate fire fighting capability should be provided.

10.5.3.8 Records Storage Areas

(As in 10.1.2.2.5.16)

10.6 Fuel Fabrication Plants

10.6.1 General

This section deals with guidelines and recommendations necessary to achieve the primary objective of a fire protection programme for an integrated nuclear fuel fabrication facility producing both UO_2 based nuclear fuels (natural) and zircaloy structural components like clad tubes, pressure tubes, calandria tubes etc. Such integrated production facilities typically include zirconium oxide plant (ZOP) for processing of zircon sand to pure zirconium oxide, zirconium sponge plant (ZSP) for conversion of zirconium oxide to pure sponge metal, zircaloy fabrication plant (ZFP) for producing various zirconium alloy tubing and sheets, rod and wire products; uranium oxide plant (UOP) for processing crude uranium concentrate to pure uranium dioxide powder; ceramic fuel fabrication plant (CFFP) for producing sintered uranium oxide pellets and ceramic fuel assembly plant for assembling them into fuel bundles. The major fire hazards in such facilities could arise due to bulk handling of zirconium in metallic form, magnesium, tri-butyl-phosphate (TBP), kerosene, furnace oil, LPG, ammonia and hydrogen etc.

10.6.2 Requirements of Specific Plant Areas/Systems

10.6.2.1 Zirconium Oxide Plant

Zircon is zirconium silicate containing 67% zirconium in association with about 2% hafnium. The separation of zirconium from hafnium and other impurities is achieved by solvent extraction using TBP in kerosene. Large quantity (several thousand litres) of TBP and kerosene is handled in such operation.

The solvent extraction is a major fire hazard area in this plant. This shall be considered as a separate fire zone. Except under special work permit, no welding, gas cutting and heat source shall be allowed in this area. The electrical fittings shall be of increased safety type or better. Motors used for rotating the equipment shall be of flameproof construction. Fire detector and alarm systems of suitable type (UV, IR and heat type) having adequate sensitivity shall be mounted in sufficient numbers to cover the entire area. Manually operated fixed fire suppression system using CO_2 shall be provided to cover mixer settler area. Suitable precautionary signboards highlighting the need for fire prevention in this area shall be prominently displayed. Personnel entry shall be restricted in this area. Spillage and waste accumulation in the section are to be avoided. Earthing of all equipment shall be ensured. A separate fire escape route shall be provided for personnel to escape in case of accidental fire. This shall be fitted with automatic self closing devices with doors opening outside the fire/smoke area. Adequate ventilation system (min. 6 air changes per hour) using required fire dampers shall be provided. Bulk quantity of TBP/kerosene shall not be stored in this area.

10.6.2.2 Uranium Oxide Plant

For production of reactor grade uranium, impurities such as boron, cadmium, rare earths etc. are to be limited to less than a part per million. To achieve this, the concentrate, magnesium diuranate is dissolved in nitric acid and purified by solvent extraction with an organic solvent TBP/kerosene. Typically several thousand liters of TBP/kerosene is handled in such operation. This is a major fire hazard area in this plant. The fire prevention and protection measures in this plant shall be similar to as described in para 10.5.2.1.

10.6.2.3 Zirconium Sponge Plant

The nuclear grade zirconium oxide is converted to zirconium sponge by using magnesio thermic reduction of zirconium tetrachloride followed by high temperature vacuum distillation of zirconium sponge. Ingress of water/air into reduction retort containing molten magnesium would lead to evolution of hydrogen, which may lead to an explosion. The water jacket of the reduction retort shall be hydraulically tested to check its integrity before every batch. Removal of zirconium sponge and crushing operation are potential fire hazard due to pyrophoric nature of sponge. UV detector type fire alarm system with reliable power supply shall be installed in crushing area. Sufficient number of portable fire extinguishers like dry chemical powder of tertiary eutectic chloride to put out metal fires shall be provided in the area. Lighting in the area shall be of flameproof type. Except under special permission, no welding or gas cutting shall be allowed in this area. Special care shall be taken to earth all equipment to take care of static electricity. Special care, such as underwater storage, shall be taken for handling of zircaloy turnings, till the cleaning and drying is taken up. Drums containing zirconium sponge shall be sealed and kept in rows with flameproof barriers between two rows. Zirconium powder generated shall be collected and burnt in a separate enclosure in controlled manner. Not more than 20 kg of zirconium powder shall be allowed to be stored inside the plant. Wet mopping and cleaning shall be done in every shift to take care of zirconium dust. Adequate numbers of TEC powder extinguishers/ dry sand filled buckets shall be made available in the plant.

10.6.2.4 Zircaloy Fabrication Plant

In this plant, zircaloy material is converted into different shapes like rods, wire, sheets, thin and thick wall tubes etc. The operations involve machining, rolling, pilgering, drawing, vacuum annealing, welding etc. The zircaloy scrap generated during the fabrication shall be collected in drums and always stored under water. The scrap may be recycled in zirconium sponge plant. In the pickling and degreasing area, where flammable liquids like tetra chloro ethylene (TCE) and acetone are used, storage of such flammable liquids shall be controlled. Adequate number of fire extinguishers for fighting class-B fire shall be available in this area. Fire detection and alarm systems of suitable types (like UV or IR) shall be installed in this area. Minimum six air changes per hour shall be provided in such area.

10.6.2.5 Ceramic Fuel Fabrication Plant

Sintering furnace area using cracked NH_3 is a major fire hazard in this plant. This area shall be a separate fire compartment and shall be isolated with a barrier of adequate fire rating. H_2 gas monitors with setting for 50% LEL value and audio/visual alarm shall be mounted in this area. Electrical fittings shall be of increased safety type or better. Adequate number of fire detectors (UV or IR type) and fire extinguishers for Class B fire shall be provided in this area. Fine zircaloy turnings and fine powder generated in the fuel element machining area shall be properly disposed off as per safety codes and measures shall be taken to prevent them from catching fire.

10.6.2.6 LPG/Furnace Oil:

Fire protection for this in general shall be governed by static mobile pressure vessel (SMPV) rules under Indian Explosives Act-1923.

10.7 Solvent Production Plants and Miscellaneous Process Plants

10.7.1 General

This section deals with guidelines and recommendations necessary to achieve the primary objective of a fire protection programme in solvent production facilities such as production of di-2 ethyl hexyl phosphoric acid (D2EHPA), trioctyl phosphine oxide (TOPO), trialkyl phosphine oxide (TAPO), dinonyl phenyl phosphoric acid (DNPPA), tributyl phosphate (TBP) etc and boron enrichment and exchange distillation (BEXD) facility. Some of the chemicals processed/used by these plants having fire and explosion potential are listed below:

(a) Tetra hydro fzuran (THF)

(b) Toluene

(c) LDO

(d) Lube oils

(e) Hexane

(f) n- butanol

(g) Boron tri-flouride etherate

10.7.2 Requirements of Specific Plant Areas/Systems

10.7.2.1 Plant Area

The plant shall be divided into fire zones/compartments. Flameproof electrical fittings shall be used for electrical connections in all flammable storage/ handling area. Provisions for providing dykes to flammable storage/ process tanks shall be made to arrest spills. Lightning arrestors shall be provided at the top of the roof of the buildings storing/handling flammable materials. Power and control cables shall be provided with fire retardant coating. Fire seals/fire breaks shall be provided where there is a penetration of cables into the wall/ premises. Provisions for suitable fire detectors and adequate fire fighting measures shall be made as per the fire load (derived from FHA).

10.7.2.2 Storage Area

10.7.2.2.1 Flammable Storage Area

Storage area layout shall have adequate margin for preventing fire propagation from one area to other area. Flameproof electrical fittings shall be used for electrical connections in all flammable storage/handling area. Provisions for providing dykes to flammable storage tanks shall be made to arrest spills. Lightning arrestors shall be provided at the top of the roof of the building. Two meter wide area to be paved by bricks/stones around the flammable storage building to prevent vegetation growth. Provisions for manual call points shall be made with annunciation at fire station.

10.7.2.2.2 Chemical Storage Area

Storage tanks shall have provisions for suitable dykes to arrest spills. Adequate fire rating walls shall be provided between storage tanks for fire exposure protection. Suitable fire detection and suppression provisions shall be made as per FHA. Provisions for manual call point shall be made at suitable locations.

10.7.2.3 Diesel Generator Room

(As in 10.1.2.2.5.8)

10.7.2.4 Control Room

(As in 10.1.2.2.5.1)

10.7.2.5 Switch Gear Rooms

(As in 10.1.2.2.5.5)

APPENDIX-A

FIRE HAZARD ANALYSIS GUIDELINES

A.1 Introduction

Fire hazard analysis (FHA) is performed on each compartment/cell, to ensure mainly three aspects viz.,

(a) That the fire does not incapacitate the safety systems. This may be done either manually or by using computer based fire modeling tools. In this analysis, the complete geometry of the compartment, along with all the combustibles present in the area, are listed. (Data related to combustive properties of the fuels are required viz., mass burning rates, heat release rates, ignition/damage temperatures of fuels, and ventilation patterns. The last parameter is important, from the point of view of oxygen availability, to sustain combustion.)

(b) That the compartment has been provided with adequate barrier rating. It has to be assumed that the entire combustibles present within a compartment, has burnt. This results from the assumption, that the detection/extinguishing systems have failed, and the fire has flashed over, from the initial pilot fire, and ignited all the fuel within the room.

(c) That the damage due to fire spread is minimised. It is assumed that a fire has started at some particular location. This is generally, the spot, which contains the ignition source, such as electric spark, open flames, hot surfaces, welding/grinding operations, and transient sources etc. However, it is prudent to assume that an ignition source is always present. Hence, choose the pilot fire (the fuel that catches fire initially), to be the most inflammable ones, or better still, repeat the analysis for all risk areas. Once these parameters are known, it is easy to determine using a fire model, whether the fire will burn itself out (due to small heat rates and/or oxygen deficiency) or will involve/ associate any other fuel in the compartment. Some models will also help, to determine safe egress time for the occupants, and design upgrades to increase venting rates of hot gases, to minimise loss.

The effects of postulated fires should be analysed for all areas containing safety systems and other locations, which constitute a significant fire hazard to these areas.

There are at least three occasions when fire hazard analysis should be performed or updated. These include:

(i) Early in the design phase.

(ii) Prior to initial commissioning (verification of initial analysis)

(iii) Whenever significant change is made (e.g. addition to combustible material inventories; prior to and immediately following major plant (building) modifications; major modifications to fire protection systems including fire barriers, fixed suppression systems, fire detection systems etc., modifications to nuclear safety related structures, systems and components).

A.2 Classification

Fire hazard analysis can be classified into 2 categories:

A.2.1 Fire Containment Approach

Fire compartments, (see definition) which have only one of the redundant/ diverse systems : In this case, an analysis called fire containment approach is used, where it is postulated that the detection and extinguishing systems have failed, and that, all the combustibles present in the compartment, will burn. This is a deterministic approach. However, even in such an approach, it is necessary to ensure that the compartment is enclosed in fire barriers of adequate rating. This approach is preferred, since even if the entire compartment is to burn out, in case of a fire, the other R-D (redundant-diverse) system, in other compartments, will still be able to perform the required safety function. However, it is still, worthwhile to perform a simple FHA on these compartments, not only to establish fire rating of the barriers, but also to minimize downtime, and/or loss of property/life. Fire barrier ratings are to be determined, using FHA. Care, however, is to be taken, to ensure that the rating of a barrier of any compartment, is adequate not only for complete burning of combustibles inside the compartment, but also, against a fire in an adjacent compartment, sharing a common barrier.

A.2.2 Fire Influence Approach

Fire compartments, divided into fire cells, (see definitions) and which have more than one safety system housed in them. In this case, an analysis called fire influence approach is used, where the probability of a fire starting, and the probabilities of failure of detection/extinguishing system is needed. This is a probabilistic approach, to determine the barrier rating, and to determine the extent of fire spread, and the potential to damage combustibles other than the pilot fire. This requires adequate and reliable data on the performance of detection/extinguishing systems, and fire history statistics of a similar plant. This method of analysis can be used, where the R-D systems, cannot be separated by barriers, such as in reactor building. A knowledge of the reliability of detection and extinguishing systems is required, viz. the active protection systems, must act reliably, when called to do so, such that, the items remaining after a fire, can perform the safety functions. Since the existence of such a database, is not assured, it is recommended to use profusely, passive fire protection systems, such as fire stops, seals for openings, fire resistant/retardant materials for construction, maximum geographical separation between R-D systems. Active systems must also be duplicated/diversified such as smoke/heat/flame detectors and automatic and manual flooding systems. In this case, it is mandatory to perform FHA, to ensure, that after a fire, the systems surviving the fire, are capable of performing the safety function envisaged of them.

A.3 Purpose

To determine the fire resistance of the fire area boundaries and the requirement of the fire extinguishment systems and fire barriers, a fire hazard analysis is necessary. The fire hazard analysis has the following purposes:

(a) To identify and establish the location of individual components of items important to safety.

(b) To analyse the anticipated fire growth and its consequences with respect to items important to safety. Items to be considered in evaluating fire growth include types of combustible materials present, their forms, heat release rates, room and distribution geometries, and ventilation rates. Fire growth may be quantified through the use of fire testing, numerical fire models, which have been suitably validated, and may be complemented by the application of probabilistic methods. Assumptions and limitations applicable to the method of analysis should be clearly stated. The effects of the fire on items important to safety should be determined.

(c) To determine the required fire resistance of fire barriers. This resistance may be determined as a function of the fire load, combustion characteristics and the radiation and convection properties of the fire, taking into account, the geometry and ventilation of the fire compartment.

(d) To determine the type of fire detection and means of protection to be provided.

(e) To identify cases where, additional fire separation or fire protection is required especially for common mode failures in order to ensure that items important to safety will remain functional during and following a credible fire. For example, the fire hazard analysis has to determine whether the arrangement of combustibles, spatial separation of equipment and the fixed fire extinguishing system provided are sufficient to prevent fire damage to redundant divisions of a safety system without the need for further fire separation.

(f) To verify that the intent of this standard has been met. The analysis should list applicable elements of the programme, with explanatory statements as needed to identify location, type of system and design criteria.

A.4 Documentation

The fire hazard analysis and documentation should include as a minimum:

(a) Drawings of the plant layout incorporating all areas with location and identification of nuclear safety-related structures/systems and proposed fire protection systems. The drawings should indicate fire protection related building design features.

(b) The estimated inventories of fixed and stored combustible and flammable materials by types and combustible loading (BTU/sq.ft) (Joule/m^2) for each fire area, including those, which present a fire exposure to critical areas. Consideration should be given to transient loadings that may be expected to regularly occur during the operation of the plant.

(c) A discussion of the means utilised to implement the defence-in-depth concept based on an analysis of the fire hazards for each fire area. This discussion should as a minimum include:

(i) An identification of the plant systems that occupy fire area.

(ii) A description of the fire barriers that delineate the fire area.

(iii) A description of the fire extinguishing and detection features within each fire area including all means for containing and inhibiting the progress of a fire e.g coatings, curbs, drains and walls, as well as the extinguishing equipment outside the area that are accessible for use within the area.

(iv) An analysis of the impact of a failure or loss of automatic fire detection or protection system on the consequences of a fire.

(v) An identification of the measures required for the protection of nuclear safety related equipment against inadvertent actuation or break in a fire protection system.

(vi) A description of the smoke control measures for each fire area.

The fire hazard analysis should define and document those portions of the fire protection systems, building/systems important to fire safety and fire protection programs which must be maintained to assure safe operation of the plant. The documentation should also include the background information, assumptions and descriptions.

A.5 Methodology

The fire hazard analysis is conducted and documented in three phases : the first involves a combination of planning, establishing and recording the methodology and determining basic assumptions; the second phase is an information collection process; and the third phase is the analysis of the adequacy of the fire protection programme.

Phase-I : Methodology of Fire Hazard Analysis

The methodology of the fire hazard analysis, as a minimum should include:

(a) Description of the format to be utilised in the formulation of the analysis. (An example of information to be included here can be a listing of the outline and brief summary of data contained in two and three phases).

(b) Listing the assumptions/parameters, which may be applied. (e.g. ignition is assumed, basis on which fire loading and combustible loading is determined, cable insulation burning rates, applicable generic information, etc.).

(c) Statement concerning the general plant design features pertinent to the fire hazard analysis (e.g. information pertaining to electrical cables, raceway(s), cable trays, covered trays, fire breaks in the trays, the horizontal and vertical separation between safety related raceway(s), other safety division(s) on non-safety raceway(s), codes and standards, fire protection water source and water supply etc.).

(d) Investigative processes/methods (e.g. scale model utilised, onsite inspection, manufacturer's data, fire test of penetration seals, etc.).

Phase-II : Required Information

Initially this effort will require the use of engineering/architectural drawings (including plan and elevation views) and summation of information on the following as available:

(a) General description of site fire protection and plot plan including:

   (i) Building layout, structural and architectural parameters (walls, floors and roofs).

   (ii) Water supplies, fire pumps, other suppression agents etc.

   (iii) Fire mains, hydrants, valves and hose houses.

   (iv) Access and egress for the plant security fencing, gates, access roads.

   (v) Miscellaneous plant features and structures (cooling towers, oil tanks, power transmission equipment, etc)

(b) Identification, description and location of fire area or fire zone of nuclear safety- related systems.

(c) Identification, description and location of areas in which fires could involve systems and components resulting in the release of radioactive material.

(d) For each fire area containing components of systems identified in (b) and (c) above, describe the following:

   (i) Fire resistance rating of the barrier (i.e. walls, floor and ceiling or roof)

   (ii) Protection of openings in fire barrier (i.e. door, duct, shaft, pipe-conduit-cable penetrations) including reference to any test results or other seal qualifications.

   (iii) Subdivisions (fire zones) in which a unique and definable fire potential exists and where appropriate isolation features are present due to either spatial separation of partition walls, floor and ceiling or roof.

(e) An inventory of combustible materials for each fire area or zone designated in (d) above. This should include consideration for both fixed and transient materials.

(f) List of fire detection and protection systems and equipment available for use within each fire area or zone including:

   (i) Fire Extinguishing Systems and Equipment

   - Automatic or manual fixed systems
   - Release rates (density or concentration)
   - Soaking periods
   - Backup supplies of extinguishing agents
   - Methods of operation
   - Portable extinguishers - size and type
   - Standpipe and hose systems

   (ii) Fire detection system

   (iii) Supervisory alarms

   (iv) Other fire control measures to contain or inhibit the progress of a fire within a given fire area e.g. coatings, curbing, drains, limiting air supply, barriers etc.

(g) Description of the measures provided for the protection of nuclear safety-related systems within each fire area or zone against a single inadvertent actuation or break in any fire protection system line. These may include:

(i) Water Control Measures:

- Use of pre-action sprinkler systems
- Drainage, baffles, shields, etc.
- Use of water resistant equipment.

(ii) Physical protection for pressurised systems.

(h) Description of ventilation system(s) and smoke control measures for each fire area or zone.

(i) A description of the impact of a failure or loss of automatic fire detection or protection systems on the consequences of a fire.

Phase-III : Analysis of the Adequacy of the Fire Protection Programme

(a) Analysis/Conclusions

An analysis, based on all of the above information, should be performed for each fire area or zone. The questions addressed in the analysis should include:

(i) Will the fire be contained within the fire area or zone ?

- With suppression and detection equipment or systems operating
- Without suppression and detection equipment or systems operating.

(ii) How would a fire in the area or zone be detected ?

(iii) How would a fire in the area or zone be extinguished ?

(iv) Does the ventilation system contribute to the spread of the fire or products of combustion to other fire areas or zones, which would otherwise be unaffected ?

(v) Will inadvertent operation or closing of a fire damper affect nuclear safety related systems located in other fire areas or zones ? (i.e. loss of an engineered safety feature (ESF), loss of ventilation, etc.)

(vi) Is there nuclear safety related equipment within the fire area or zone for which the nuclear safety function cannot be fulfilled by other nuclear safety-related equipment in other fire areas or zones ?

(vii) Will any nuclear safety related equipment located outside the immediate fire area being evaluated, be affected by a fire within such area ? (i.e. electronic equipment located outside the fire area, but mounted on the separating fire barrier).

(viii) Can the nuclear safety functions be performed despite any fire within the fire area ?

(b) Appropriate Recommendations

(i) Based on the analysis above, problem areas will be identified. Modification/design changes may not be apparent, but solutions must be investigated. Potential modifications must be evaluated until a design is found that will result in a positive answer for question (a)-(viii) above.

(ii) Any recommendations should be scheduled and implemented by the plant owner.

A simple step-by-step procedure is outlined below, for the case of a deterministic approach.

A.6 Deterministic Approach

This FHA assumes that an automatic fire protection system will malfunction. If redundant automatic fire protection systems are provided in the area, only the system, which causes the most vulnerable condition, is assumed to fail. Passive fire protection features, such as blank fire rated walls or continuous fire rated cable wraps, are assumed to remain viable.

Alternately, an assumption can be made that all potentially vulnerable systems will be damaged within the fire area. Acceptable exceptions to this assumption are water-filled steel pipes, tanks, and similar components of superior structural integrity with welded fittings and adequate pressure relief.

The focus of the FHA shall be the individual fire areas, which comprise the facility. A fire area is defined as a location bounded by fire rated construction, having a specified minimum fire resistance rating, with openings protected by suitably rated fire doors, dampers or penetration seals.

An essential element of an acceptable FHA is an inventory of all safety class systems within the fire area that are susceptible to fire damage. This includes those primary and supporting mechanical and electrical systems, which must function effectively during and after a fire event to assure safety, including safe shutdown where applicable. For example, loss of the building ventilation system in a fire (due to damage to power cables) may result in an ambient air temperature rise, which may cause the failure of sensitive electrical safety class components, such as relays. Such safety class systems may include, but are not limited to, process monitoring instrumentation, instrument air, the facility hydraulic system, and emergency lighting system.

A FHA must include an assessment of the risk from fire and related perils (direct flame impingement, hot gases, smoke migration, fire fighting water damage, etc.) in relation to existing or proposed fire safety features to assure that the facility can be safely controlled and stabilized during and after a fire.

Step-I : Identification of Safety Systems

(a) Firstly one has to have a broad and clear understanding of the safety systems of the plant. Hence, to start with, define the safety criteria, that could be compromised in case of a fire. For instance, in a nuclear power plant, this could be, safe shutdown, removal of decay heat and release of activity to the public domain. In any other nuclear installation, such as a reprocessing/fabrication facility, it could just be release of radioactivity, due to inadvertent criticality, or fire/ explosion. In a heavy water plant, it could be release of toxic gases/ products. In other units, it could be loss of some functionality, and/or loss of property and life.

(b) Based on the above, identify those safety related items (SRI), i.e. systems/components/structures important to safety, which perform the functions identified above. Include supporting service/auxiliary systems, such as power supply, lubrication, cooling systems etc.

Step-II : Event Tree Analysis

The above identification may be done using event tree analysis. At the apex of the tree, is the safety function, such as decay heat removal or safe shut down etc. Branches below provide information about redundant/diverse systems, which fulfill these functions. Further branching for each of these safety related items are carried out, listing the systems/components/structures that are required to make the SRI functional. The tree is elaborated till all components and auxiliaries are included, and it is felt that no further breaking apart is needed. All components, which are linked to the apex safety function, then become a SRI. The event tree will show the components branched off by an OR gate. Such systems are diverse systems and are required to be separated geographically and/or provided with fire barriers. An AND gate suggests that all components in this chain are to be protected from fire, if they have to perform their intended function. Even if these components are placed in separate fire compartments, any one failure will disable the branch function.

Step-III : Zoning

This is an important aspect of the FHA. Identify the locations of these SRIs within the plant viz., the compartments/cells within which these are located. Once the SRIs and the compartments have been identified, it is now time, to begin the evaluation of adequacy of fire protection, in each of the compartment/ cell thus identified.

A.7 Analysis and Evaluation

In a facility under design, the redundant and diverse safety systems would have been placed in separate fire cells. However, it is prudent to check this out, with the help of the event tree and the layout. In some cases, like the reactor building, in a nuclear power plant, it will not always be possible to separate the safety systems. In such cases, and in existing plants, it is worthwhile to consider these components, in more detail. On a close examination of the event tree and the physical layout, it will be rather easy to identify, those components, which are located in the same compartment.

Tabulate these systems/components for further analyses. Wherever possible, separate these redundant/diverse systems into separate compartments, and/or separate them geographically. Where such separation is not feasible, divide these compartments into smaller cells, each housing an individual safety system.

Now, examine the cells thus formed. Within these cells, identify, the combustibles, and make an inventory of these combustibles. Then perform the FHA as outlined above. Results from analyses will reveal any unsafe fire protection design. These could be inadequate separation/barrier rating, too large an inventory of combustibles in an enclosure, inadequate venting provision, or secondary damage to combustibles in an enclosure. These have then to be corrected, and the whole analysis is to be repeated , till a satisfactory result is obtained.

APPENDIX-B

FIRE DETECTION AND ALARM SYSTEM

B.1 Detection, Signaling and Alarm Devices

Detection systems are designed to detect some phase of activity occurring during one or more of the four stages of fire development. The four stages are the incipient, the smoldering, the flame and the heat stages. The incipient stage is the earliest stage of fire development wherein preheating and gasification process producing submicron size aerosols. The smoldering stage is one in which the decomposition reaction is further advanced and visible smoke is evolved. Aerosol and smoke travel are dependent on local airflow conditions. The flame stage covers the period from initial occurrence of the flame to a fully developed fire. Radiant energy is evolved sufficiently to be detected at appreciable distances. Thermal energy during later stages is sufficient to result in an appreciable temperature rise at ceiling level.

The length of time of these periods and therefore the effectiveness of the detector varies depending on the type of combustible material and the ignition source. If lubricating oil is discharged under pressure through a ruptured cooling system impinging on a surface above its ignition temperature, incipient and smoldering stages would be very short. Detectors, which are most sensitive to the flame stage, would be most effective for this type of fire. Fires initiating in cable insulation may have long incipient and smoldering stages. Detectors, which are most sensitive for these stages, would be most effective. Table-B1 provides guidance on the relative performance of fire detectors.

Detection systems can be used to perform a number of functions. They may be used to actuate fire protection systems, to close fire doors and smoke dampers, shut down power operated equipment, alarm etc. Additional guidance can be found in national fire protection association (NFPA), 'National Fire Alarm Code', NFPA Standard 72-1998.

(a) Smoke Detectors

(i) Ionisation type detectors - This unit consists of one or more chambers, which are capable of sensing air made electrically conductive. Actuation occurs when smoke particles enter the chamber and reduce the conductivity of air in the chamber below a predetermined level.

(ii) Photoelectric detector - Actuation occurs when smoke passes through a light beam either obscuring the beam's path (beam type) or reflecting light into a photocell (spot type).

(b) Flame Detectors

Flame detectors respond to radiant energy of different wavelengths. Principle detector types are infrared and ultraviolet.

(c) Heat Detectors

(i) Fixed temperature detector - This unit actuates when the detection element reaches a predefined temperature.

(ii) Rate of temperature rise detector - This unit is designed to actuate when a pre-set rate of temperature increase is exceeded.

(iii) Combination of the above.

(d) Linear Heat Sensing (LHS) Cables

These are unique heat sensing cables made of polymer insulating material having a negative temperature coefficient of electrical resistance. These cables and associated systems can detect heat anywhere along the length of the cable. They are of two types - (a) analog and (b) digital. Temperature change anywhere along the zoned length of the sensor cable produces a corresponding change in the resistance of the insulating material used in the cable. In analog type LHS cables, this data is being used by the associated system for generation of alarm. In digital LHS cables, the temperature change causes an insulation break down (short-circuit) which is used by the associated system for generation of alarm. Analog LHS cables are self-restoring type if not subjected to a temperature of more than 250^0 C. Digital LHS cables are not self-restoring type. Portions affected are to be cut and replaced by new one.

TABLE-B1 : RELATIVE SENSITIVITY OF DETECTORS FOR VARIOUS COMBUSTIBLES

Detector Type	**Effective Stage**	**Sensitivity**			
		Class A	**Class B**	**Class C**	**Class D**
Ionisation	Incipient	High	Medium	Medium	-----
Photoelectric	Smoldering	High	Medium	Medium	-----
Fixed temperature	Heat	Low	High	Medium	Medium
Rate of rise	Heat	Medium	High	Low	High
Ultraviolet	Flame	Low	Low	Medium	High
Infrared	Flame	Low	High	Low	High

Class A - Fires involving wood, cable insulation, cardboard, packaging materials.

Class B - Fires involving flammable liquids and combustible liquids such as lubricating or cooling oils.

Class C - Fires involving gases.

Class D - Metal fires

Sensitivity — Expected response time. Sensitivity can be increased for thermal and smoke detectors by reducing threshold setting.

Reliability — Based on the ability of individual components of system to be in proper working condition over life of system. Simplicity and sealed construction are factors, which improve reliability.

Maintainability — Based on the maintenance requirements of detectors. High means minimal maintenance, i.e. thermal units usually has no periodic maintenance requirements. Other units must be checked periodically. This is not an extensive effort, which would cause problems and interfere with plant operation.

Stability — Based on the ability to sense fires over extended time periods without change in sensitivity.

Heat detectors do not have components, which change appreciably over extended period of time. All other detectors have electronic components, which may require periodic adjustments.

B.2 General Guidelines for Selection

The general guidelines to be followed while selecting the fire detectors to suit various environmental conditions are as below:

TABLE-B2 : FIRE DETECTOR SELECTION (ENVIRONMENT)

Environmental conditions	Type of detectors to be used or not to be used
Presence of gas, alcohol and other vapours	Use heat/flame detector do not use smoke detector
Dusty or smoky conditions prevailing in an area	Do not use smoke detectors of either Optical or ionisation type
Air humidity greater than 90 %	Use heat detector
Areas where high levels of combustion products are likely (e.g.: furnace areas)	Do not use smoke detectors
Areas where working temperature is high such as Boiler House, etc.	Use rate of rise heat detector.

TABLE-B2 : FIRE DETECTOR SELECTION (ENVIRONMENT) (Contd.)

Environmental conditions	Type of detectors to be used or not to be used
Areas where sudden temperature changes occur (e.g. near furnace doors)	Do not use rate of rise heat detectors
Areas connected to air handling units (AHUs)	Use smoke detectors
High radiation areas	Ionisation type smoke detector, if used shall have higher source strength, provide shielding around detector.
For covering large areas with high ceiling levels	Use beam type smoke detectors
Slow smoldering fires (low energy) which may release large smoke such as electrical cable fire	Use optical type smoke detectors
For open flaming fires (high energy) that generates larger number of smaller smoke particles use ionisation type smoke detectors.	Use ionisation type smoke detectors.

B.3 Area Coverage

Generally the area coverage for the various types of Fire Detectors is as under:

TABLE-B3 : FIRE DETECTOR SELECTION (AREA COVERAGE)

Type of detector	Area covered (sq. meters)
Heat detector	40 to 60
Air sampling type	40 to 60
Ionization smoke detector	50 to 80
Optical smoke detector	50 to 80
Flame detector	Line of sight
Beam type smoke detector	10 to 100

The area coverage depends upon the ceiling heights. The above values are generally applicable for ceiling heights of up to 7 m.

B.4 Detector Application Guide (General)

TABLE-B4 : FIRE DETECTOR SELECTION (APPLICATION)

Stages of fire	Fire characteristics	Application types
Incipient	Invisible smoke, no heat, no visible flame	Ionisation
Smoldering	Smoke, no ceiling heat, no visible flame	Optical, ionisation
Early flaming	Smoke, visible flame, no ceiling heat	Ionization, optical, flame
Fully developed	Smoke, heat, visible flame	Ionization, optical, flame, thermal.

B.5 Comparison of Various Types of Fire Detectors

A comparison of various types of fire detectors which will be useful in their selection is given as under:

TABLE-B5 : FIRE DETECTOR COMPARISON

Type of detector	Advantages	Disadvantages	Application
Heat detectors	Reliable and simple. Effective indoor. Low unit cost.	Slow. Affected by wind.	Indoors. Enclosed areas. Class B and C fires.
Smoke - ionisation	Early warning. Incipient fires. Low unit cost.	Response may be adversely affected by environmental dust, humidity greater than 95%, temperature (> 60 deg. C) etc. Affected by high radioactive environment.	Indoors, homes, offices, computer rooms. Class A, B and C fires.
Smoke - optical	Early warning of smoldering fire. Low unit cost.	Smoke must be contained. Limited to indoor use. Response may be adversely affected by environment.	Indoors, homes, offices, commercial buildings. Class A fires.
Infrared (IR)	Fast response. High sensitivity. Manual self-test through the window.	No automatic self test. High unit cost.	Indoors, air ducts. Class B and C fires.

TABLE-B5 : FIRE DETECTOR COMPARISON (Contd.)

Type of detector	Advantages	Disadvantages	Application
Ultraviolet (UV)	Highest speed. Highest sensitivity.	Subject to false alarms from other sources in the vicinity. High unit cost. Blinded by thick smoke.	Outdoors/indoors. Class D fires.
Dual detector (IR and UV)	High speed. High sensitivity. Low false alarm rate. Wide temperature range. Automatic self-test.	Thick smoke reduces range. High unit cost.	Outdoors/indoors. Class A, B, C and D fires.

B.6 Fire Alarm Systems (General)

Fire alarm systems fall broadly in to two groups - conventional systems and analogue addressable systems.

'Conventional' fire alarm systems, in their various forms, have been around for many years and have changed little in that time in terms of technology although design and reliability have improved significantly. However, conventional systems are a well-proven technology and are often the immediate choice for small premises.

In a typical conventional fire alarm system, the 'intelligence' of the system resides solely within the fire alarm control panel which receives a trigger signal from a conventional detector or call point and in turn, signals the condition to other devices such as alarm sounders and remote signaling equipment.

Conventional detectors are normally connected to the fire control panel via dedicated circuits, each circuit protecting a designated 'zone' or 'area' of the facility. Detectors have two states, normal healthy and alarm.

'Analogue addressable' fire alarm systems differ from conventional systems in a number of ways and certainly add more flexibility, intelligence, speed of identification and scope of control. For these reasons, analogue addressable fire alarm systems are the natural choice for larger premises and more complex system requirements.

In an analogue addressable system, detectors are wired in a loop around the area with each detector having its own unique 'address'. The system may contain one or more loops depending upon the size of the system and design requirements. The fire control panel 'communicates' with each detector individually and receives a status report e.g. healthy, in alarm or in fault etc.

As each detector has an individual ‘address’, the fire alarm control panel is able to display/indicate the precise location of the device in question, which obviously helps in finding the location of an incident quickly and for this reason ‘zoning’ of the system is not necessary, although it may be done for convenience.

Addressable detectors are, in themselves, ‘intelligent’ devices which are capable of reporting far more than just fire or fault conditions, for example most detectors are able to signal if contamination (dust) within the device reaches a pre-set level enabling maintenance to take place prior to problems being experienced. Addressable detectors are also able to provide pre-alarm warnings when smoke/heat levels, reach a pre-set level enabling investigation of the fire before a full evacuation alarm and fire brigade signaling taking place.

APPENDIX-C

FIRE BRIGADE ORGANISATION

C.1 Classification of Fire Station for a Site

Fire stations are brought under various classifications based on fire hazard potential, area of coverage besides functional requirement like operation of fire station and training/fire drills.

They are: Class-I, Class-II, and Class-III.

Class-I is two-crew station, i.e., a station with staff strength for two turnouts on round-the-clock operation.

Class-II is a single crew station, i.e. a station, which has staff strength for a single turn out for round the clock operation.

Class-III is nominal arrangement with skeleton staff strength with at least one fireman for round the clock operation.

Class-I includes more than two operating unit nuclear power stations, hydrogen sulphide based heavy water plants and large-scale fuel fabrication facilities. Class-II includes two unit operating nuclear power stations, ammonia based heavy water plants and other solvent plants. Units under construction are included in Class-III.

A crew may consist of one subofficer, one lead fireman, one driver-cum-operator and four firemen who will approach the fire spot with tender and other auxiliaries as required.

The classification based on above criteria is as follows:

Tarapur	-	Class-I
Kalpakkam (IGCAR complex, MAPS, PFBR) Rawatbhata (Kota)	-	Class-I
NPCIL (more than 2 and up to 6 units)	-	Class-I
HWP, Kota	-	Class-I
HWP, Manuguru	-	Class-I
NFC, Hyderabad	-	Class-I
Kaiga Generating Stations	-	Class-I
Kudankulam Nuclear Power Project (Will be upgraded to Class-I during operation)	-	Class-II

HWP (Tuticorin, Hazira and Thal)	-	Class-II
Narora Atomic Power Station	-	Class-II
Kakrapar Atomic Power Station	-	Class-II
HWP, Baroda	-	Class-II
HWP, Talcher	-	Class-II
IRE, Udyogamandal	-	Class-II
RR CAT, Indore	-	Class-II
IRE, OSCOM	-	Class-II
Zirconium Complex, Pazhayakayal	-	Class-II
UCIL, Mill	-	Class-III
ECIL	-	Class-III
BRIT	-	Class-III
VECC	-	Class-III
IRE, Chavara	-	Class-III
IRE, Manavalakurichi	-	Class-III
Zirconium Complex, Pazhayakayal	-	Class-II

Note: For addition of every twin units or any other facilities to the existing site, above classification should be augmented by one additional turnout on round-the-clock shift basis or as recommended by AERB.

C.2 Recommended Minimum Fire Staff and Equipment for Various Fire Stations

CLASS-I:

<u>Staff</u>

CFO/Dy. CFO	1
Station Officer	1
Sub Officer	5
Leading Firemen	5
Driver cum Pump Operator cum Fireman including 1 in Fire Station CR	40

<u>Equipment [see note (a)]</u>

Water tender - type B as per IS 950 - 1980/water tender type X as per IS 6067-1983	1

Multipurpose Foam/CO2/DCP/Tender generally as per IS 10460-1978	1
Emergency tender with rescue equipment generally as per IS 949/Additional multipurpose foam/CO2/DCP/Tender generally as per IS 10460-1978	1
Trailer fire pumps as per IS 944, 1800 1pm, 7 kg/cm^2	2
Towing jeep 4 x 4	1
High capacity portable pumps as per IS 12717-1989	2
Breathing apparatus sets with spare cylinders	12
High power charging compressor for breathing apparatus	1
Exhaust blower as per IS 941-1980	1
Built-in floodlight in the Tender/Tractor mounted electrical generator with capacity for 4 floodlights each with 1000 Watt halogen lamp at telescopic mast	1
Training aids	1 set
Portable water/foam monitors	2
Fire retardant blankets 7' x 5'	4
Fire retardant blankets 3' x 2'	4
Water gel containers	4
High expansion foam unit	2
Fire proximity suit	2

CLASS-II:

<u>Staff</u>

Dy. CFO/Station Officer	1
Sub Officer	5
Leading Firemen	5
Driver cum Pump Operator cum Fireman including one in Fire Station CR	24

<u>Equipment [see note (a)]</u>

Water Tender - Type B as per IS 950 - 1980/ Water Tender - Type X as per IS 6067-1983	1
Multipurpose foam/CO2/DCP/tender generally as per IS 10460-1978	1

Trailer fire pumps as per IS 944,1800 l pm, 7 kg/cm^2	1
Towing jeep 4 x 4	1
High capacity portable pumps as per IS 12717-1989	1
Breathing apparatus sets with spare cylinders	8
High power charging compressor for breathing apparatus	1
Exhaust blower as per IS 941-1980	1
Builtin floodlight in the tender/Tractor mounted electrical generator with capacity for 4 floodlights each with 1000 Watt halogen lamp at telescopic mast	1
Training aids	1 set
Portable water/foam monitors	2
Fire retardant blankets 7' x 5'	4
Fire retardant blankets 3' x 2'	4
Water gel containers	4
High expansion foam unit	2
Fire proximity suit	2

CLASS-III:

<u>Staff</u>

Fire officer (Station officer & above)	1
Leading firemen	1
Fireman	5 (at least one in each shift)
Fire squad members	5 (in each shift)

<u>Equipment [see note (a)]</u>

Trailer Fire Pumps as per IS 944, 1800 l/min, 7 kg/cm^2.	2
Towing jeep 4 x 4	1
Tractor mounted electrical generator with capacity for 4 floodlights each with 1000 watt halogen lamp at telescopic mast	1
Breathing apparatus sets with spare cylinders	8

Note:

(a) Where chemical hazards are present, such as in NFC, HWP etc., 2 sets of totally encapsulated chemical suits, shall be provided.

(b) The minimum fire staff indicated above is only for maintaining the fire crew.

APPENDIX-D

FORMAT FOR FIRE ORDER

Government of India
Department of Atomic Energy
(Name of Unit)

D.1 STANDING FIRE ORDERS FOR ________________________

(EMERGENCY PLAN FOR FIRE/EXPLOSION)

(i) BRIEF DESCRIPTION OF PLANT

(ii) HAZARDS ASSOCIATED WITH PLANT

(iii) AVAILABLE FIRE FIGHTING MEASURES

 (i) Portable systems
 (ii) Fixed systems

(iv) EMERGENCY CONDITIONS (Probable)

Emergency condition may arise due to the following:

Such an emergency will have to be dealt with utmost speed and efficiency in order to avoid casualties and minimise damage to property. It is therefore, necessary that all the activities of the staff should be governed by certain set of rules on the principles and practices of Fire Fighting and Salvage Operations. This set of rules shall be termed as 'STANDING FIRE ORDERS FOR __________' and will take into account other emergency conditions also.

D.1.1 Emergency Control Room

Location of control room
Internal telephone numbers
Direct telephone numbers

D.1.2 Fire Station

Fire station phone numbers
Fire station office phone numbers

Direct telephone numbers

Neighbourhood fire station phone numbers

D.1.3 Areas and Duty Officers

For easy and quick action and co-ordination in an emergency, divide the site in to areas and list them as Annexure-I

D.1.4 Manned Areas and Unmanned Areas

General shift (working days)	senior most person in area
Other shift/Holidays	shift-in-charge of area

For an area not functioning at the time of the incident, security officer to act in the absence of area officer

List the name of areas for which security officer to act in the absence of area officer

List the duty officers of various areas in Annexure-I

List the duties of duty officer

Each area shall have a duty officer designated by plant.

D.2 Duties

Duties of various officers/groups concerned are detailed below:

D.2.1 By Person(s) who detects fire

D.2.2 Duty Officer

List out the general duties

D.2.2.1 List the action of duty officer in case of fire

By duty officer of other areas

By officer of emergency control room

By telephone operator

By fire squads

By plant manager

By subofficer (fire service)

By medical officer

By utility services

By power distribution

By health physics unit

By transport services

By incharge of safety

By security

ANNEXURE-I

DIVISION OF FIRE ZONES IN AN EMERGENCY

For easy and quick actions and good coordination, in an emergency the __________ has been divided into convenient areas

FIRE ZONES	DUTY OFFICER	PABX/RAX	RES.TEL.NO

EMERGENCY EQUIPMENT

Layout maps indicating fire exits, air masks, fire hydrants and fire extinguishers etc. may be enclosed.

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