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1. INTRODUCTION

The Eskom Fire Protection and Life Safety standard specifies the fire systems and life safety philosophies and requirements that Eskom will apply not only on new builds, but also to current facilities and power plants throughout Eskom Holdings when evaluating existing systems or when modifications / refurbishments are undertaken.

This standard will provide a rational, flexible, economic, and uniform fire protection approach throughout Eskom, allowing for alternative design-based approaches to be explored. This standard captures best practices and the experience gained from various implementations of fire protection systems within industrial premises, in particular those where power generation takes place.

The fire safety requirements for any given facility cannot be entirely dictated due to variable risks and varying fire safety performance objectives. These factors vary, not because of uncertainty in fire protection but because the hazards as well as criticality, replacement and strategic values vary widely. Hence an inflexible design standard is not appropriate. More importantly it is necessary to understand the rationale behind certain requirements. The Fire Protection / Detection Assessment (FPDA) have been defined to capture all these aspects.

A FPDA shall be done in accordance with the Fire Protection / Detection Assessment Standard [3], for any new build, modification, or refurbishment to any Eskom asset where the risk profile of the asset is influenced. The FPDA shall determine the fire protection and fire detection approach that must be followed for the specific new build, modification, or refurbishment. The details of the fire system requirements shall be in accordance with this standard.

The inappropriate selection of fire protection and fire detection equipment in a facility or a power utility environment may contribute to unnecessary false alarms, slow detection times of fires, high installation and maintenance costs, increased outages and potentially unwanted ignition sources within hazardous areas representing a fire and explosion hazard. This could possibly be the cause of subsequent risks to life safety and asset loss.

This standard covers the following requirements from a Fire Protection and Life Safety point of view for Eskom assets:

- Passive Fire Protection Requirements
- Active Fire Protection System Requirements
- Manual Fire Protection Requirements

In some instances, the location of Fire Detection and required Smoke and Heat Ventilation are also stipulated. Fire Detection requirements for the various areas shall be in accordance with the Fire Detection and Life Safety Standard [5].

This standard is primarily intended for use in Eskom Holdings Limited Divisions, consequently International and South African standards and codes of practice have been referenced. The principles of system operation and maintenance, as well as the technical information about components and systems, can be applied in other Eskom facilities subject to local authority and code requirements.

2. SUPPORTING CLAUSES

2.1 SCOPE

The scope of this Standard is to guide all persons responsible for the specification, design, construction, commissioning, operating, maintenance, and modification of fire protection systems for Eskom Holdings. It shall also assist other parties to determine the most suitable systems to be installed in a specific area within any Eskom asset.

2.1.1 Purpose

The purpose of this document is to provide a fire protection system Standard for persons responsible for the specification, design, construction, commissioning, operation, maintenance, and modification of fire protection systems at Eskom Holdings. The Standard aims to capture best practices and the experience gained from various implementations.

This standard is developed to complement SANS 10400-T Fire Protection Systems [61].

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions. The requirements in this standard will not be fitted retrospectively, but is applicable for new builds, modifications, and refurbishments.

2.2 NORMATIVE/INFORMATIVE REFERENCES

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] Act 103 of 1977 National Building Regulations and Building Standards Act

[2] 32-124 Eskom Fire Risk Management

[3] 240-54937439 Fire Protection / Detection Assessment Standard

[4] 240-54937454 Inspection, Testing and Maintenance of Fire Protection Systems

[5] 240-56737448 Fire Detection and Life Safety Design Standard

[6] 240-56737654 Inspection, Testing and Maintenance of Fire Detection Systems

[7] 240-53114026 Project Engineering Change Management Procedure

[8] 240-53114002 Engineering Change Management Procedure

[9] 240-53113685 Design Review Procedure

[10] 240-112287980 Work Instruction for the Application of Standards for Engineering Work

2.2.2 Informative

2.2.2.1 Eskom Standards

[11] 32-123 Eskom Emergency Planning

[12] 32-107 Fire Risk, Emergency Management and Firefighting Training Program

[13] 32-108 Eskom Firefighting Organization

[14] 32-128 Eskom Firefighting PPE

[15] 240-126468603 Operational Standard for Fire Management in Generation

[16] 240-126467640 Operational Standard for Fire Fighter Training in Generation

[17] 240-126467668 Operational Standard for Inspection, Testing of Fire and Rescue Non-Plant Equipment in Generation

[18] 240-123801640 Standard for Low Pressure Pipelines

[19] 240-105020315 Standard for Low Pressure Valves

[20] 240-86973501 Engineering Drawing Standard Common Requirements

[21] 240-56536505 Hazardous Locations Standard

[22] 240-56227413 Hydrogen Systems Standard

[23] 240-56177186 Design Guide for Power Station Battery Rooms

[24] 240-70164623 Eskom Heating Ventilation and Air Conditioning (HVAC) Design Guideline

[25] 240-106680663 Lifts, Escalators, Lifting and Crane Design Guideline

[26] 240-56177186 Battery Room Standard

[27] 240-62772907 Standard for Stationary Diesel Generator Systems

[28] 240-105929225 Compressed Air System Standard

[29] 240-156552996 Generic Technical Specification for Eskom Real Estate Project for Fire Protection and Fire Detection Systems

[30] 240-66917056 Standard for Passive Fire Protection in Distribution Substation Yards

[31] 240-168911966 Fire Prevention Mill Operation During Mill Fire Standard

[32] 240-139687256 Battery Energy Storage Systems for Grid-scale Applications

2.2.2.2 Eskom Internal Documents (Not to be distributed outside of Eskom)

[33] 474-11308 Auxiliary Bay Intermediate Level Cable Spreading Areas Position Paper

[34] 474-11121 Identification of Critical Conveyors in Eskom Report

[35] 474-11306 Conveyor Belt Shut Down on Activation of Fixed Fire Protection Evaluation Report

[36] 474-11040 Air Heater Fire Protection and Detection and Fan Vibration Protection Minimum Requirements Position Paper

[37] 474-11867 Coal Fired Power Station Natural Draft Cooling Towers Fill Replacement FPDA Report

[38] 474-11504 Fire Protection System Water Demand WCS Methodology Position Paper

[39] 474-11450 Fire Protection Automatic Water Control Valve Qualification Evaluation Report

[40] 474-10560 Fire Protection System – Clack Type MJC Valves Evaluation Report

[41] 474-12601 ERE IT Server Room FPDA Report

2.2.2.3 South African National Standards

[42] SANS 246 Code of Practice for Fire Protection for Electrical Equipment Installations

[43] SANS 428 Fire Performance Classification of Thermal Insulated Building Envelope Systems

[44] SANS 543 Fire Hose Reels (Semi Rigid Hose)

[45] SANS 1091 National Colour Standard

[46] SANS 1128 Hydrant Systems

[47] SANS 1186 Symbolic Safety Signs

[48] SANS 1253 Fire-doors and Fire-shutters

[49] SANS 1567 Portable rechargeable fire extinguishers – CO2 type extinguishers

[50] SANS 1910 Portable Refillable Fire Extinguishers

[51] SANS 10087 The handling, storage, distribution and maintenance of liquefied petroleum gas (LPG) in domestic, commercial, and industrial installations

[52] SANS 10089 The petroleum industry

[53] SANS 10090 Community Protection against Fire

[54] SANS 10105 The use and control of fire-fighting equipment

[55] SANS 10131 Above Ground Storage Tanks for Petroleum Products

[56] SANS 10140 Identification Colour Marking

[57] SANS 10177 Fire Testing of Materials, Components, and Elements Used in Buildings

[58] SANS 10252 Water supply and drainage for buildings

[59] SANS 10287 Automatic Sprinkler Installations for Fire Fighting Purposes

[60] SANS 10400 The Application of the National Building Regulation

[61] SANS 10400-T The Application of the National Building Regulations Part T: Fire Protection

[62] SANS 10400-W The Application of the National Building Regulations Part W: Fire Installation

[63] SANS 11601 Wheeled fire extinguishers – Performance and construction

[64] SANS 14520 Gaseous Fire Extinguishing Systems – Physical Properties & System Design

[65] SANS 15779 Condensed Aerosol fire extinguishing systems – General Requirements

2.2.2.4 National Fire Protection Association (Free access NFPA codes and standards)

[66] NFPA 11 Standard for Low, Medium, and High Expansion Foam

[67] NFPA 12 Standard on Carbon Dioxide Extinguishing Systems

[68] NFPA 13 Standard for Installation of Sprinkler System

[69] NFPA 15 Standard for Spray Fixed Systems

[70] NFPA 16 Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems

[71] NFPA 20 Standard for the Installation of Stationary Pumps for Fire Protection

[72] NFPA 30 Flammable and Combustible Liquids Code

[73] NFPA 31 Standard for the Installation of Oil-Burning Equipment

[74] NFPA 37 Combustion Engines and Gas Turbines

[75] NFPA 58 Liquefied Petroleum Gas Code

[76] NFPA 59A Standard for the Production, Storage, and Handling of Liquefied Natural Gas

[77] NFPA 68 Standard on Explosion Protection by Deflagration Venting

[78] NFPA 70 National Electrical Code

[79] NFPA 72 Fire Alarm Code

[80] NFPA 80 Standard for Fire Doors and Other Opening Protectives

[81] NFPA 80A Recommended Practice for Protection of Buildings from Exterior Fire Exposures

[82] NFPA 85 Boiler and Combustion System Hazard Code

[83] NFPA 101 Life Safety Code

[84] NFPA 214 Standard for Water-Cooling Towers

[85] NFPA 220 Standard on Types of Building Construction

[86] NFPA 221 Standard for High Challenge Fire Walls, Fire Walls, and Fire Wall Barriers

[87] NFPA 251 Standard Methods of Tests of Fire Resistance of Building Construction and Materials

[88] NFPA 550 Guide to the Fire Safety Concepts Tree

[89] NFPA 551 Evaluation of Fire Risk Assessments

[90] NFPA 655 Standard for Prevention of Sulfur Fires and Explosions

[91] NFPA 750 Standard on Water Mist Fire Protection Systems

[92] NFPA 805 Fire Protection for Light Water Reactor Electric Generating Plants

[93] NFPA 850 Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

[94] NFPA 855 Standard for the Installation of Stationary Energy Storage Systems

[95] NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems

[96] NFPA 2010 Standard for Fixed Aerosol Fire Extinguishing Systems

2.2.2.5 Factory Mutual Global Data Sheets (FM Global Data Sheets)

[97] Data Sheet 1-6 Cooling Towers

[98] Data Sheet 1-15 Roof Mounted Solar Photovoltaic Panels

[99] Data Sheet 3-7 Stationary Pumps for Fire Protection

[100] Data Sheet 5-3 Hydroelectric Power Plants

[101] Data Sheet 4-1N Fixed Water Spray Systems for Fire Protection

[102] Datasheet 5-4 Transformers

[103] Datasheet 5-31 Cables and Bus Bars

[104] Data Sheet 7-11 Belt Conveyors

[105] Data Sheet 7-83 Drainage Systems for Ignitable Liquids

[106] Data Sheet 7-88 Flammable Liquid Storage Tanks

[107] Data Sheet 7-101 Fire Protection for Steam Turbines and Electric Generators

2.2.2.6 Other

[108] HIPAP 4 Risk Criteria for Land Use Safety Planning, NSW Department of Planning, 2011.

[109] Zalosh, R.G. Industrial Fire Protection Engineering, Wiley, 2003.

[110] Tewarson, A. Generation of Heat and Gaseous, Liquid, and Solid Products in Fires, SFPE Handbook of Fire Protection Engineering, Chapter 3-4, 4th Edition.

[111] Quintere, J.G. Fundamentals of Fire Phenomena, Wiley, 2006.

[112] McGrattan, K., B Thermal Radiation from Large Pool Fires, NISTR 6546.

[113] Babrauskas, V. Heat Release Rates, Chapter 3-1, SFPE Handbook of Fire Protection Engineering, 4th Edition.

[114] BS EN 12101-3 Smoke and Heat Control Systems Part 3: Specification for Mechanical Smoke and Heat Exhaust Ventilators

[115] International Guidelines for the Fire Protection of Nuclear Power Plants (Nuclear Pool's Forum)

[116] UL 9540 Safety of Energy Storage Systems and Equipment

[117] UL 9540A Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

[118] Electric Power Research Institute (EPRI) Resource: Energy Storage Integration Council (ESIC) Energy Storage Reference Fire Hazard Mitigation Analysis

2.3 DEFINITIONS

Definition	Description
Active Fire Protection	Active fire protection consists of all fire protection systems that are actuated in the event of a fire and need to operate in terms of discharging a suppression medium. These include fire protection by water, water mist, foam, gaseous and aerosol agents.
Aerosol extinguishing agent - Condensed aerosol	Extinguishing medium consisting of finely divided solid particles, generally in the order of magnitude of microns in diameter suspended in gas generated and distributed by a combustion process of a solid aerosol-forming compound.
Approved (equipment)	In the context of fire protection equipment, this signifies components, devices or assemblies having been tested and accepted for a specific purpose or application by a locally or internationally recognised testing laboratory.
Approved (person)	Acceptable to a relevant authority
Authority	Organization, office, or individual responsible for approving equipment, installations or procedures
Acceptable	Acceptable a) in the opinion of any local authority, or b) in relation to any document issued by the council, in the opinion of the council
Adequate	Adequate in a) the opinion of any local authority, or b) relation to any document issued by the council, in the opinion of the council
Bulk Materials Handling	Refers to the systems used to transport materials from one point to another and includes all conveyors and transfer facilities. The materials transported include coal, ash, limestone and gypsum.
Cable Tunnels	Means cable basements, underground cable spreading areas that conforms to the definition of a tunnel.
Churning Pressure	The Churning Pressure is the pressure at the outlet of a pump that is running but with zero flow
Combustible Liquid	Combustible liquids are defined in the NFPA 30 as any liquid with a closed-cup flashpoint at or above 37.8°C.
Competent person	Person who is qualified by virtue of his education, training, experience and contextual knowledge to make a determination regarding the performance of a building or part thereof in relation to a functional regulation or to undertake such duties as may be assigned to him in terms of the National Building Regulations.
Competent person (fire engineering)	Person who a) is registered in terms of the Engineering Profession Act, 2000 (Act No. 46 of 2000), as either a Professional Engineer or a Professional Engineering Technologist, and

Definition	Description
	b) is generally recognized as having the necessary experience and training to undertake rational assessments or rational designs in the field of fire. NOTE Fire engineering can be broadly described as the application of scientific and engineering principles, rules, codes, and expert judgement, based on an understanding of the phenomena and effects of fire and the reaction and behaviour of people to fire – to protect people, property, production and the environment from the destructive effects of fire.
Critical	Any part or area of plant/facility is seen to be critical if its loss during a fire incident has the potential to cause the following, either immediately or within a 6-12 hour period after the incident: • A multiple-unit load loss or trip; • Loss of transmission or distribution capability; • Permanent loss of production or products; or • Danger to fire-fighting personnel involved in fighting the fire
Facilities	Any building or site that is not directly part of the power generation process, but that is an asset of Eskom (these facilities can be located on power station sites or in other areas).
Fire Area	Fire Area is an area that is physically separated from other areas by space, barriers, walls, or other means in order to contain fire within that area.
Fire Barrier	A fire barrier is a continuous membrane, either vertical or horizontal as a wall, floor or ceiling assembly that is designed and constructed with a specified fire resistance rating to restrict the spread of fire and the movement of smoke.
Fire Compartment	A fire compartment is an area within a building which is completely surrounded with fire-resistant construction.
Fire Detection and Alarm System	The term fire detection and alarm systems, in the context of this standard, includes systems that range from those comprising only one or two manual call points and sounders to complex networked systems that incorporate a large number of automatic fire detectors, manual call points and sounders, connected to numerous inter-communicating control and indicating panels. Details of a fire detection and alarm system can be found in the Eskom document Fire Detection and Life Safety Standard [5].
Fire Door (assembly)	Automatic or self-closing door assembly which complies with the requirements contained in SANS 1253, and which is especially constructed to prevent the passage of fire for a specific length of time.
Fire Protection	Method of providing for fire control or fire extinguishment.
Fire Protection / Detection Assessment (FPDA)	A fire protection/detection assessment is the initial, multi-disciplinary process in which reasonably foreseeable hazards are identified, the impact of the potential harm, to people and plant, is assessed, and reasonable engineering solutions to mitigate these hazards are proposed.
Flammable Liquid	The definition of flammable liquid differs between sources. As such, the definition should be viewed in the context of the document cited. For example: General Health and Safety Regulation (pertaining to OHS Act) "Flammable liquid" means any liquid which produces a vapour that forms an explosive mixture with air, and includes any liquid with a closed cup flash point of less than 55°C.

Definition	Description
Flash Point	The minimum temperature of a liquid at which sufficient vapour is given off to form an ignitable mixture with the air, near the surface of the liquid or within the vessel used, as determined by a specified test procedure.
Foam-Water Sprinkler System	A piped system that combines foam and piped water to discharge and extinguish over the area to be protected. A piped water supply linked to a control valve is actuated upon operation of the automatic detection system within the area. Upon activation of the control valve, and water flows through the piped system, foam concentrate is introduced into the water supply, with the resulting foam solution discharging over the area affected.
High Hazard	These occupancies are normally commercial and industrial occupancies having abnormal or high fire loads, where the materials handled or processed are of a combustible nature likely to develop rapid and intensely burning fires. This would include turbine areas (with high temperature, high pressure oil) as an example.
Ordinary Hazard	Light non-commercial, commercial and industrial occupancies involving the handling, processing and limited storage of mainly ordinary combustible materials unlikely to develop intensely burning fires in the initial stages. This would include general office areas or coal handling plant areas as examples.
Passive Fire Protection	A Passive fire protection system is preferred above active fire protection. Because it is passive it does not require any mechanical or electrical parts that can fail in the event of a fire. These systems include spatial separation from other areas, containment areas, drainage, fire separation barriers, fire breaks, fire retardant cables, etc.
Redundant	A system or equipment is redundant when it is duplicated to enable a continued service when there is a complete failure of the one system or piece of equipment.
Risk	A quantitative or qualitative measure of an incident loss potential in terms of both the event likelihood and the conditional, aggregate consequences.
Manual Fire Protection	Manual fire protection is typically fire protection equipment that requires human intervention to operate it. This could include equipment such as hydrants, hose reels and portable / mobile fire extinguishers.
Sprinkler System	A network of piping connected to a reliable water supply that will distribute the water throughout the area protected and will discharge the water through sprinklers in sufficient quantity either to extinguish the fire entirely or to prevent its spread. The system, usually actuated by heat, includes a controlling valve and a device for actuating an alarm when the system is in operation. The following categories of sprinkler systems are defined in NFPA 13 [68] - • Wet-Pipe System • Dry-Pipe System • Antifreeze System • Deluge System • Drencher System • Combined Dry-Pipe and Pre-action System • On-Off System

Definition	Description
Subsystem	Subsystem refers to a part of the fire protection system to protect a part of the plant such as the generator transformer fire protection subsystem.
System	System refers to the complete fire protection system.
Total Flooding Extinguishing System (chemical agent or inert gas)	A fire extinguishing system where the extinguishing agent is released throughout a room to flood the total room volume. The extinguishing agent can be a gaseous agent, chemical agent or water mist. Gaseous total flooding systems are typically installed where the presence of water based system would cause a problem (e.g. rooms containing electronic processing equipment) or to protect against shielded or 3-dimensional fire hazards (e.g. flammable liquid pooling underneath equipment or liquid flowing down vertical surfaces). Not suitable for large, open areas like turbine halls.
Unit	A boiler, turbine and generator set and all its dedicated auxiliaries for a coal fired plant. Unit can refer to any generating technology which includes all aspects for that unit (hydro turbine unit, wind turbine unit, OCGT unit) to generate electricity.
Water Spray Curtain System	A water curtain is protection system designed to provide a protective "curtain," or barrier of water in the air between high risk systems and valuable personnel, equipment and facilities. They typically consist of sprinkler heads with the bulb removed and are not to be confused with water drencher systems.
Water Mist System	A network of piping similar to a sprinkler system, except that nozzles deliver a very fine water spray (water mist) to control or extinguish a fire by cooling the flame and fire plume, oxygen displacement by water vapour, and radiant heat attenuation. NFPA 750 [91] provides guidance on these systems.
Water Spray / Deluge System	Networks of piping similar to a sprinkler system, except that it utilizes open-head spray nozzles. NFPA 15 [69] provides guidance on these systems.

2.4 ABBREVIATIONS

Abbreviation	Description
ASIB	The Automatic Sprinkler Inspection Bureau
BLEVE	Boiling Liquid Expanding Vapour Explosion
CSP	Concentrated Solar Power
DCP	Dry Chemical Powder
DTS	Deemed to Satisfy
EPRI	Electrical Power Research Institute
ERP	Emergency Response Plan
FM	Factory Mutual
FPDA	Fire Protection / Detection Assessment
HFDL	Heat Flux Damage Level
HRRPUA	Heat Release Rate Per Unit Area
HVAC	Heating, Ventilation and Air Conditioning
IEC	International Electro-technical Commission
LPG	Liquefied Petroleum Gas

Abbreviation	Description
MJC	Multiple Jet Controller
NB	Nominal Bore
NFPA	National Fire Protection Association
OHSA	Occupational Health and Safety Act
PMMA	Polymethyl Methacrylate
PV	Photovoltaic
SANS	South African National Standards
UL	Underwriters Laboratories
WTG	Wind Turbine Generator

2.5 ROLES AND RESPONSIBILITIES

Eskom person accountable for Fire Systems: The Fire Protection and Life Safety measures detailed in this document are to be implemented by a competent person (as per Eskom Governance and Competency requirements) only. The competent person is to ensure that they fully comply with the Project Engineering Change Management Procedure [7], Engineering Change Management Procedure [8] and the Design Review Procedure [9].

Contractors designing Fire Systems for Eskom: The Fire Protection and Life Safety measures detailed in this document are to be implemented by a Competent person (fire engineering).

2.6 PROCESS FOR MONITORING

Not Applicable

2.7 RELATED/SUPPORTING DOCUMENTS

Not applicable.

3. FIRE AND LIFE SAFETY DESIGN PROCESS

The fire and life safety design process should be initiated as early in the project design process as practical to ensure that the fire prevention and fire protection recommendations as described in this document have been evaluated in view of the plant- / building-specific consideration regarding design, layout, and anticipated operating requirements.

The fire and life safety design process should be initiated under the direction of someone experienced in fire engineering and having extensive knowledge and experience in power plant operation or the type of plant / building under consideration.

In South Africa, fire and life safety for buildings are governed through the National Building Regulations and Building Standards Act [1].

3.1 DESIGN OBJECTIVES

The design objectives for any building, plant, or site layout from a fire system point of view include the following:

- ✓ Optimise life safety considerations for employees and /or plant operating personnel.
- ✓ Eliminate primary risks of exposure fires and minimise secondary exposures.
- ✓ Reduce the frequency of fires and limit individual fire losses to acceptable levels.

- ✓ In a power plant - limit the interruption of plant operation by ensuring the loss of only one boiler unit or turbine-generator unit, given a large fire.
- ✓ Arrange the plant layout to facilitate fire brigade operations.

3.2 DESIGN APPROACH

The fire system design approach is described in detail in Step 2 of the Fire Protection / Detection Assessment Standard [3]. Once the design approach for a specific new build / plant modification / refurbishment have been established in the FPDA, it forms the foundation for the development of fire engineering designs that deliver adequate fire safety in terms of life safety, asset protection and/or business continuity. A FPDA which is conducted as per the Eskom Standard [3] is the initial, multi-disciplinary process in which reasonably foreseeable hazards are identified, the severity of the potential harm, to people and plant, is assessed, and reasonable engineering solutions to mitigate these hazards are proposed.

One of the first considerations during the fire system design approach development is fire risk reduction measures (Fire Protection / Detection Assessment Standard [3]). Fire risk reduction measures are evaluated and addressed in the following sequence:

1. Minimise the risk of fire initiation by the application of fire prevention and mitigation measures which includes design safeguards and administrative controls.
2. Fire detection provides systems for early warning through alarming in a fire situation.
3. HVAC systems which provide smoke ventilation.
4. Fire protection provides systems to control / extinguish / suppress a fire.
5. Emergency management systems provide the response to emergency situations at a facility.

Figure 1: Fire Risk Control Measures

Once the fire risk reduction measures have been applied and it is determined that fire protection and fire detection systems will be required as part of the solution the user of this Standard has three options to approach the design of the fire protection and fire detection systems.

a) Deemed to Satisfy – Follow the requirements in the South African National Standards (SANS).
b) Rational Fire Design
    i. Rational Alternative Code Compliant Design - Follow the requirements in codes and standards other than the South African Nation Standards (SANS).

ii. Rational Fire Engineered Design - Use a risk-based approach and follow acceptable decision-making process using fire engineering principles. This will particularly apply to special risk applications.

3.2.1 "Deemed to Satisfy" Approach

SANS 10400 [61] sets out the different possible ways of demonstrating compliance with functional regulations, including a range of prescriptive provisions that are "deemed to satisfy" the requirements of the National Building Regulations. If a design is compliant to SANS 10400 [61] and any of the normative SANS documents referenced within, then the design can be classified as "deemed to satisfy". The use of any document other than a SANS document would require justification as the design would then be deemed a "rational fire design".

3.2.2 Rational Fire Design - Code Compliant Design Approach

Where the South African National Standards does not address a specific fire risk or area of plant a Rational Fire Design will need to be performed and this will usually require looking at codes of practise other than the South African National Standards. For example, recommended fire protection measures for power stations can be found in application-specific fire protection design Standards such as those produced by the NFPA.

These solutions have been found to be adequate and are considered best industry practice for their environments, Compliance to these codes is acceptable for providing a safe, workable solution to some of the buildings, equipment, areas and sites at Eskom Holdings.

Even though there are many documents which prescribe an adequate code compliant approach, there will always be factors which cannot be accounted for and will require additional engineering. Such factors are:

- Suitability of the fire protection and fire detection components;
- Nature of the site, buildings and equipment;
- Environmental and atmospheric factors specific to the area, such as temperatures, humidity, wind, dust, smog, etc.
- Operations in the areas;
- The level of monitoring and control required for the site as a whole;
- The personnel occupying the buildings as well as using and monitoring the Fire Protection and Fire Detection systems;
- Areas not covered in the documents;

An alternative to complying with the Rational Fire Design – Code Compliant Design approach may be taken by implementing a Rational Fire Design – Fire Engineered Design approach.

3.2.3 Rational Fire Design - Fire Engineered Design Approach

A fire engineered solution is recognised in South Africa as an effective way of meeting fire safety objectives. Although specialist fire safety engineers develop and deliver fire engineering design solutions, designers from other disciplines (such as fire protection, fire detection, HVAC, emergency preparedness, access control, etc.) will often be asked to provide a major input into the way in which the fire safety strategy is developed. Fire safety engineering offers a flexible alternative to code prescriptive approaches, especially when designing for unusual or difficult buildings. A fire safety engineering approach can provide an alternative approach to fire safety, a fact that is recognised in SANS 10400 [61] fire safety code and standards.

Fire engineered solutions may be the only viable way to achieve a satisfactory standard of fire safety in large and complex areas of the power utility assets, and often it is the most effective way of dealing with changes to existing buildings. It can be usefully adopted for certain elements of a building design where the remainder of the building has been designed according to the prescriptive codes. This alternative approach is often the most effective and sometimes the only way to achieve the appropriate level of safety in meeting the latest code requirements for existing buildings.

The use of fire engineering solutions allows beneficial effects to be recognised. For example, the provision of automatic fire suppression can reduce the design fire size, which may in turn lead to a more economic smoke control system design or reduced structural fire protection.

The concept of fire safety engineering provides a framework that enables designers to demonstrate that the functional requirements of legislation are met, or bettered, even though the design solutions adopted fall outside the recommendations of prescriptive codes and guidance.

Fire engineering solutions also allows functional objectives beyond life safety to be addressed, for example, property protection, business continuity, environmental and sustainability objectives.

To achieve this objective, the first step is to understand the functional requirements underlying the prescribed standards. Small departures can then be accepted without a full fire engineering analysis. For example, adding fully automatic fire detection may allow an increase in escape travel distance or an increase in compartment size due to the early alarm and earlier contact with the Fire Service.

However, where there is a greater difference between the building design and the guidance offered by codes, the best way is to follow analytical techniques that demonstrate the control of fire growth, the control of smoke spread and the movement of people which may be required to prove the overall fire safety strategy. The first step in preparing such an analysis is to define the building geometry, functional planning, construction materials and the general use of the building.

While many aspects of the analysis may be quantified, others will require subjective judgment and will be subject to discussion with the building control and fire authorities. They may include, for example, the consequences of fire (which will be subject to the standard of construction and maintenance) or people movement (subject to a motivation or mobilisation time, which may be improved with training or stewarding).

4. GENERAL PLANT DESIGN REQUIREMENTS

4.1 PASSIVE FIRE PROTECTION

4.1.1 Plant Arrangement – Fire Areas

Any Eskom facility shall be subdivided into separate fire areas for the purpose of limiting the spread of fire and limiting the resultant consequential damage to the facility. The overall plant layout philosophy shall align with the design objectives as stated in Section 3.1. Fire areas should be separated from each other by spatial separation, fire barriers or other approved means. Fire area boundaries shall be determined based on consideration of the following:

- Personnel safety / exit requirements.
- Types, quantity, density, and location of combustible / flammable material.
- Location and configuration of plant and equipment.
- Consequences of losing plant or equipment.
- Location and layout of fire detection, passive fire protection and fire protection systems.

If a fire area is defined as a detached structure, it should be separated from other structures by an appropriate separation distance. Section 3.1 of this document provides detail on the determination of separation distances to be maintained.

Two (2) hour fire area boundaries shall be provided for all Eskom facilities to separate the following if applicable to the specific facility (based on the FPDA and the design approach):

a) Cable spreading room(s), and cable tunnel(s) and high voltage lead shafts from adjacent areas.
b) Control room, computer room, or combined control/computer room from adjacent areas.
c) Rooms with major concentrations of electrical equipment, such as a switchgear room or relay room, from adjacent areas.
d) Battery rooms from associated battery chargers, equipment, and adjacent areas.
e) Maintenance shop(s) from adjacent areas.
f) Main fire pump(s) from reserve fire pump(s) where these pumps provide the only source of fire protection water.
g) Fire pumps from adjacent areas.
h) Warehouses from adjacent areas.
i) Emergency generators from each other and from adjacent areas.
j) Fossil fuel–fired auxiliary boiler(s) from adjacent areas.
k) Fuel oil pumping, fuel oil heating facilities, or both, used for continuous firing of the boiler from adjacent areas.
l) Storage areas for flammable and combustible liquid tanks and containers from adjacent areas.
m) Office buildings from adjacent areas.
n) Telecommunication rooms, supervisory control and data acquisition (SCADA) rooms, and remote terminal unit (RTU) rooms from adjacent areas.
o) Adjacent turbine generators beneath the underside of the operating floor.
p) Between the boiler house and the areas of the coal handling system above the bin, bunker, or silo.
q) Fan rooms and plenum chambers from adjacent areas.
r) Switchgear area and sulfur hexafluoride (SF6) switchyard area from adjacent areas.
s) All openings in fire barriers shall be provided with fire door assemblies, fire dampers or penetration seals with a fire resistance rating equivalent to the designated fire resistance rating of the barrier.
t) Windows in fire barriers are to be provided with a fire shutter or automatic water curtain.
u) Wherever so determined by the FPDA.

4.1.2 Escape Routes and Travel Distances

Escape routes and travel distances are to be in accordance with SANS 10400 Part T [61]. Where it is not possible to implement these general recommendations due to the non-standard layouts typically found in power stations NFPA 101 [83] shall apply.

A Rational Fire Engineered Design may be necessary where prescriptive methods are inappropriate or excessively onerous.

Any escape route within the power plant and/or its supporting buildings and facilities should be clearly marked and signposted to indicate the available escape routes to a place of relative safety for all operatives.

Typically the exit door from any area which has an occupant population less than 25 people is not required to have an emergency exit sign to meet the recommendations of SANS 10400 Part T [61], however given the nature of the buildings and areas to be protected, and the sheer size and scale of these buildings, the actual requirement to provide exit signage within individual areas should be considered during the Fire Protection/Detection Assessment process. For instance, cable tunnels would typically have an occupancy level not exceeding 25 people, however emergency exit signage should be provided from this area to assist with means of escape for any occupants carrying out repairs and maintenance.

All escape signage provided shall be either internally or externally laminated, or be of the photo luminescent type, and shall be designed in accordance with SANS 1186 [47].

4.1.3 Building Construction Materials

Building construction materials shall in general meet the requirements of SANS 10400 [60].

The construction materials used in the boiler or turbine generator building, or other buildings critical to power generation, transmission and distribution shall meet the definition of non-combustible in according to SANS 428 [43]. A Rational Fire Engineered Design based approach may be incorporated to achieve alternative building solutions where prescriptive methods are inappropriate or excessively onerous.

4.1.3.1 Building Construction Materials – Surface Finishes

All material finishes, other than those applied to floors, shall meet the Surface Fire Index ratings as detailed within SANS 10400 Part T [61], Table 17. Any finishing material chosen should be tested in accordance with SANS 10177 [57] Part 3, or alternative applicable testing standard.

All material finishes applied to as floor coverings shall meet the Fire Index coverings detailed SANS 10400 Part T [61], Table 18 and be tested in accordance with SANS 10177 [57] Part 4, or alternative applicable testing standard.

4.1.4 Fire Doors

Fire doors are provided in buildings / plant areas / rooms to maintain a fire area integrity as part of the design of that building / plant area / room. New fire door assemblies (door and frame) shall be designed and supplied in accordance with SANS 1253 [48]. When a fire door is replaced, it must be of the same rating as per the original design.

Some practical notes on fire door replacement:

- When fire doors are being replaced due to damage, it is advised that the whole assembly is replaced.
- When it is not practical to replace the frame already built into the existing structure – replace only the fire door. Care must be taken to ensure the door will fit properly into the existing frame.
- In older structures there are instances where it is not clear if the existing door is a fire door (no name plates provided on doors or frame). Do not just replace doors. A field inspection on the type of frame and type of door could be done to give an expected fire rating based on door and frame material type, construction, and installation. This type of field labelling is allowed as per NFPA 80 [80].

4.1.5 Fire Proofing

The purpose of fire proofing relates to one of the following aspects –

- Fire proofing of openings in the walls / floors of fire areas where pipes, cables, ducting etc. penetrate to maintain the fire area integrity in a fire scenario.
- Fire proofing of cables to limit flame spread along cable racking.
- Fire proofing of steel or other construction to provide structural stability in a fire scenario.

Fire proofing shall be rated to provide a minimum of 2 hours fire resistance (integrity (E), insulation (I) and stability (R) ratings) in accordance with SANS 10177 [57] testing standard, or alternative testing standard as per the applicability and / or rating of the fire area.

Annexure B gives applicable checklists to consider for fire proofing.

Fire stops, and the method of installation proposed by any designer or installer shall be identical to those proposed by the fire stop manufacturer. Any deviation from the manufacturer installation methods should be discussed directly with the manufacturer to ensure any proposed alternative method of installation will achieve the same level of fire resistance required.

The material selected for use as a fire stop should be suitable for its application, and the size and type of gap or penetration, and the type of material and construction used in the fire separation.

Any fire proofing (seal / barrier / stopping / coating) that is supplied must be marked to provide the details of the fire proofing. As a minimum the product name, fire rating and date of installation should be provided.

4.1.5.1 Fire Barrier/Seals/Stopping Application Considerations

Effective fire barrier seals can be achieved using various sealant materials.

Irrespective of the method or material selected for the seals, the installation should conform to the following:

a) The sealant material and the application rate specified should not affect the performance characteristics of the cables do not cause overheating of cables due to heat build-up.

b) The fire barrier seal should be capable of withstanding the penetration of water, including firefighting water jets directed at the seals.

c) Horizontal seals should be applied to a height just above floor level and dome shaped to prevent the accumulation of oil or water around the penetration.

d) The fire barrier seal should be capable of carrying loads where necessary. Any reinforcing required for this purpose should be subject to Eskom's approval.

e) The performance of fire barrier seals should not be downgraded by normal ageing, vibration or other environmental conditions associated with the plant or facility.

f) The fire barrier sealant material should not crack when the sealant dries or shrinks. If it is necessary for additional sealant to be used on the seal, sufficient curing time should be allowed before its application.

g) Fire barrier sealant material should be asbestos free, non-toxic and resistant to chemical attack where specified.

h) Fire barrier sealant material should be compatible with the cable insulation or other penetration materials, have good adhesion and be free of volatiles which could adversely affect these materials.

i) Fire barrier sealant material may be of the intumescent type capable of expansion under heat to seal voids, cracks or fissures which may exist due to application defects and cable configurations.

4.1.5.2 Fire Barrier/Seals/Stopping Installation Considerations

Installation of the material should be subject to the manufacturer's requirements. The following points should be adhered to during installation.

a) Horizontal barriers for vertical penetrations should be sealed on the floor side only.
b) Vertical barriers for horizontal penetrations should be sealed on both sides of the barrier to withstand the effects of fire and to ensure that an acceptable finished coating/seal is achieved.
c) All tools or equipment used in and around cable penetrations for the application of sealant material should be rounded to prevent damage to the cable insulation.
d) Cables should where possible be laid evenly spaced to allow the penetration of sealant materials between the cables. Where cables have not been evenly laid and spaced a sealant material capable of being applied under pressure should be utilised to effect penetration between the cables in the fire barrier.
e) The use of coating materials as fillers will only be approved if the effectiveness of the application is proved and if the fire rating is maintained.

f) Combustible or toxic materials used for shuttering during installation should be removed on completions of the seal.
g) Mineral wool, ceramic fibre board or other materials with similar properties may be utilized to fill large voids.
h) Openings to be sealed should be properly prepared. Oil and excess water should be removed before installation of sealants begins.
i) The manufacturer's specified curing time should be allowed during the application process.
j) Thickness and volumes for the sealant material applied should be strictly in accordance with the manufacturer's requirements and tests.
k) All seals should be provided with a final layer or coat to provide a smooth finish.
l) The sealant material utilised should allow for the replacement of cables or additional cables or any other penetration component to be installed without disturbing the major portion of the seal.
m) If the sealant material utilised is subject to excessive expansion, steps should be taken to ensure that the bulk of the sealant material remains within the seal when expansion occurs during application.
n) Seals may be of the rigid or flexible type.
o) If coating of cables is necessary to assist the adhesion of the sealant material, or if sections of cables need to be coated on either side of the seal, this should only be done with Eskom's approval.
p) If reinforcing of the seals is necessary the type, pattern and anchoring of the reinforcing should be approved by Eskom.
q) Where openings cannot be completely sealed due to work in progress the use of temporary seal bags is recommended.
r) The method of application and materials utilised should be approved by Eskom.
s) Penetration seals should be uniquely identified as a fire barrier with the specified fire rating of the barrier. Reinstatement or repairs to the barrier should be in accordance with the relevant specification.

4.1.6 Containment and Drainage

Provision shall be made in fire areas of the plant or facility for removal of all liquids directly to safe areas as well as confinement of liquid spills to a defined catchment area as per NFPA 13 [68], NFPA 15 [69], and NFPA 850 [93] on the provisions to be adopted to remove fire water from the area of discharge, with the recommendations followed within FM Data Sheet 7-83 [105] for the removal of flammable liquid.

During the Fire Protection/Detection Assessment process consideration should be made to adopting one, all, or several the following prevention measures:

a) Floor drains
b) Floor trenches
c) Curbs or bunds for containing or directing drainage
d) Provision of key generating equipment on pedestals
e) Pits, sumps, and sump pumps
f) Fire traps within floor drains for combustible/flammable liquid applications.
g) Provisions for storing run-off fire-fighting water that will contain contaminants, which may potentially impact upon the surrounding environment (ground contamination, contamination of natural water courses etc.).

Where gas suppression systems are installed, drains and appropriate dampers shall be provided with adequate seals, or the gas suppression system shall be sized to compensate for the loss of suppression agent through the drains.

4.1.7 Passive Fire Protection in Distribution Substation Yards

The Eskom standard - Standard for Passive Fire Protection in Distribution Substation Yards [30] - sets out the passive fire protection methods to be used in HV and MV yards in all Distribution Substations.

4.2 ACTIVE FIRE PROTECTION

In addition to the specific areas of the plant identified in this standard, the provision of fire suppression systems shall be determined by a Competent person (fire engineering). The applicable design standard shall give guidance on fire water volumes and required pumping capability (if required) for the appliable active and manual fire protection provided on the site or facility.

4.2.1 Types of Fixed Fire Protection Systems

Different hazards and risks can be protected with different types of fixed fire protection systems. The typical types of systems that is used in Eskom include –

a) Foam fire protection systems designed to NPFA 11 [66], NFPA 16 [70].
b) Sprinkler fire protection systems designed to SANS 10297 [59], NFPA 13 [68].
c) Deluge fire protection systems designed to NFPA 15 [69].
d) Water mist fire protection systems designed to NFPA 750 [91].
e) Gaseous fire protection systems designed to SANS 14520 [64], NFPA 12 [67], NFPA 2001 [95]. Systems could include full flooding, localised flooding or in-cabinet type systems.
f) Aerosol type fire extinguishing systems designed to SANS 15779 [65], NFPA 2010 [96]. Systems could include full flooding, localised flooding or in-cabinet type systems.

Equivalent alternative design standards for these systems or other applicable fire suppression systems can be utilised and must be defined and accepted as part of the Eskom and Fire System design processes - [3], [7], [8], [9], [10].

4.2.2 Water Supplies

Water supplies for any facility or site shall be designed to support the required active and manual fire protection requirements on site.

The installation and construction of storage tanks shall be in accordance with the relevant Design Standards and sound engineering practice.

Remote facilities such as substations which are generally not manned and where fire water is not readily available must apply passive fire protection measures as far as practically possible and still comply to the South African Building Regulations SANS 10400 [60] accordingly.

4.2.2.1 Power Station Water Supply

The water supply or supplies for fixed fire protection installations on a power station (generally fossil fuel power stations, or where applicable) shall as a minimum be based on the fire scenario with the largest designed fire water demand (also referred to as the worst case scenario) taken from activation of the fixed suppression systems, plus the maximum hose stream demand of not less than two (2) hydrants for a minimum duration of two (2) hours. The actual supply demand should be calculated to take into consideration the actual number of hydrants that may be in operation at any one time, their location in relation to the building or item of equipment to be protected, and the mode of operation required. This is in line with NFPA 850 [93] requirements.

Common tanks may be used for fire and other water services (i.e. use of water for floor washing) – provided that the minimum fire water storage requirements are always guaranteed and unnecessary starting of main fire water pumps is avoided.

Given the small volume of water required for wash down services in comparison to the fire protection system, the provisions of a separate pump associate with these facilities may be required if the static water pressure is inadequate. The flow rate and required pressure for these services should be separate from the pump duty and requirements of the fire protection system.

The volume of water usage required for these services supplementary to the fire protection system requirements should be calculated and added to the overall water storage requirements for the fire protection system to determine the overall tank size required.

When tanks are used, they shall be connected to an automatic refilling system that shall be able to replenish the fire water requirement in a maximum of eight (8) hours. This requirement is not strictly required should "back-up" water supplies be available for fire protection.

A power station must have the assumed worst-case scenario documented as part of the fire system design baseline documentation as this is what the water supply of the power station are based on. Any modifications or additions to the power station fire systems should consider the impact on the defined worst-case scenario of the station. The Eskom document "Fire Protection System Water Demand Worst Case Scenario Position Paper" [38] gives more details.

4.2.3 Fire-Fighting Water Reticulation System

Sectionalising and damage control of the reticulation system shall be catered for through looped piping systems and strategically positioned sectional isolation valves.

The fire water range is designed to provide for ready access at sufficient head all over the power station site. The site water main shall typically be charged at high pressure – ranging around 8 to 12 bar. The use of pressure reducing valves is not recommended if pipe velocities for fixed systems can be managed through pipe sizing. The hydraulic calculations of a system must support the use of pressure reducing valves.

The source of water for floor washing, random availability, or access to the reticulation system and the pressure requirements make the fire range almost ideal for the purpose of floor washing. For this reason, as well as purging of the fire range system with freshly produced water, the combination of fire water and floor washing reticulation system shall be considered. If these two systems are combined, the following must be prevented:

- Encroaching on the 2 hours of fire water supply that should be available for firefighting purposes.
- Starting up main fire pumps to feed water for floor washing purposes.
- Pilfering; and damage of fire-fighting equipment such as fire hoses, branches, and fittings by using them for floor washing purposes.

Hydraulic designs of fire systems - pipe velocities in fire-fighting water reticulation systems should be kept within the following boundaries:

- Reticulation Mains at maximum 3 meters / second.
- Branch Pipes feeding toward fixed systems (before control valve) at maximum 6 meters / second.
- Sprinkler / nozzle piping (after control valve) at maximum 8 meters / second.

4.2.4 Fire Water Pumps

The fire water pumps are required to meet the fire flow requirements determined by the largest fire area demand.

Power stations shall be provided with enough pumps to ensure 100% redundancy in fire water pump capacity. The preferred installation is:

- 100% pumping capacity by SANS/ASIB approved electrical fire water pumps and
- 100% pumping capacity by SANS/ASIB approved diesel-driven fire water pumps.

The combination can be varied based on size and lead time of pumps, as long as a 100% redundancy in pumping capacity is supplied.

Maintaining the pressure in the fire water piping systems can be achieved either by pressure maintaining pump(s) (jockey pumps) or with head tank pressure.

Fire pump installations shall conform to sound fire protection engineering practice. The fire pumps shall be automatic starting with manual shutdown. The manual shutdown shall be at the pump controllers only. The selection of pump drivers shall be at the discretion of the designers – fire pumps shall not be subject to a common failure, mechanical or electrical.

A diesel pump driver as well as the diesel tank supply shall be provided with automatic fire suppression systems.

The electric and diesel pumps and pump set drive controllers shall conform to the requirements of SANS 10287 [59] and in addition shall incorporate the following features:

- Electric Pump Churn Cooling: The electric pump should have a small bore (12.7 mm) pressure relief valve installed (set at 1 bar below churn pressure), to allow cooling water to flow through the pump casing during churn (no system flow) conditions. The lack of a cooling line will allow excessive temperatures to build up in the pump casing and could lead to cavitation damage to the pump impeller casing and/or over heating bearings.
- Diesel Pump Cooling Water Return: The diesel pump cooling water return line should be piped to drain (into a visible tonnage cup) or back to the tank (with a site gauge installed). The cooling water return line shall not pipe back to the suction side of the pump.
- Automatic Air Release Valves: Both pump (electrical and diesel) should be provided with an automatic air release valve, installed on top of the casing.

NFPA 20 [71] can also be looked at for fire pump requirements but ensure that fire water pumps that are procured are fit for purpose, locally available and locally supported.

4.2.5 Actuation of Active Fire Protection Systems

Each fire suppression system shall be equipped with approved local alarm devices with audible and visual annunciation in the main control room and connected to the site wide fire detection and alarm network.

Active fire protection systems shall be activated by mechanical, automatic means as far as practically possible to ensure prompt operation of the system. Electronic, automatic activation shall only be allowed if mechanical activation is not viable. Manually activated systems could cause delays in response times which is unacceptable for most hazards. Any other method of activation shall be subject to the approval of Eskom.

This does not apply to Clean Agent Extinguishing systems.

4.2.6 Fixed Protection System Pipework and Associated Fittings and Fixtures

Any piping or equipment associated with the Fire Protection equipment shall be designed in accordance with SANS 1091 [45] and SANS 10140 [56] colour coding requirements – A11 Signal Red.

All fire protection equipment (i.e. pipework, equipment, and apparatus other than fire extinguishers) shall be painted in full with signal red for identification purposes. Banding can be allowed on piping but is not preferred. Banding must be provided in such a manner to ensure clear identification of the fire systems.

Fire protection pipe networks shall be designed in accordance with sound pipe engineering practices and include all required fittings such as automatic air releases on high spots, drain points for flushing purposes etc.

4.2.6.1 Pipework

The Eskom Standard for Low Pressure Pipelines [18] shall be used as guidance.

All the above ground pipelines for fire water systems shall be hot dipped galvanized steel. All mild steel pipes and equipment shall be pressure rated according to the maximum working pressure in the system.

Any underground pipes should be protected against corrosion where necessary. The decision as to what type of pipe to use for below grade fire protection pipelines rests with the designer and should be documented during the Fire Protection/Detection Assessment process confirming its suitability for its intended application.

All steel pipes up to 50NB shall be screwed and anything above 50NB shall be flanged.

4.2.6.2 Pipe Supports

The fire protection system pipe supports shall be capable of supporting the loads of the system without exceeding the maximum permissible deflection. Pipes shall be positioned to maintain a clearance to any other fixed structure, except the members to which such pipes are clamped. Supports shall be designed in accordance with SANS 10287 [59].

Structural pipe supports are to be provided at intervals not exceeding 2.5 m for the piping up to 50 mm Nominal Bore (NB) and all other piping shall be supported at 4.5 m intervals.

4.2.6.3 Valves

The Eskom Standard for Low Pressure Valves [19] shall be used as guidance. All valves used in fire water reticulation systems are deemed suitable for use dependant on the application and SANS approved (or applicable international alternative).

Locking facilities shall be provided for all valves that need to be locked in the open position as per NFPA 850 [93].

All manual isolation valves shall have an indication of the open or closed position so that valve position can be determined from a distance, or the shaft shall be permanently marked with the disk position.

Gate valves shall be installed in the horizontal position to prevent the accumulation of debris in the valve seat. Geared butterfly valves are the preferred type of sectional isolation valve for fire water systems.

All fixed fire protection control valves shall be of the ‘non-clack’ type valves (see Eskom document “Fire Protection System – Clack Type MJC Valves Evaluation Report” [40] for details). Diaphragm-type valves are the preferred type of control valve. Control valves of fixed fire protection systems shall have the typical wet/dry pilot control valve trim. Automatic water control valves that will be considered suitable for water-based fire protection systems shall have either one of the following listings or approvals (See the Eskom document “Fire Protection Automatic Water Control Valve Qualification Evaluation Report” [39] for details):

- FM approved; or
- LPC approved; or
- Tested in accordance with the requirements of ISO 6182.

It is critical to note the “number of” and “location of” automatic water control valves for fixed fire protection systems in relation to the plant that is being protected as well as from a fire system isolation perspective. A separate automatic water control valve shall be supplied for each system or zone to allow for maintenance activities on the plant to take place without having to isolate the complete fire protection system in the area. Consideration shall always be made to not locate automatic water control valves where it is exposed to the fire hazard that it is protecting or any other fire hazard or risk.

4.2.6.4 Pressure Gauges

Glycerine filled (or alternative dependant on environment) pressure gauges fitted to a water-based suppression system shall be suitable for use and be capable of taking measurements between 0kPa and 1600kPa, or 500kPa above the maximum working pressure of the proposed water supply, whichever is the higher.

The scale shall be sub-divided into units not exceeding:

- 20kPa, in the case of a maximum scale value up to and including 1000kPa.
- 50kPa, in the case of a maximum scale value exceeding 1000kPa, and up to and including 1600kPa.
- 100kPa in the case of a maximum scale value exceeding 1600kPa.
- Be suitable for their application and use.

4.2.6.5 Pressure and Flow Switches

Pressure switches and flow switches shall be located on every fixed fire protection system to allow for alarming in the control room when the fixed fire protection systems are actuated. Fire detection status monitoring of all pressure and flow switches is required where multiple branch pipes exist and are fed from one source of water supply.

Typically pressure switches are best suited for deluge systems and flow switched are best suited for sprinkler systems.

In addition, level transducers and alarm devices should be provided to monitor the water levels within any storage tank and this level must be indicated in the control room.

4.2.7 Sprinkler Heads

Sprinkler heads shall conform, as a minimum to the following:

- Sprinklers must be of approved makes and types. Generally, the Factory Mutual (FM) and Loss Prevention Certification Board (LPCB) are deemed to be an acceptable approving authority.
- Sprinklers must not be altered in any respect nor have any type of ornamentation, coating applied or be painted other than by the manufacturer after leaving the manufacturers facilities.
- Sprinklers shall not be screwed into range pipes before range pipe erection and may only be installed once the pipework is secured in place.
- Only the manufacturers sprinkler wrench may be used to fit sprinklers to pipe work.
- Sprinkler heads that have been in service may not be reused or relocated regardless of the circumstances. Once a sprinkler or a sprinkler pipe with sprinkler fitted to it is unscrewed from the fitting it shall be discarded.
- Where a sprinkler is contaminated by paint or any other substance that adheres to any part of the sprinkler, it must not be cleaned but shall be replaced with a new one.
- Sprinklers shall be installed with the sprinkler frame running parallel to the pipe to avoid pipe or frame shadow.
- Sprinkler heads shall not be intermixed. All sprinklers within any compartment at roof or ceiling level shall have identical operating characteristics inclusive of K-Factor, manufacturer, distribution patterns, orientation, and thermal sensitivities. A compartment is defined as a room or area separated from any adjoining area with walls or partitions where a door lintel is at least 200 mm below the level of the sprinkler deflector.

4.2.7.1 Temperature Ratings

- Sprinklers are approved in nominal temperature ratings ranging from 57°C to 260°C.
- The temperature rating chosen shall be as close as possible to, but not less than, 30°C above the highest anticipated temperature conditions.

- For normal conditions in Southern Africa, a rating of 68°C or 79°C will be generally suitable for Ordinary Hazard occupancies.
- Under unventilated concealed spaces which includes ceiling or roof voids, it will be necessary to install sprinklers with a temperature rating between 93°C and 141°C.
- Unless otherwise stipulated, in High Hazard systems, 141°C sprinklers must be used on all High Hazard risks. This would typically include turbine protection systems as an example.

The table below has been adopted to distinguish sprinklers of different nominal temperature ratings:

Table 1: Fusible Bulb Colour Codes

Glass bulb types (°C)	57	68	79	93	141	182	204/260
Colour of bulbs	Orange	Red	Yellow	Green	Blue	Mauve	Black

4.2.8 Water Based Fixed Fire Protection Nozzles

Other nozzles for water based fixed fire protection systems such as high velocity and medium velocity deluge system nozzles and foam monitors and nozzles must be of approved makes and types. Generally, the Factory Mutual (FM) and Loss Prevention Certification Board (LPCB) are deemed to be an acceptable approving authority.

4.3 MANUAL FIRE PROTECTION

For the purposes of this standard the manual fire protection referred to includes fire extinguishers, hose reels and hydrants. The spacing and quantity of fire extinguishers, hose reels and hydrants must comply to the minimum requirements as set out in the South African Building Regulations SANS 10 400-T [61] based on the occupancy classification of the building. Additional requirements related to power stations, remote areas and aspects that does not fall directly in the classification of a “building” are recorded here.

Fire extinguishers, hose reels and hydrants shall be provided for manual fire protection and located such that access to them will not be impeded by fire.
Ensure the working pressure of the fire water system for a particular power station or building area is checked before hose reels and hydrants are specified as power station fire water system working pressures can be as high as 1200kPa.

4.3.1 Fire Extinguishers

Fire extinguishers should be located as per the occupancy classification of the area in accordance with SANS 10400 [60] and comply with SANS 10105 [54]. Fire extinguishers must be located at positions close to potential fire risks. The fire extinguisher sizes and types depend on the location and related fire risk – see SANS 10400-T [61] for guidance. Dry Chemical Powder (DCP) and Carbon Dioxide (CO_2) fire extinguishers are generally used in plant areas. Plant areas should in general have extinguishers of 9 – 10kg and office type areas can have extinguishers of 4.5 – 5kg.

Portable fire extinguishers shall comply with the requirements of SANS 1567 [49] (CO_2) and SANS 1910 [50]. Wheeled fire extinguishers (20kg – 450kg) shall be in accordance with SANS 11601 [63].

4.3.2 Hose Reels

Fire hose reels must comply with all the requirements of the latest edition of SANS 543 [44], SANS 10105 [54] and SANS 10400-W [62].

As the buildings on a power station and other services may not be conducive to effective location of fire hose reels, locations may be adjusted to provide the best coverage based on the 30m length of hose associated with hose reels.

In remote areas where fire water for hose reels is not available, the requirement can be substituted with fire extinguishers as per SANS 1400-T [61].

4.3.3 Fire Hydrants

Fire hydrants shall be supplied in the areas where hydrant protection is required, based on the fire risk analysis of the power station site or other facility. Fire hydrants must comply with all the requirements of the latest edition of SANS 1128 [46], SANS 10105 [54] and SANS 10400-W [62]. All hydrant connections are standardized fittings throughout the facility or power station and readily available in the industry.

Pipes feeding hydrants shall not be less than 100 NB. The flow rate for the fire hydrants is 20 l/s (1 200 l/min) and the standard requirement for a power station is the simultaneous flow of two hydrants. Where feed pressures only are required at the hydrant (the fire brigade is to provide boosting of systems), the system should be designed with the most remote hydrant having a pressure of 350kPa, as per Eskom minimum requirements.

Fire hydrants shall be supplied through 80 mm risers. Double outlet hydrants supplied through 100 mm risers are also acceptable where required. High volume hydrants are allowed based on the requirements of the specific site and input from the fire officers on site. There is no reference to high volume hydrants in any of the South African standards, thus care must be taken in the specification of high-volume hydrants.

Diaphragm-type hydrant valves are also acceptable as they are maintenance free, with no spindle to collect dust and no gland leakages.

If a site has existing hydrants, any addition or replacement should be made with the same type of hydrant (for standardisation purposes), only if the current hydrant type is not problematic.

In remote areas such as stock yards and overland conveyors, a spacing of 90 m to 150 m shall be allowed. The hydrants should be positioned such that at least one is within 40 m of the building or item of plant it is intended to protect.

4.3.4 Other Manual Fire Protection Equipment

There are many other types of manual fire protection equipment specifically utilised by fire fighters that do not form part of this standard as it is not seen fire engineered system (non-plant equipment). For more information related to this type of equipment refer to the Eskom Standard – Operational Standard for Inspection, Testing of Fire and Rescue Non-Plant Equipment in Generation [17].

4.4 FIRE DETECTION SYSTEMS

The fire detection and alarm system will comprise a site-wide analogue addressable distributed fire control network. The status of all fire related devices, including but not limited to suppression systems, vents, dampers, fans, detectors, and manual call points, will be physically connected to strategically located subordinate Fire Detection Panels which report to a master Fire Detection Panel in a location suitable for ready access by the responding fire services and other control personnel.

All fire system alarms, and status points will be interfaced to the site SCADA system by means of a high-level interface. Graphic displays shall be incorporated into the site SCADA system rather than by means of independent fire system graphics. This is to promote familiarity of normal / abnormal fire alarm conditions with operators. Video Based Fire Detection displays will be incorporated into the standard operational CCTV system displays.

The design of the fire detection and alarm system shall be in accordance with the Fire Detection and Life Safety Design Standard [5].

4.5 SMOKE VENTILATION

General HVAC (Heating, Ventilation and Air Conditioning) requirements are stipulated by the following standards:

- Eskom Heating Ventilation and Air Conditioning (HVAC) Design Guideline [24].
- The Application of the National Building Regulations, SANS 10400 [60].

4.6 LIFTS

The requirement and design for any lift shall be in accordance with the National Building Regulations, SANS 10400 Part T [61], and the Eskom document Lifts, Escalators, Lifting and Crane Design Guideline [25].

4.7 FIRE STATION

The fire appliances and equipment of the fire brigade should be stored in a building set aside for this purpose. Every nuclear and coal fired power station shall make provision for a suitably sized fire station to house the emergency vehicles required for the risks, as identified in the risk assessment performed in terms of the Eskom Fire Risk Management Standard [1].

Such fire station shall incorporate facilities for change rooms, showers, toilets, a workshop for carrying out minor repairs to fire appliances and other equipment, storage, administrative duties and in-service training. Facilities for drying hose and an area for carrying out routine fire exercises should be provided.

4.8 CLASSIFICATION OF HAZARDOUS LOCATIONS

Eskom Standard for Hazardous Locations [21] covers the design and classification of locations in which fires or explosions can occur due to the presence of flammable gases, vapours, dust, or fibrous material in the air, to permit the proper selection of electrical apparatus and mechanical equipment to be used in such locations.

This standard will give the designer an indication of where certain types of rated equipment should be used. The Eskom standard Fire Detection and Life Safety Design Standard [5] also gives guidance on the classification of hazardous locations.

4.9 BRUSH FIRE EXPOSURE – FIRE BREAKS

An insidious fire hazard at a power plant, substation, building, or facility is that of exposure from dry grass, brush, and weeds. The hazard may appear to be obvious, and yet, since it is a hazard requiring infrequent attention of maintenance personnel, it may be overlooked, or its control given secondary consideration since it does not directly affect plant operation or facility productivity. In times of plentiful rain, brush may not appear to be a hazard at all. However, during times of drought or winter, dry grass can and does present a severe exposure hazard to such areas as conveyors, storage areas, gas storage containers, flammable liquid fuel storage, the boiler structure, transformers, substations, buildings and transmission lines.

Adequate fire breaks in line with the relevant standards and requirements must be done at all sites, facilities and power station as a fire risk control measure.

4.10 FIRE PROTECTION SYSTEM DESIGN INFORMATION / SPECIFICATION / REVIEW

The National Building Regulations and Standards Act [1] requires a Fire Protection Plan. Details of what is required in relation to this fire plan are stipulated in the South African Building Regulations SANS 10400-A [60].

Any modification, refurbishment or new fire protection system in Eskom must follow the Eskom Design Process. This process includes the following standards, procedures and works instructions –

- Fire Protection / Detection Assessment Standard [3].
- Project Engineering Change Management Procedure [7].
- Engineering Change Management Procedure [8].
- Design Review Procedure [9].
- Works Instruction for the application of Standards for Engineering Work [10].

An information design manual (system description) is to be compiled and shall verify that the fire protection features required by law and addressed in this standard have been met. This manual should form part of the design baseline documentation that must be kept by the owner of the plant / property to be able to understand what fire and life safety systems are implemented where and for what purpose.

The manual shall list all fire protection features, i.e. active and passive, with explanatory statements as needed to identify location, type of system and design criteria. The manual shall also identify any deviations from this standard and shall present alternatives for review. Justification for deviations shall show that an equivalent or better level of fire protection will be achieved. Deletion of a protective feature without compensating alternative protective measures will generally not be accepted, unless it is clearly demonstrated that the protective measures are not needed because of the design arrangement of the plant. A Rational Fire Engineered Design approach is required under such circumstances.

Annexure D gives some guidance on typical information that should be specified or given when fire and life safety systems are designed.

4.10.1 Labels, Signs and Notices

The relevant labels, signs and notices required as per SANS 10287 [59] shall be provided for all fire and life safety systems as a minimum.

4.11 COMMISSIONING, TESTING AND ACCEPTANCE OF FIRE PROTECTION SYSTEMS

4.11.1 Inspection and Visual Examination

Systems shall be examined visually to determine that they have been installed in accordance with approved plans and specifications. Systems shall be inspected for such items where applicable:

- Conformity with installation plans.
- Continuity of piping.
- Removal of temporary blinds.
- Accessibility of valves, controls, and gauges.

4.11.2 Flushing

To remove foreign materials that have entered both underground and aboveground water supply mains during installation, the water supply mains shall be flushed thoroughly at the maximum practicable rate of flow before connection is made to system piping.

The flushing operations for all supply pipes shall be continued for a sufficient time to ensure thorough cleaning. All supply pipes shall be made free of debris that would inhibit system discharge.

Where flushing is not possible, cleanliness shall be determined by internal examination of all sections of pipe not flushed.

4.11.3 Pressure Testing

The testing of pipelines may vary slightly dependant on the design code that is used.

Pneumatic Pressure Testing - All dry pipework in water-sensitive areas of the installation (such as computer areas) shall be pneumatically pressure tested.

Hydrostatic Pressure Testing - All pipework not in water-sensitive areas shall be hydraulically tested. Pipework shall be deemed to be satisfactory if the water test pressure is maintained for a period of not less than 2 hours without any additional input of water into the installation.

If any fault, such as permanent distortion, rupture or leakage, is disclosed by the pressure test, the fault shall be corrected, and the test shall be repeated.

4.11.3.1 Operating / Performance Testing

Operating / performance tests shall be conducted to ensure that systems will respond as designed, both automatically and manually. The operating / performance test differ dependant on the type of system that is being tested. Details of the required operating / performance test that needs to be done for the various systems are as per the relevant design standard requirements –

- Foam fire protection systems designed to NPFA 11 [66], NFPA 16 [70].
- Sprinkler fire protection systems designed to SANS 10297 [59], NFPA 13 [68].
- Deluge fire protection systems designed to NFPA 15 [69].
- Water mist fire protection systems designed to NFPA 750 [91].
- Gaseous fire protection systems designed to SANS 14520 [64], NFPA 12 [67], NFPA 2001 [95].
- Aerosol fire protection systems designed to SANS 15779 [65], NFPA 2010 [96].

4.12 INSPECTION, TESTING AND MAINTENANCE

Once installed fire and life safety systems shall be inspected, tested, and maintained in accordance with the manufacturer's recommendations and the guidance provided in the Eskom Standards -

- Inspection, Testing and Maintenance of Fire Protection Systems [4].
- Inspection, Testing and Maintenance of Fire Detection Systems [6].

4.13 CONSTRUCTION SITE FIRE PROTECTION

Consideration should be made to both the safety of occupants during new build and refurbishment works, whilst also considering the impact upon existing buildings and infrastructure adjacent to any construction site. Given the uncertain nature of construction sites adequate measures should be adopted to ensure the continuity of services is not affected. The impact of a construction site fire can be significant, especially when resulting in loss of life, or the ability to generate power. Strict guidelines should be enforced to limit the impact of construction and refurbishment works.

Further guidance can be found in relation to construction site fire safety within the South African Construction Regulations and NFPA 850 [95].

5. FIRE PROTECTION REQUIREMENTS FOR GENERAL AREAS

In general, the identification and selection of fire and life safety systems should be based on the FPDA. This section identifies fire system requirements for general areas and specifies the required fire and life safety measures that should be implemented unless the FPDA indicates otherwise.

Section 4 of this document shall be applicable to all areas mentioned in the following sections.

5.1 GENERAL BUILDINGS AND FACILITIES

5.1.1 General

General Eskom buildings and facilities which are seen as buildings and structures not directly associated to power generation infrastructure can include buildings such as offices, storerooms (not associated with the storage of flammable or combustible liquids or materials), warehouses, workshops, sleeping quarters, auditoriums / halls, document archives etc.

These facilities must have an occupancy classification in accordance with SANS 10400-A [60], and the occupancy classification will assist in identifying all the fire system design requirements for a particular facility in accordance with SANS 10400-T [61].

Where Eskom facilities contain rooms such as control rooms, equipment rooms, cable spreading rooms / cable concentrations, switchgear rooms, battery room, substations and switchyards, transformers, diesel generators or oil storage areas the specific requirements for the hazard and risk must incorporate the requirements as detailed in this Standard.

The primary fire hazards associated with facilities are typically the equipment that is stored, people and the activity taking place inside the facility. Other aspects to consider include

- Maintenance shops and workshops - high value of tools, hot work activities and possible combustible materials that constitute a fire exposure to other buildings.
- Warehouses - containing high-value equipment and combustible materials that are critical to power generation or business continuity or that constitute a fire exposure to other important buildings.
- Document rooms or archives – if the facility contains vital records (where original copies must be available) then additional type of passive or active fire protection measures can be considered.

5.1.2 Fire Protection System Measures

Once the occupancy classification of the applicable facility is determined all the requirements for fire protection (passive, active and manual), fire detection and ventilation are provided in SANS 10400-T [61]. If active fire protection is required it is recommended that closed head, wet pipe sprinkler systems be installed. Any sprinkler system provided shall be designed in accordance with SANS 10287 [59] or NFPA 13 [68].

Firstly, passive fire protection measures shall be considered for document rooms or archives where vital records are kept. This includes fire rated rooms, record vaults as well as fireproof or fire-resistant filing cabinets. Only if this is not feasible can room flooding, or in-cabinet gaseous or aerosol fire protection systems be considered. These systems must be designed in accordance with SANS 14520 [64], NFPA 12 [67], NFPA 2001 [95], SANS 15779 [65], NFPA 2010 [96].

A generic technical specification [29] for fire protection and fire detection system for general buildings and structures have been developed for guidance to Eskom Real Estate to use.

5.2 ELECTRONIC EQUIPMENT INSTALLATIONS

5.2.1 General

These facilities must have an occupancy classification in accordance with SANS 10400-A [60], and the occupancy classification will assist in identifying all the fire system design requirements for a particular facility in accordance with SANS 10400-T [61]. Control Rooms, Computer Rooms, Communication Rooms, Server Rooms, Equipment Rooms, Data Centres, and any other electronic equipment installations shall be assessed for fire system requirements in accordance with SANS 246 [42]. The information captured in the Eskom document "ERE IT Server Room FPDA Report" [41] can be used for guidance for IT server rooms.

Typically, where possible, these rooms should be separated from high-risk areas, either through distance, or fire-resistant separations.

These electronic equipment installations are typically the hub of a power plant / facility where the process is controlled and operated, whilst also monitoring environmental conditions critical to the safety of operatives. Server Rooms, although not critical for plant process control, are critical for providing IT services which ensure continued business productivity. The fire protection measures incorporated to protect operatives and to safeguard business productivity and continuity throughout these areas should reflect their overall importance.

Consideration should be made to the on-going use of equipment and the ability for a power station or facility to continue to operate should critical systems be lost due to fire. Each area and item of equipment should be evaluated within these rooms (i.e. within the rooms, beneath raised floors where critical systems and cabling is contained, critical items of equipment, critical power distribution and control boards) with an appropriate form of protection provided.

The primary fire hazards associated with electronic equipment installations are typically large numbers of electrical cables with combustible insulation and direct exposure to the room from any other hazardous processes outside the room.

A major contributing factor in the potential loss resulting from a fire in electronic equipment installations are the combustibility of construction, interior finish materials or paper records stored in the rooms. The importance of eliminating all unnecessary fire risks from this type of facility cannot be overstated when considering the essential functions controlled by these rooms.

Generally, electronic equipment installations are provided with redundancy. Consideration should be given to physical separation of such redundant equipment so that in the event of a fire both the main and redundant equipment is not affected in the same event.

5.2.2 Fire Protection System Measures

Fire protections system measures shall be determined by assessing the applicable room in accordance with SANS 246 [42]. There are several suppression options available for these rooms, each coming with different hazards and associated risks, are it business continuity, potential property damage, or life safety. The requirements of NFPA 850 [93] can also be considered.

If the assessment shows that active fire protection is required Eskom recommends the use of full flooding / localised Clean Agent or Aerosol type fixed extinguishing systems in equipment rooms designed in accordance with -

- Water mist fire protection systems designed to NFPA 750 [91].
- Gaseous fire protection systems designed to SANS 14520 [64], NFPA 12 [67], NFPA 2001 [95].
- Aerosol fire protection systems designed to SANS 15779 [65], NFPA 2010 [96].

Full flooding gaseous fire protection systems are not recommended for power station control rooms that are manned 24/7/365.

Manual fire protection is provided as per the requirements of SANS 10400-T [61]. CO_2 type extinguishers are recommended for electronic equipment installations.

Passive fire protection – fire areas shall be separated from all adjacent areas via a minimum of two (2) hours fire resistant construction which includes walls, doors, and floors. Fire proofing shall be provided for openings and cables.

Fire detection is generally required in electronic equipment installations (this includes floor and ceiling voids). This will depend on the assessment of the specific area in question. The fire detection systems shall be design in accordance with the Eskom Fire Detection System Standard [7].

Generally, temperature control for electronic equipment installation is critical and HVAC plays a critical role. Smoke ventilation must be considered as part of the design for any electronic equipment installation. The HVAC system for a control room shall be separate and distinct from other HVAC systems to prevent possible spread of heat and smoke into the control room form adjacent areas. Control rooms should be pressurised, and consideration should be made to providing the control room with a means for smoke ventilation from the area.

5.3 CABLE CONCENTRATIONS, CABLE SPREADING ROOMS AND CABLE TUNNELS

5.3.1 General

Given the large volume of cables typically located within cable spreading rooms and cable tunnels, the impact of a fire within these areas, with the potential to impact upon numerous other areas and items of equipment, protection from fire for these areas should not be overlooked. The down time and interruption to power station and other facilities could be significant, with long delays expected where re-cabling is required. Where practicable, cable trays shall be routed away from fire exposure or hazards. Where it is not practical to re-route the cable routes they should be protected from exposure to fire and heat.

Where cable trays are subject to oil spills, the trays shall be designed to either prevent the spread of oil spill fires, or prevent the accumulation of oil across the trays (i.e. provision of covers to the cable trays, with a means for catching and storing any oil spill below the tray). Should a drip / tray store be provided below the cable tray, consideration should be made as part of the maintenance regime to cleaning these areas on a regular basis.

The extent of the cable hazard is dependent to a large degree upon the combustibility of the cable insulation. Insulation for control and signal cables commonly consists of rubber or plastic based materials which greatly affect not only their ease of ignition and combustibility, but also the amount of smoke generated during combustion.

In addition to the effects of various types of insulation, a major consideration in the fire hazard of the grouped electrical cables is that of configuration and routing of cables. The configuration of cables greatly affects the flame spread rate of a cable fire. For example, cable trays are frequently installed in tiers on top of each other, substantially increasing the fire loading of an area. Also, the stacking of cable trays exposes a large number of cables to a single fire loss. The flame spread and ease of ignition of cables in cable trays is dependent on the number of cables and their configuration within the tray. The more random the configuration of cables, the greater the expected flame spread would be in the event of a fire.

Vertical cable shafts create one of the largest fire problems associated with grouped electrical cables. Cable runs in vertical cable shafts create large fire loadings within a small area and the enclosed vertical shaft creates a "chimney" which greatly increases flame and smoke spread. Cable tunnels provide hazards like other areas of grouped cables. However, the confined areas and limited access impede fire brigade efforts and introduce a life safety hazard to plant operating personnel. Cable spreading areas present an inordinately large number of cables in a single area, thereby exposing cables for a variety of control equipment to a single loss.

5.3.1.1 Cable Tunnels – Cable Requirements

Given the remote nature of cable tunnels and the difficulties posed when attempting to access and conduct fire-fighting operations within these areas, careful consideration should be made to the choice of cable used within the tunnels.

In the first instance the use of wiring systems designed to maintain circuit integrity under fire conditions should be designed (i.e. non-halogenated cables). This limits the impact upon the cables from heat exposure, designs resilience into the system to assist with business continuity and limits the amount of residue and products emitted should the cables be exposed to excessive heat. This will help assist with any fire fighter operations in that access to the area will not be via smoke logged areas.

Should the use of non-halogenated cables not be possible additional protection measures should be provided. Where possible, and cost effective, both non-halogenated cables and suppression should be provided to these areas.

5.3.2 Fire Protection System Measures

The most appropriate fixed protection system installed within this area should take into consideration the hazards and associated risks during the Fire Protection/Detection Assessment process and document any decisions made in detail for future reference. Typically cable concentrations, rooms or tunnels are unoccupied spaces, with minimal access required for maintenance and repair. Given the infrequent access requirements within these areas any fixed fire protection system provided should be for asset protection only and should not be over designed as a life safety system.

Typically, at large Eskom power stations cable concentrations (cable racks) are protected with passive fire protection and large cable concentrations, room and tunnels are protected with wet pipe sprinkler systems (sprinkler systems should be designed for a minimum density of 12.2mm/min over 232m^2, or the most remote 30m of cable tunnel up to an area of 232m^2). This would be the preferred option of fixed fire protection for these types of areas that can be designed in accordance with SANS 10287 [59] or NFPA 13 [68]. The requirements of NFPA 850 [93] applies. Drainage requirements must be considered if wet fire protection is supplied.

Note the position paper [33] that has been drafted for coal fired power station auxiliary bay cable spreading rooms.

Gaseous type fire protection can also be considered for cable concentrations in enclose areas such as floor or ceiling voids.

Manual fire protection is provided as per the requirements of SANS 10400-T [61]. CO_2 type extinguishers are recommended for cable areas.

Passive fire protection – fire areas shall be separated from all adjacent areas via a minimum of two (2) hours fire resistant construction which includes walls, doors, and floors. Fire proofing shall be provided for openings and cables.

Fire detection is generally required for cable areas as it give early warning of a possible fire (this includes floor and ceiling voids). This will depend on the assessment of the specific area in question. The fire detection systems shall be design in accordance with the Eskom Fire Detection System Standard [7].

Consideration should be made to providing the Cable Spreading Room and Cable Tunnels with a means for venting smoke from the area. The aim of a smoke ventilation system is typically to provide conditions that are safe for occupants to evacuate from. Given the cable tunnels and cable spreading rooms are typically unoccupied any smoke ventilation system will be purely for clearing the affected area of smoke, and not one for maintaining tenable conditions for operatives. It may be possible to combine the smoke extract system with the day-to-day ventilation system provided within this area. Careful consideration to the rating of the extract fan should be made in this instance as a fan typically chosen for day-to-day ventilation will not be able to operate under fire conditions given the increased smoke temperatures to be extracted. The design of the system, and the competency of any staff member with design responsibility, should be carefully considered.

Eskom Heating Ventilation and Air Conditioning (HVAC) Design Guideline [24] and SANS 10400 Part T [61] provide guidance on the design of mechanically assisted or natural smoke and heat ventilation systems.

Care should be taken when designing any system to ensure discharge points do not affect walkways or escape routes in other areas.

5.4 SWITCHGEAR ROOMS

5.4.1 General

Switchgear rooms must have an occupancy classification in accordance with SANS 10400-A [60], and the occupancy classification will assist in identifying related fire system design requirements for a switchgear room in accordance with SANS 10400-T [61].

Electrical distribution equipment such as switchgear can present a moderate fire hazard, depending on their size, construction, and location. The source of combustibles for switchgear type equipment consists of insulation for wires and cable, plastic components, and possible oil for insulation and cooling. Fire may develop rapidly, even explosively. Because of the high voltages involved, fighting such a fire involves risk to untrained personnel.

Switchgear equipment shall use air or gas insulation as far as practically possible. Oil insulation should not be allowed. Typically oil filled circuit breakers should be located where practicable outdoors and shall be separated from adjacent areas via applicable safety distances. Where it is not possible to provide this level of separation by distance, fire rated construction shall be provided to physically separate areas. No oil piping or equipment shall be permitted in this room.

Switchgear equipment may provide ignition sources in the form of electrical arcing, overheating, and catastrophic fault failures. The primary fire hazards associated with these rooms are typically large numbers of electrical cables with combustible insulation and direct exposure to the room from any other hazardous processes outside the room.

5.4.2 Fire Protection System Measures

In general switchgear rooms in large power stations does not require fixed fire protection based on the risk and criticality definition of the plant. Should a switchgear room be identified as critical to the continuous operation of a power station or facility the installation of a gaseous suppression system could be considered. During the Fire Protection/Detection Assessment process the most appropriate form of gaseous suppression, taking into consideration the geometry and construction of the room should be taken into consideration.

Where gas suppression systems are installed, drains and appropriate dampers shall be provided with adequate seals, or the gas suppression system shall be sized to compensate for the loss of suppression agent through the drains.

Manual fire protection is provided as per the requirements of SANS 10400-T [61].

Passive fire protection – switchgear rooms shall be separated from all adjacent areas via a minimum of two (2) hours fire resistant construction which includes walls, doors, and floors. Fire proofing shall be provided for openings and cables.

Fire detection is generally required for switchgear rooms as it give early warning of a possible fire. This will depend on the assessment of the specific area in question. The fire detection systems shall be design in accordance with the Eskom Fire Detection System Standard [5].

Consideration should be made to providing switchgear rooms with a means for venting smoke from the area.

5.5 BATTERY ROOMS

5.5.1 General

Battery rooms must have an occupancy classification in accordance with SANS 10400-A [60], and the occupancy classification will assist in identifying related fire system design requirements for a switchgear room in accordance with SANS 10400-T [61].

Battery equipment provides normal DC power as well as backup power in the event of loss of normal AC power. Ordinarily, no automatic fire extinguishing systems are required for the protection of a battery room. Primary reliance is placed on fire prevention of battery room fires and explosions through adequate ventilation.

All batter rooms shall follow the requirement of the Eskom Battery Room Standard [26]. The Eskom Hazardous Location Standard [21] shall be applied for all battery rooms.

The principal hazard found here is the generation of combustible hydrogen gas which is explosive between the limits of 4 percent to 75 percent by volume in air. The amount of gas generated is dependent primarily on the rate of charging of the batteries. To determine the impact of a fire loss in the battery room, it is necessary to consider the importance of the battery power to continued plant operations. In addition, since these batteries frequently provide control voltages for motor control centres or motor-operated isolation valves, the effect of the loss of control of this equipment must also be evaluated.

5.5.2 Fire Protection System Measures

Should a battery room be identified as critical to the continuous operation of a power station or facility the installation of a gaseous suppression system could be considered. During the Fire Protection/Detection Assessment process the most appropriate form of gaseous suppression, taking into consideration the geometry and construction of the room should be taken into consideration.

Where gas suppression systems are installed, drains and appropriate dampers shall be provided with adequate seals, or the gas suppression system shall be sized to compensate for the loss of suppression agent through the drains.

Manual fire protection is provided as per the requirements of SANS 10400-T [61].

Passive fire protection – battery rooms shall be separated from all adjacent areas via a minimum of two (2) hours fire resistant construction which includes walls, doors, and floors. Fire proofing shall be provided for openings and cables.

Fire detection requirements are determined through the assessments of the Eskom Battery Room Standard [26] and the Eskom Hazardous Location Standard [21]. The fire detection systems shall be design in accordance with the Eskom Fire Detection System Standard [5].

Battery rooms should be provided with ventilation to ensure the hydrogen content within the battery room is limited to a concentration of 0.8% percent by volume. The Eskom Battery Room Standard [26] and the Eskom Hazardous Location Standard [21] provides guidance on the sizing of the ventilation system.

Hydrogen gas that is mechanically exhausted from battery rooms shall be discharged to a safe location and preferably, directly to the outside of the power station building. The installation of fire dampers in any ventilation exhaust duct from a battery room is not recommended. Any exhaust duct, which leads through a fire barrier or fire-resistant separation, shall be protected throughout its length by a material having a fire resistance rating equal to the barriers penetrated. Exhaust air fans shall be interlocked with a battery charger(s) to prevent equalize charging of batteries when the exhaust fans are not operating.

5.6 SUBSTATIONS AND SWITCHYARDS

5.6.1 General

The requirements stated here apply to all Eskom's substations and switchyards (which includes assets of generation, transmission, or distribution). Where Eskom substations and switchyards consist of facilities, control rooms, equipment rooms, document archives, cable rooms / cable concentrations, switchgear rooms, battery rooms, transformers, diesel generators or oil storage areas the specific requirements as specified in this document must be followed (see Section 5). This standard looks at these rooms / equipment as stand-alone as they can exist outside of substations and switchyards.

Substations and switchyards are normally located in an area remote from electrical generating stations and are generally unmanned. Water for firefighting may or may not be available.

The physical layout of the substation and switchyard has a large effect on the consequences of a fire. Busbars and cables located in a fire plume are subject to cross phase arcing and ground faults. Flaming oil from a failed transformer can involve other equipment if no bunding, drainage, curbs or ditches have been provided to prevent it. Because these areas are often unmanned, an otherwise small, easily controlled fire can cause much damage. Lack of firefighting water at required pressures and quantities can limit the effectiveness of automatic fire fighting systems, where provided.

Often these areas have oil and/or general storage areas associated with them. These areas, depending on their contents, can provide additional sources of combustibles and ignition sources.

5.6.2 Fire Protection System Measures

Substations and buildings associated with switchyards must have an occupancy classification in accordance with SANS 10400-A [60], and the occupancy classification will assist in identifying related fire system design requirements for the area in accordance with SANS 10400-T [61].

Generally, the Eskom Distribution Standard for Substations [30] will apply. Manual fire protection is provided as per the requirements of SANS 10400-T [61].

Passive fire protection – substations and associated buildings shall be separated from all adjacent areas via a minimum of two (2) hours fire resistant construction which includes walls, doors, and floors. Fire proofing shall be provided for openings and cables.

Transformers associated with substations and switchyards are generally protected via passive fire protection measures due to the unavailability of fire water systems and the remoteness of the sites.

Fire detection is generally not required for substations and associated buildings. This will depend on the assessment of the specific area in question. The fire detection systems shall be design in accordance with the Eskom Fire Detection System Standard [5].

Special consideration shall be given to vegetation control in and around substations, associated buildings and the switchyard. Veld fires poses a significant threat that can be easily controlled if vegetation control is maintained appropriately through the life of the assets.

The Eskom standard - Standard for Passive Fire Protection in Distribution Substation Yards [30] - sets out the passive fire protection methods to be used in HV and MV yards in all Distribution Substations.

5.7 TRANSFORMERS

5.7.1 General

Electrical distribution equipment such as transformers can present a moderate fire hazard, depending on their size, construction, and location. The rating of a transformer is a major parameter in determining the magnitude of the hazard. The higher the energy input to the transformer, the greater the potential for a large fire. Most large transformers use mineral oil as a dielectric fluid which, of course, presents a substantial fire hazard. Fires in oil-insulated transformers result principally from a breakdown of insulation caused by overload, switching or lightning surges, gradual deterioration, low oil level, moisture or acid in the oil, or failure of an insulating bushing. A considerable quantity of oil may be expelled during these incidents which can be followed by an intense fire. Associated with the distribution of electricity are circuit breakers used to provide overcurrent protection for transformers and used as disconnects for normal operations. Once again, fire hazards of circuit breakers are dependent on the voltage and amperage ratings of the circuit breakers and the dielectric insulation used. Oil filled circuit breakers, using the same type of mineral oil commonly found in oil-filled transformers, are frequently used with large outdoor transformers. The hazards of the insulating media are similar to those outlined for transformers. Therefore, the location of this equipment is of prime consideration.

The requirements of NPFA 850 [93] and NFPA 15 [69] shall apply for all oil filled transformers.

All oil filled equipment shall be located outdoors, if possible. Any new transformers located indoors (or other equipment located indoors) should firstly be considered to be of the dry-type, and not be oil filled to minimise the risk.

The most appropriate fire system installed within this area should take into consideration all the hazards and associated risks during the FPDA process [3] for the specific project and document any decisions made in detail for future reference. This section aims to address the most appropriate systems and technologies to use within each specific area of the Eskom asset. The proposed systems are combinations of codes, standards, industry best practice and experience. The table below serves as a quick reference guide for transformers and oil-filled circuit breakers.

Table 2: Transformer Fire Protection Systems Measures

Hazard or Risk Area	Passive Fire Protection	Active Fire Protection	Manual Fire Protection	Fire Detection	Smoke Ventilation	Comments
Indoor oil-filled transformers	x	x	x	x	x	This also includes oil-filled circuit breakers.
Outdoor oil-filled transformers	x	x	x			This also includes oil-filled circuit breakers.
Dry-type transformers	x		x			

5.7.2 Fire Protection System Measures

5.7.2.1 Passive Fire Protection

Ensure equipment arrangement is such that there will be a minimal impact on equipment redundancy in a fire event. Generally, to determine the type and physical separation between transformers and any other adjacent areas, buildings, and equipment should take into consideration the following aspects as stated in NFPA 850 [93]:

1. Type and quantity of oil in the transformer
2. Size of a postulated oil spill (surface area and depth)
3. Type of construction of adjacent structures
4. Type and amount of exposed equipment, including high line structures, motor control centre (MCC) equipment, breakers, other transformers, and so forth.
5. Power rating of the transformer
6. Fire suppression systems provided
7. Type of electrical protective relaying provided
8. Availability of replacement transformers (long lead times)
9. The existence of fast depressurization systems

The outcome of the above considerations will form part of the FPDA process [3] for the specific project and documented in detail for future reference.

Passive fire protection measures shall be applied to outdoor oil filled transformers in the following order (as per NFPA 850 [93]):

1. Provide adequate spatial separation distance without a fire wall. As a minimum the separating distance (measured from the edge of the bund to the adjacent equipment / structures) to be afforded between transformers and adjacent structures where separating fire walls are not provided should be:
   a. Oil Storage of less than 1890 litres per transformer - A separating distance of 1.5m shall be maintained between the transformer and any adjacent structure or item of equipment.
   b. Oil storage >1890 litres and <18925 litres per transformer – A separating distance of 7.6m shall be maintained between the transformer and any adjacent structure or item of equipment.
   c. Oil storage >18925 litres per transformer – A separating distance of 15m shall be maintained between the transformer and any adjacent structure or item of equipment.
2. Provide fire barriers between the transformer and any adjacent area where the separation distances cannot be met. Typically, this separation should be constructed to provide a minimum of two (2) hours fire resistant separation. All openings shall maintain the fire area integrity by having a two-hour fire resistance.

Where oil-filled transformers must be located indoors, they shall be separated by an enclosure of three (3) hours fire resistance with a 150 mm high curb on all doorways.

Weeds, brush, and long grass shall be eliminated within 8m of transformers. Care shall be exercised in locating transformers to prevent exposure to unprotected windows or mechanical vents on adjacent building walls.

All cable and piping penetrations into the transformer fire area from adjacent areas shall be sealed to prevent fire exposure through these openings. These seals shall maintain the fire resistance rating of the wall.

Where outdoor oil filled transformers are provided adequate drainage (see requirement stated in NFPA 850 [93]) is required to drain any oil spill away from any adjacent building, transformer, or other items of equipment. Consideration should be made to the impact of a fixed suppression system activating (including manual firefighting) and potentially flooding equipment and spreading burning liquids to adjacent areas.

5.7.2.2 Active Fire Protection

In general, water spray systems are not required on transformers unless any of the following conditions apply:

1. Fire barrier walls or spatial separation cannot be provided, and the transformer poses an exposure risk to any other adjacent areas, buildings, and equipment etc.
2. The transformer is a main generator transformer, station transformer, auxiliary transformer located adjacent to a building.
3. The transformer is in an area with an existing adequate water supply system and is of strategic importance or located next to equipment or structures of strategic importance.

Eskom recommends the use of high velocity water spray deluge systems on transformers and the bund area around a transformer activated automatically via the pneumatic/hydraulic pilot line that forms part of the valve trim.

Any water spray deluge system provided shall be designed in accordance with NFPA 15 [69]. The water spray deluge system should be designed for a minimum density of 10.2 (L/min)/m^2 on the projected area of the transformer and its appurtenances, and not less than 6.1 (L/min)/m^2 on the expected non-absorbing ground surface area of exposure.

5.7.2.3 Additional Measures

Manual fire protection - Portable fire extinguishers and hose reels (if fire water is available) are supplied for indoor transformers or other oil filled equipment in and around the building that it is located in. The number of firefighting equipment shall be spaced in accordance with the requirements of SANS 10400-T [61]. Fire hydrants must be provided (if fire water is available) based on the location of the transformers and fire hydrants shall be located so that access to the hydrants will not be impeded by a fire on the transformers.

Fire detection is generally not required for outdoor areas. Where oil filled equipment is located indoors it is recommended that fire detection be part of the fire system solution for the early warning of any fire event in the room / area. The fire detection systems shall be designed in accordance with the Eskom Fire Detection System Standard [5].

Smoke ventilation is required for indoor oil filled transformers or any other indoor oil filled equipment.

5.8 PUMPS, GENERATORS AND COMPRESSORS

5.8.1 General

In general pumping systems, generators and compressed air systems shall be designed in accordance with the applicable process requirements. Fire water system pumps is specified and designed in accordance with SANS 10287 [59], or NFPA 20 [71], diesel generators in accordance with the Eskom Standard for Stationary Diesel Generator Systems [27] and compressors in accordance with the Eskom Standard for Compressed Air Systems [28].

Generally electrical motor driven pumps, generators and compressors present less of a hazard than petrol / diesel engine driven pumps, generators, and compressors. This section also applies to blowers and blower houses.

The petrol / diesel engine driver of the pump, generator or compressor presents hazards associated with the fuel supply and ignition sources such as the hot exhaust manifold. The location of the pump, generator or compressor can pose a substantial exposure risk to other plant operations / areas. For example, the location of a diesel fuel tank for an emergency generator located beneath an elevated conveyor poses a serious exposure hazard to the conveyor system. These aspects should be considered very carefully during the FPDA process [3].

All fire protection and life safety systems should take into consideration the recommendations as stated in NFPA 850 [93]. Day and bulk fuel tanks will comply with the requirements of SANS 10131 [55].

The fire and life safety design objectives for pumps, generators and compressors consist of the following:

1. Eliminate fire and explosion hazards to as great an extent as is practical.
2. Where the hazard cannot be removed, minimize the damage resulting from a fire.
3. In all cases, ensure that a single pump, generator or compressors will not damage any other pump, generator, compressor, structure, or other important equipment in the event of a fire.

The most appropriate fire system installed within this area should take into consideration all the hazards and associated risks during the FPDA process [3] for the specific project and document any decisions made in detail for future reference. This section aims to address the most appropriate systems and technologies to use within each specific area of the Eskom asset. The proposed systems are combinations of codes, standards, industry best practice and experience. The table below serves as a quick reference guide for fire system requirements for pumps, generators and compressors.

Table 3: Pumps, Generators and Compressors Fire Protection System Measures

Hazard or Risk Area	Passive Fire Protection	Active Fire Protection	Manual Fire Protection	Fire Detection	Smoke Ventilation	Comments
Electrical motor driven pump, generator, compressor	x		x	x[2]	x[3]	This also includes blowers.
Petrol/Diesel engine driven pump, generator, compressor	x	x[1]	x	x[2]	x[3]	This also includes blowers.
Petrol/Diesel fuel tank (day tank) for pump, generator, compressor	x	x	x	x[2]	x[3]	
Petrol/Diesel fuel tank (bulk tank) for pump, generator, compressor	x	x	x			Should be located outside.

[1] Active protection required for the whole room (if petrol/ diesel engine driven pump, generator, compressor is in a room), or targeted on the petrol/diesel engine driven equipment if located among other equipment.
[2] Only required if located in a room where fire detection is practical.
[3] Only required if located in a room where smoke ventilation is possible.

5.8.2 Fire Protection System Measures

5.8.2.1 Passive Fire Protection

Pumps, generators and compressors shall be well separated from other plant exposures. Electrical motor driven pumps, generators and compressors, when located adjacent to one another, shall be physically separated by means of adequate spatial separation or by means of a fire resistive barrier to ensure that failure of one pump, generator or compressor will not cause failure of the adjacent pump, generator or compressor.

Petrol / diesel engine driven pumps, generators and compressors shall be separated from one another and from the electric motor driven pumps, generators and compressors by a fire resistive barrier to reduce the exposure hazard. Care shall be exercised in the location of the fuel supply tank(s) to prevent fuel leakage from exposing the remaining equipment. Consideration shall be given to the slope of the ground surrounding fuel tanks to prevent fuel leakage from spreading to and exposing other equipment and buildings in the area.

Fuel supply day tanks shall be located outside of the building as far as practically possible. If not located outside, fuel supply day tanks shall be separated from the engine driven pump, generator and compressor. If the day tank is designed as part of the engine, active fire protection over the engine will also provide protection over the day tank.

Where pumps, generators and compressors are located in a room the layout shall be such that each engine driven pump, generator and compressor is located in its own compartment separated from each other and other plant areas. If located in a room / house the pumps/generators/compressors shall be completely separated from all other plant areas by division walls rated for a minimum of two-hour fire resistance. All openings shall maintain the fire area integrity by having a two (2) hour fire resistance. Fire areas shall be separated from each other by approved fire barriers or construction to minimize the risk of fire spread and the resultant consequential damage from fire gases, smoke, heat and fire-fighting activities.

Consideration should be made to the impact of a fixed suppression system activating and potentially flooding equipment and spreading burning liquids to adjacent areas. Drainage should typically be provided where this is a problem.

All cable and piping penetrations into the room from adjacent areas shall be sealed to prevent fire exposure through these openings. These seals shall maintain the fire resistance rating of the room.

The position and location of any standby emergency generator should be carefully considered during the FPDA process [3] to ensure any 'back up supply' provided is not affected by a fire that would interrupt the normal supply to the plant. Generators should typically be located such that they are adequately separated from each other as well as adjacent areas, either through distance, or fire-resistant separation. Any fire-resistant construction or barrier provided should be designed to provide separation for a minimum of two (2) hours.

Unenclosed emergency diesel generators shall maintain a minimum spatial separation of 15 m from important buildings, equipment, and other generators. Where adequate separation is impractical, masonry barrier walls should be designed to provide separation for a minimum of two (2) hours.

Brush and long grass shall be kept a minimum of 8 m away from outdoor pumps, generators, compressors, and fuel supplies.

5.8.2.2 Active Fire Protection

The most appropriate fixed protection system installed within this area should take into consideration the hazards and associated risks during the Fire Protection/Detection Assessment process and document any decisions made in detail for future reference. Typically pump, generator and compressor areas / rooms are unoccupied spaces, with minimal access required for maintenance and repair. Given the infrequent access requirements within these areas any suppression system provided should be for asset protection only and should not be over designed as a life safety system.

In general, active fire protection is not required on pumps, generators and compressors unless any of the following conditions apply:

1. Fire barrier walls or spatial separation cannot be provided, and the pump, generator, compressor, or fuel tanks pose an exposure risk to any other adjacent areas, buildings, and equipment etc.
2. The pump, generator and compressor are petrol / diesel engine driven.
3. The petrol / diesel driven pump, generator and compressor are located indoors.
4. The petrol / diesel driven pump, generator and compressor is in an area with an existing adequate water supply system and is of strategic importance or located next to equipment or structures of strategic importance.

Eskom recommends the use of either a sprinkler system or a high velocity water spray deluge systems on engine driven pumps and compressors (room that it is in), including day and bulk fuel tanks feeding the pumps and compressors. Active fire protection systems shall be designed to protect all areas where fuel or oil might spray, flow, or collect.

- Automatic Sprinkler (suitable for indoor only) system shall be designed in accordance with NFPA 13 [68]. Automatic sprinkler systems shall be designed to provide a density of 10.2 (L/min)/m^2.
- Automatic Water Deluge system (suitable for indoor and outdoor) in accordance with NFPA 15 [69]. Automatic water deluge systems shall be designed to provide a density of 10.2 (L/min)/m^2.

Eskom recommends the use of either a sprinkler system or a high velocity water spray deluge systems on diesel generators, including day and bulk fuel tanks feeding the diesel generators. Active fire protection systems shall be designed to protect all areas where fuel or oil might spray, flow, or collect.

- Automatic Sprinkler (suitable for indoor only) system shall be designed in accordance with NFPA 13 [68]. Automatic sprinkler systems shall be designed to provide a density of 12.2 (L/min)/m^2 over the most remote 230 m^2 in accordance with NFPA 37 [74].
- Automatic Water Deluge system (suitable for indoor and outdoor) in accordance with NFPA 15 [69]. Automatic water deluge systems shall be designed to provide a density of 12.2 (L/min)/m^2.

Where diesel storage in day tanks is in the same fire areas as the fire pumps, they shall be provided with an automatic active fire protection system as detailed above. In addition, the tanks shall comply with SANS 10131-1 [55].

It must be noted that there are diesel generators in Eskom that are protected by water mist and gaseous active fire protection systems. This is acceptable if systems are designed, installed and maintained in accordance with applicable standards for those type of fire protection systems.

5.8.2.3 Manual Fire Protection

Where pumps, generators and compressors are in a room (or pump house / compressor house / blower house) portable fire extinguishers and hose reels are typically required inside or outside the room dependant on the size of the room and the high-risk areas.

Exterior hydrants shall be located near the outdoor and/or indoor pumps, generator sets and compressors to facilitate manual firefighting efforts of the fire brigade. Hydrants shall be separated by a maximum of 60 m surrounding the area.

5.8.2.4 Fire Detection

Fire detection is generally required in all rooms / houses where pumps, generators and compressors are located. When equipment is in a large open area or outside, fire detection is not practical. The fire detection systems shall be design in accordance with the Eskom Fire Detection System Standard [5].

5.8.2.5 Smoke Ventilation

Smoke ventilation could be considered where this type of equipment is located indoors.

5.9 STORAGE AND HANDLING OF COMBUSTIBLE / FLAMMABLE LIQUIDS

5.9.1 General

Storage of major supplies of "high" flash point liquids presents only a minimal fire hazard when appropriate consideration is given to spatial separation from exposures. When careful thought is given to the location of potential sources of ignition, steps can easily be taken to minimize the risk of a severe fire. Paints, solvents, and other similar chemicals normally used in connection with maintenance operations pose a greater hazard due to the lower flash points of these materials. However, because they are normally used in relatively small quantities, the prime considerations are proper handling and storage. Due to the generally low flash point, there are many possible sources of ignition including heat producing devices, exposure to dry grass and brush, and faulty electrical equipment.

The fuel oil system at coal fired power stations used during light-up of the boiler creates fire hazards typical of storage and handling of combustible liquids. These hazards include those of tank storage, pumping stations, piping, and boiler fronts. One of the main fire problems of tank storage of fuel oil is fire exposure. A large spill, if ignited in a tank farm, can burn with intense heat. Such a fire could damage adjacent buildings and equipment if not adequately separated.

Fires in tank storage areas are normally the result of leaks in piping, pumps, or tanks. Another major cause of spills is overfilling of tanks. These oil spills, if ignited, expose piping, pumps, and/or tanks, causing further damage and leakage of fuel. Additionally, inadequate tank venting can lead to a major violent tank failure during fire exposure. In areas prone to frequent severe thunderstorms, lightning strikes on tanks also can result in a tank failure and subsequent fire.

Where fuels require heating, fuel heaters shall be equipped with automatic high-temperature sensors to shut off the heat source should the operating thermostat fail.

The requirements stated in this section shall apply to all systems that involve the off-loading, storage, piping, heating, and pumping of any combustible or flammable liquid. Typical Eskom related systems include,

- Oil stores (where drums of lubrication / control oil are housed for daily usage)
- Dirty and clean oil storage and handling
- Lubrication oil storage and handling
- Hydraulic control oil storage and handling
- Fuel oil storage and handling
- Diesel storage and handling
- Etc.

Combustible and flammable liquid off-loading, storage, pumping facilities and associated piping shall comply with SANS 10089 [52] and SANS 10131 [55].

The recommendations of NFPA 30 [72] and NFPA 31 [73] shall also be taken into consideration as - should the recommendations of FM Data Sheet 7-83 [105] and 7-88 [106] be taken into consideration.

NFPA 850 [93] gives recommendations for the fire system requirements for hydraulic control oil systems. Generally, if a fire-resistant fluid is not used for hydraulic control oil systems, then fixed fire protection should be considered for hydraulic equipment, tanks, coolers and associated oil-filled equipment.

All areas where combustible and flammable vapours can be expected shall be evaluated in terms of the Eskom Hazardous Location Standard [21].

The most appropriate fire system installed within these areas should take into consideration all the hazards and associated risks during the FPDA process [3] for the specific project and document any decisions made in detail for future reference. This section aims to address the most appropriate systems and technologies to use within each specific area of the Eskom asset. As part of the FPDA process [3] the following measures should also be considered as part of the design:

- Location of any emergency shut off valves.
- Any buried pipes should be at a depth where any future works will not damage or restrict the flow of fuel oil.

- Measures to identify the location of buried pipes at grade level.
- Any concealed pipes to be sleeved.

The proposed systems are combinations of codes, standards, industry best practice and experience. The table below serves as a quick reference guide for fire system requirements for the storage and handling equipment of combustible/flammable liquids.

Table 4: Combustible/Flammable Liquid Equipment Fire Protection System Measures

Hazard or Risk Area	Passive Fire Protection	Active Fire Protection	Manual Fire Protection	Fire Detection	Smoke Ventilation	Comments
Storerooms	x	x	x	x	x[2]	Drum loads stored in a room.
Storage Tanks (day and bulk)	x	x	x	x[1]	x[2]	Includes hydraulic control and lub oil.
Pumping Facility	x	x	x	x[1]	x[2]	Includes hydraulic control and lub oil.
Heating Facilities	x	x	x	x[1]	x[2]	Includes hydraulic control and lub oil.
Piping	x		x			Includes hydraulic control and lub oil.
Off-loading Facilities	x		x			

[1] Only required if located in a room where fire detection is practical. Fire detection could also be utilised to automatically activate foam systems in bulk tank bund areas, where mechanical detection would not be effective.
[2] Only required if located in a room where smoke ventilation is possible. Ventilation of combustible/flammable vapours must also be taken into consideration.

5.9.2 Fire Protection System Measures

5.9.2.1 Passive Fire Protection

Fire areas shall be separated from each other by approved fire barriers or construction to minimize the risk of fire spread and the resultant consequential damage from fire gases, smoke, heat and fire-fighting activities. All indoor combustible or flammable liquid pumping or heating facilities shall be separated from adjacent areas via a minimum of 2 hours fire resistance.

Care shall be exercised in the location of the fuel supply tank(s) to prevent fuel leakage from exposing the remaining equipment. Consideration shall be given to the slope of the ground surrounding fuel tanks to prevent fuel leakage from spreading to and exposing other equipment and buildings in the area.

All passive fire protection measures such as bunding, curbing, drainage, safety distances etc. shall comply with the minimum requirements as set out in SANS 10089 [52].

Consideration should be made to the impact of a fixed suppression system activating and potentially flooding equipment and spreading burning liquids to adjacent areas. Drainage should typically be provided where this is a problem.

Brush and long grass shall be kept a minimum of 8 m away from outdoor storage and handling equipment of combustible/flammable liquids.

5.9.2.2 Active Fire Protection

The most appropriate fixed protection system installed within this area should take into consideration the hazards and associated risks during the Fire Protection/Detection Assessment process and document any decisions made in detail for future reference.

Eskom recommends the use of either a sprinkler system or a high velocity water spray deluge systems for indoor facilities containing combustible/flammable liquids. This would include storage located indoors, pumping and heating facilities. Active fire protection systems shall be designed to protect all areas where the fuel or oil might spray, flow, or collect.

- Automatic Sprinkler system shall be designed in accordance with NFPA 13 [68]. Application density shall be determined using NFPA 30 [72].
- Automatic Water Deluge system in accordance with NFPA 15 [69]. Application density shall be determined using NFPA 30 [71].

Eskom recommends the use of foam systems for the protection of bulk storage tanks located in bunded areas with an automatic deluge water spray system with medium velocity spray nozzles covering the shell of the tank for exposure protection. Active fire protection systems shall be designed to protect all areas where fuel or oil might spray, flow, or collect.

- Automatic / manual foam system provided in the bunded area of the bulk fuel / oil tank shall be designed in accordance with NFPA 11 [66].
- Automatic Water Deluge system (medium velocity spray system for exposure protection) in accordance with NFPA 15 [69]. Automatic water deluge systems shall be designed to provide a density of 10.2 (L/min)/m^2.

Fuel tanks outflow piping shall be equipped with emergency shut-off valves to stop the flow of fuel in the event of a fire. The provision of non-return valves in fuel oil distribution pipe work shall be ensured to prevent the back flow of fuel into a fire area.

NFPA 850 [93] should be consulted to ensure all shut off, control, and sensing valves are considered during the design of the Fuel Oil facilities.

5.9.2.3 Manual Fire Protection

Off-loading and indoor storage, pumping, and heating facilities shall have portable fire extinguishers and hoses reels strategically positioned in accordance with the size of the room and high-risk areas.

The provision of fire hydrants adjacent to any outdoor combustible or flammable liquid handling or storage areas should be considered. It will allow remote fire-fighting operations to be carried out, allowing cooling and damping down of facilities at a safe distance. Fire hydrants shall be located as a minimum at intervals of 60 m. Fire hydrants shall be provided for manual fire protection and located such that access to them will not be impeded by fire.

5.9.2.4 Fire Detection

Fire detection is generally required in all rooms / houses where tanks, pumping facilities and heating facilities are located. When equipment is in a large open area or outside, fire detection is not practical such as off-loading facilities and bulk tanks.

Bulk tanks located outside could require fire detection for the automatic activation of foam systems in the bund areas.

The fire detection systems shall be design in accordance with the Eskom Fire Detection System Standard [5].

5.9.2.5 Smoke Ventilation

5.9.2.5.1 Ventilation Requirements

The build-up of hazardous flammable vapours associated with combustible and flammable liquid storage and associated pumping and piping facilities within indoor pumping facilities should be restricted. Ventilation can be designed to be mechanically assisted (use of extract fans), or via natural means (louvres, openings in external facades) for systems containing flammable or combustible liquids. Care should be taken when designing any system to ensure adequate high- and low-level ventilation is provided, to clear any vapour emitted that is denser than air. The system/s should be designed such that they cover all areas where flammable vapour may collect. The exhaust rate from the area should ensure that concentration of flammable vapours is kept below 25% of the lower explosion limit. Ventilation rates are typically a minimum of 0.071m^3/sec or 0.3m^3/min/m^2, whichever is greater.

5.9.2.5.2 Discharge of Flammable Vapour

During the design process the location of the flammable vapour system discharge point should be taken into consideration to ensure the flammable vapours are not discharged into an area where ignition may occur (i.e. adjacent heat sources, ignition sources, areas containing static electricity generation, to a confined space where the vapours may re-build due to inefficient ventilation etc.). Typically, the discharge point should be located at high level, above the roof of the structure from the area which it is extracted. The final discharge point should be positioned such that it is remote from any ventilation opening, or fresh air intake point.

The electrical equipment associated with these areas should comply to the relevant zoning as per the Hazardous Location [21] classification of the areas.

6. SPECIFIC GENERATING TECHNOLOGY AREA FIRE PROTECTION REQUIREMENTS

This section will detail fire protection and life safety systems for areas specific to the applicable power generating technology. Some areas mentioned under one generating technology may be applicable to other generating technologies as well. This must be read in context and can be applied across power generating technologies if applicable.

Section 3 to Section 5 of this document must be read in conjunction with the sections below. NFAP 850 [93] shall be used as guidance if the specific generating technology or components are not highlighted in this standard.

6.1 FOSSIL FUELED POWER STATIONS

This generating technology generally includes for coal fired power stations and open / closed cycle gas turbines.

6.1.1 Fuel Handling and Storage - Liquid Petroleum Gas (LPG)

6.1.1.1 General

The design and construction of any Liquefied Petroleum Gas (LPG) cylinder installations shall be in accordance with SANS 10087 [51] Part 1. This also includes power stations that have propane cylinders providing pilot ignition gas to the boilers.

The design, erection and protection of any bulk LPG vessel, which has a water capacity in excess of 500litres, including associated vaporisers, pipework and fittings shall be in accordance with SANS 10087 [51] Part 3.

Additional guidance on LPG equipment could also be sought from NFPA 58 [75].

Note that the application of these standards is mandatory as they are called up in the Pressure Equipment Regulations of the OHSA.

All areas where combustible and flammable vapours can be expected shall be evaluated in terms of the Eskom Hazardous Location Standard [29].

The primary hazard associated with LPG is the exposure fire potential of an LPG storage area. LPG is commonly defined as material composed predominantly of propane, propylene, butane, and butylene either by themselves or as mixtures. A particular hazard of LPG is that a gas leak may travel along the ground for a considerable distance until it reaches a source of ignition in some remote plant operation.

LPG systems present fire hazards associated with tank storage and piping. LPG when stored and transferred is more easily ignited than fuel oil because it need not be heated to produce vapour.

A major fire hazard concerning LPG storage is exposure fires. Exposure from brush and grass, combustible / flammable liquid spill fires, or other potential fire sources can cause a failure of the storage vessel above the liquid level. The resulting release of superheated liquid can develop into a violent explosion, termed a boiling liquid expanding vapour explosion (BLEVE).

Another serious hazard to LPG storage and reticulation is exposure to mechanical damage. Damage to cylinders and piping from excessive vibration or from being struck by vehicles or other heavy objects creates the major source of LPG leaks.

Transfer of LPG from rail or tank trucks to storage tanks presents one of the more serious and more likely hazards associated with LPG. Temporary flexible connections can fail and, without proper precaution, release large amounts of combustible vapours.

The most appropriate fire systems installed within these areas should take into consideration all the hazards and associated risks during the FPDA process [3] for the specific project and document any decisions made in detail for future reference. This section aims to address the most appropriate systems and technologies to use within each specific area of the Eskom asset.

The proposed systems are combinations of codes, standards, industry best practice and experience. Table 5 serves as a quick reference guide for fire system requirements for the handling and storage equipment of LPG.

Table 5: Liquefied Petroleum Gas (LPG) Equipment Fire Protection System Measures

Hazard or Risk Area	Passive Fire Protection	Active Fire Protection	Manual Fire Protection	Fire Detection	Smoke Ventilation	Comments
Cylinders located indoors	x	x[1]	x		x[3]	
Cylinders located outdoors	x	x[1]	x			
Storage Vessels	x	x	x	x[2]		
Off-loading Facilities	x		x	x[2]		
Piping and associated equipment	x		x			

[1] Active fire protection on gas cylinders is limited to exposure protection if required.
[2] The detection as indicated in the table above relates to gas detection as per SANS 10087 [51].
[3] The smoke ventilation as indicated in the table above relates to ventilation as per SANS 10087 [51].

6.1.1.2 Fire Protection System Measures

6.1.1.2.1 Passive Fire Protection

LPG installations shall, as a minimum, meet the requirements of SANS 10087 [51] with regards to all passive fire protection related aspects such as location of equipment, safety distances etc.

All LPG equipment shall be strategically located to be protected against mechanical damage.

All brush, tall grass, and other vegetation shall be separated from LPG equipment by a minimum of 8 m.

6.1.1.2.2 Active Fire Protection

The most appropriate fixed protection system installed within this area should take into consideration the hazards and associated risks during the Fire Protection/Detection Assessment process and document any decisions made in detail for future reference.

Eskom recommends the use of open head medium velocity water spray deluge systems for cylinder exposure protection and for bulk storage tanks located on Eskom sites irrespective of the size of the tank. The protection on the bulk storage tanks should include LPG valves and vaporisers located inside the fenced off area.

- Automatic Water Deluge system shall be designed and installed in accordance with NFPA 15 [69]. The application density shall be 10 mm/min as per SANS 10087 [51].

The water spray system shall be designed to provide sufficient water for cooling surfaces to protect containers from heat of exposure fires. This allows for the areas that are on fire to be cooled, with adjacent areas to be pre-wet to control the build-up of heat, and possible spread of fire to adjacent areas. The extinguishing system shall consist of a fixed, open head water spray system automatically actuated upon activation of fixed temperature type thermal detectors. The deluge system is actuated by a wet pilot line with 68°C detector heads. If ambient freezing conditions are prevalent in the area a dry pilot line can be utilised for activation of the system.

6.1.1.2.3 Manual Fire Protection

Portable extinguishers shall be provided for use by fire brigade personnel in the vicinity of LPG equipment such as offloading towers and transfer connection points where piping leaks are possible, near unloading compressors, pumps and near vaporizers.

Exterior fire hydrants for fire fighter use shall be strategically located around the perimeter of LPG storage areas.

Hydrants around an LPG installation shall conform to SANS 10087 [51].

6.1.1.2.4 Fire Detection

In general fire detection is not required for any LPG equipment. The requirement for detection relates to gas detection as stipulated in SANS 10087 [51]. It must be noted that LPG gas is heavier than air and gas detection should be located appropriately if required.

6.1.1.2.5 Smoke Ventilation

In general smoke ventilation is not required for any LPG equipment. The requirement for ventilation relates to gas ventilation for LPG cylinders located indoors as stipulated in SANS 10087 [51].

6.1.2 Fuel Handling and Storage - Hydrogen

6.1.2.1 General

Hydrogen gas systems that include the production, off-loading, storage and piping of hydrogen gas shall be design and constructed in accordance with the Eskom Hydrogen Systems Standard [22].

All areas where combustible and flammable vapours can be expected shall be evaluated in terms of the Eskom Hazardous Location Standard [21].

One of the major concerns in the use of hydrogen is that of an unwanted combustion (fire, deflagration, or detonation) because of hydrogen's properties such as its wide flammability range, low ignition energy, and flame speed. A potential fire hazard always exists when hydrogen is present. Given the near invisible flame of a hydrogen fire, untrained personnel should not attempt to extinguish any flame. The control of hydrogen to the fire should be disconnected by a trained engineering operative or appropriate automatic shutdown system, with any attempt to extinguish a hydrogen fire carried out by trained fire-fighting staff members.

6.1.2.2 Fire Protection System Measures

The required fire protection measures for hydrogen plants are captured in the Eskom Hydrogen System Standard [22].

The most appropriate fire systems installed within these areas should take into consideration all the hazards and associated risks during the FPDA process [3] for the specific project and document any decisions made in detail for future reference.

The required deluge fire protection systems shall be designed in accordance with NFPA 15 [69].

6.1.3 Bulk Materials Handling and Storage

6.1.3.1 General

Bulk materials handling structures shall be designed for open construction, allowing natural ventilation to prevent accumulation of combustible dust and flammable gas, except as modified for explosion venting. Where enclosed structures are necessary, a means of controlling dust and combustible gases shall be provided.

Due to the nature of materials handling, an ever-present danger exists of fire or explosion occurring because of dust generation. The control of dust generation and the risk it poses should be considered during the Fire Protection / Detection Assessment process, with appropriate measures incorporated as required.

NFPA 850 [93], Section 9 gives guidance on all design requirements and fire protection measures that should be considered for bulk materials handling and storage for a fossil fuelled power station.

Eskom coal fired power stations have been evaluated to identify critical bulk materials handling and storage systems at each power station that require fixed fire protection. This is captured in the following Eskom report - "Identification of Critical Conveyors in Eskom" [34] - and must be considered when determining fire protection requirements.

Activation of the fixed protection system (sprinkler system) should shut down the conveyor belt involved in the fire situation and any belts feeding into the belt under fire conditions. This requirement has been evaluated as necessary for Eskom conveyors – see the report "Conveyor Belt Shut Down on Activation of Fixed Fire Protection Evaluation Report" [35].

It is preferred that fixed fire protection systems be actuated by mechanical means as far as practicably possible.

The sprinkler or water spray control valve should be in an area or enclosure separated from the conveyor system to ensure it cannot be damage by fire on the conveyor system, thereby restricting its operation.

Any fans or dust collection systems shall also shut down to restrict the spread of smoke along the conveyor belt system upon activation of the automatic detection or suppression system protecting the conveyor belts.

6.1.3.2 Bins, Bunkers, Silos

6.1.3.2.1 General

Coal piles are typically subject to fires caused by spontaneous heating of the coal. In the first instance coal piles, as well as any other material being stored or dumped, shall typically be provided in external air, with access provided to tackle and control any developing fire situation.

It is not always possible to provide open air storage facilities, and it is recognised that indoor storage facilities may be required. There are several items to consider during the design process when storing coal, or other material, indoors, including the most appropriate fire protection system.

6.1.3.2.2 Fire Protection System Measures

Due to the difficulty of extinguishing a fire in a silo or coal bunker means of removing coal from the area should be considered as part of the fire protection system. This may be in the form of conveyors removing coal to a safe area outside of the storage facility and located where it cannot damage any other building or structure.

Should it not be possible to remove all the coal a micelle-encapsulating agent should be considered for insertion into the internal storage area. It is critical that the structural stability of the silo or coal bunker be considered before water is discharged into it. If it is considered unsafe to discharge water into the silo or coal bunker, then injection of an inert gas should be considered.

The guidance provided within the Fire Detection and Life Safety Design Standard [6] should be considered when designing the fixed protection system, and the most appropriate method for its activation.

A structural engineer should be consulted wherever a water-based suppression system is installed within a silo or bunker (whether it contains coal, ash, lime or gypsum) to determine whether the additional weight introduced will impact upon the design of the overall structural support provided.

6.1.3.3 Bulk Material Conveyors and Handling Structures

6.1.3.3.1 General

Bulk material conveyor belts, their structures and supports shall be constructed from non-combustible materials where possible. Typically, Eskom does not make use of fire-resistant belts and it cannot be assumed that these belts will be used to limit the down time to the system in the event of a fire.

Where the construction of the bulk material conveyor system cannot be carried out in open air (i.e. open construction) an explosion venting system should be considered during the FPDA process and incorporated into the design. Any system should take into consideration the recommendations within NFPA 68 [77].

All electrical equipment within the bulk materials handling system areas, which are subject to coal dust, shall be of the type approved for a Zone 22 location, and shall be in accordance with the Eskom Hazardous Location Standard [21] requirements.

Any hydraulic system associated with the bulk materials conveyor system should only use fire retardant fluids. Should fire retardant fluids not be available or used, consideration should be made to protecting the pipework with an appropriate fire suppression system.

Consideration to the installation of draft barriers along the length of any subterranean coal conveying system should be considered during the FPDA process. They will have the effect of separating the conveyor system into several areas, effectively restricting the flow of smoke and in turn reducing the time for the detection or suppression system to actuate.

6.1.3.3.2 Fire Protection System Measures – Bulk Materials Handling Conveyor Belts

Where bulk materials handling conveyor belts are considered to form a critical system for continuous power generation, Eskom generally recommends that a sprinkler system shall be provided as fire protection. For sprinkler protection the system should be designed to provide a minimum density of 10.2 mm/min over 186 m^2 of enclosed area or the most remote linear 30m of conveyor structure up to 186m^2. Sprinkler systems shall be designed in accordance with SANS 10287 [59] or NFPA 13 [68].

Where a sprinkler system is provided to protect the bulk materials conveying system the Fire Protection designer should take into consideration the location of the sprinkler heads above and around the system to ensure they are located directly in the path of any heat generated from a fire on the belts and any associated surfaces.

Should a water spray system (deluge) be considered more appropriate due to shielding effects that may occur to sprinkler heads given the location of the conveyor belt and its supporting structure (as determined during the FPDA process) then the system should be designed in accordance with the design criteria listed within NFPA 15 [69].

Where the conveyor system is inclined at a pitch greater than 10 it is possible any fire may ‘race ahead’ of the suppression system protecting the belt. Careful consideration during the FPDA process to the type of suppression protecting these belts and the number of points operating should be made to ensure any fire does not spread faster than the system may operate.

For information only the following table highlights the differing rates of flame spread across paper strips laid over an inclined surface:*

Orientation	Rate of flame spread (mm/s)
0°	3.6
+22.5°	6.3
+45°	11.2
+75°	29.2
+90° (vertically upwards)	46-76 (erratic)

*Information taken from Table 7.2 – An Introduction to Fire Dynamics 2nd Edition – Dougal Drysdale

Where there is a possibility of electrical components being damaged by water from the fire suppression system, consideration shall be given to protecting these components by proper positioning of water spray nozzles, or by providing water deflection shields. Electrical components to be protected from water damage include:

- Motorized drive equipment
- Belt alignment switches
- Motion sensing devices
- Belt misalignment disconnect switches

6.1.3.3.3 Fire Protection System Measures – Underground Conveyors

Conveyor systems that are below grade or enclosed provide an extremely hazardous environment to maintenance and fire-fighting personnel required to work within these areas. Underground bulk materials handling conveyors, located within the power station boundary fence, shall be provided with hose reels, hydrants and fixed sprinkler systems dependent on the FPDA process.

6.1.3.3.4 Fire Protection System Measures – Handling Structures

Where facilities and handling structures are considered critical to power generation Eskom general practice is to install automatic water sprinkler systems for protection. Any sprinkler system should be designed to provide a minimum density of 10.2mm/min over an area of $232m^2$. Transfer houses and inclined conveyors shall be protected against structural fire damage by means of sprinkler systems. This shall include the head and tail ends of conveyors.

Sprinkler systems shall be designed in accordance with SANS 10287 [59] or NFPA 13 [68].

Should a water spray system (deluge) be considered more appropriate (as determined during the FPDA process) then the system should be designed in accordance with the design criteria listed within NFPA 15 [69].

Draft barriers installed at the end and midpoints of enclosed conveyors and between separate sprinkler and water spray systems where the length of the conveyor requires multiple systems should be considered in the Fire Protection/Detection Assessment. Draft barriers will improve the response time of installed automatic sprinkler or detection systems and minimize the chimney effects in the event of fire.

The requirement for water spray curtains must be determined by carrying out a FPDA, considering structural layouts, ventilation, drainage, thermal updrafts and windage. Water spray curtains are less effective than direct application but can, under favourable conditions, provide some protection against fire exposure and smoke propagation through subdivision of fire areas.

6.1.3.4 Coal Stacker-Reclaimer and Ash Stackers

Consideration should be given to the installation of an Automatic Water Deluge or sprinkler system over the conveyor belt and striker plate areas within the stacker-reclaimer. The water supply could be from a 11,355 L to 18,925 L capacity pressure tank located on-board. A fire department pumper connection should be provided so connection can be made to the fire hydrants in the area during down or repair periods to provide a more adequate water supply. Consideration should be given to protecting enclosed electrical control cabinets by a pre-engineered fixed automatic gaseous-type suppression system actuated by a fixed temperature detection system.

Fire protection measures on this equipment would typically be specified and detailed (as an add-on feature) by the OEM of the major equipment.

6.1.3.5 Fire Protection System Measures - Hydrants

The provision of fire hydrants to any part of the bulk materials conveying or handling system shall be considered as part of the Fire Protection/Detection Assessment process (FPDA), in tandem with any fixed protection system installed to provide a fall-back fire-fighting strategy for this area. It will allow remote fire-fighting operations to be carried out, allowing cooling and damping down of facilities at a safe distance. Typically, hydrants and their associated water supply pipework shall be installed to protect the following areas where practical:

- Adjacent overland conveyor systems
- To provide protection and coverage to coal, ash, limestone and gypsum stockyards
- Underground conveyor systems

Fire hydrants shall be located at intervals of 60 m (for overland conveyors, 90 m to 150 m spacing is acceptable). Fire hydrants shall be provided for manual fire protection and located such that access to them will not be impeded by fire.

6.1.4 Boiler Plant and Associated Equipment

6.1.4.1 General

Boiler plant fire protection shall be provided where the hazards associated with oil fired boilers, and the use of oil for ignition of plant poses a risk to operatives working within the vicinity of these areas, and where the generation of power may be affected by a fire situation. The required level of protection should be determined during the FPDA process. The following sections highlight the fire protection measures to be typically incorporated into specific areas, or to cover items of equipment associated with a steam generation plant.

NFPA 850 [93] gives guidance on fire protection system measures to be considered for the following boiler plant and associated equipment – boiler burners, fuel feed equipment including mills (pulverisers), feed pumps, flue gas equipment (forced draft and induced draft fans), regenerative air heaters, flue gas bag-type dust collectors, electrostatic precipitators, scrubbers (including scrubber buildings and exhaust ducts) and stacks. The below paragraphs highlight the Eskom specific fire protection system measures. Section 3 to Section 5 of this document must be read in conjunction with the sections below.

6.1.4.2 Fire Protection System Measures – Boiler Furnace

The multiple oil-fired burners on a boiler furnace that use oil as an ignition source shall be protected with a fixed fire protection system. In Eskom the burners and surrounding areas are typically protected with high velocity deluge systems. This system should be designed to cover the fuel oil burners, igniters, and any adjacent fuel oil piping and cables within 6.1 meters from the boiler front. In addition, any structural member or walkway within 6.1 meters of the boiler front shall be afforded protection, as should any area where the accumulation of oil may occur:

- Water Spray Systems in accordance with NFPA 15 [69] - systems should be designed to provide a minimum density of 10.2mm/min over the area to be protected.

Protection to the boiler furnaces or the boiler burners is to control and stop the spread of a fire on the boiler burners because of a fuel oil leak. In the first instance a Fixed Water Spray System is to be provided to protect the burner front from oil spill. Where there is a possibility of electrical components being damaged by water from the fire suppression system (as identified during the Fire Protection/Detection Assessment process), consideration shall be given to protecting these components by proper positioning of water spray nozzles, or by providing water deflection shields. Where this is not possible the FPDA process should be revisited, and a more appropriate form of suppression considered, or an upgrade of the electrical components be considered to make them less susceptible to water damage.

Fuel isolating valves or controls shall be incorporated into the fixed fire protection design to isolate the fuel-oil in the case of a fire situation. The isolation shall be by remote means, typically provided within the Main Control Room under the control of the Unit Operator.

6.1.4.3 Fire Protection System Measures – Mills (Pulverisers)

The potential for fire and explosions to occur during the process of pulverizing coal, and the subsequent formation of coal dust, is well known and needs to be controlled at the source.

In general, there is no fixed fire protection installed as part of the mills in Eskom.

The Eskom Standard – Fire Prevention and Mill Operation during a Mill Fire [31] gives the details on how to prevent mill fires as well as how to approach mill fires once they have stared.

6.1.4.4 Fire Protection System Measures – Feed Pumps

Hydraulic and lubricating oil hazards associated with feed pumps (steam feed and electrical driven pumps) are to be protected by Automatic Water Deluge systems. The spray systems shall be extended to protect areas and equipment below the feed pumps as well as oil channel floor areas. The spray system shall be designed in accordance with NFPA 15 [69].

Where there is a possibility of electrical components being damaged by water (as determined during the Fire Protection/Detection Assessment process) from the fire suppression system, consideration shall be given to protecting these components by proper positioning of water spray nozzles, or by providing water deflection shields, or an upgrade of the electrical components be considered to make them less susceptible to water damage.

6.1.4.5 Fire Protection System Measures – Air Pre Heaters

Fires have occurred in air heaters after the accumulation of appreciable quantities of unburned combustibles on plate surfaces resulting from incomplete combustion of fuel in the boiler. Incomplete combustion is most likely to occur during start-up. Incomplete combustion also can occur during load changes, periods of low firing rate, or normal operation due to unstable or over-rich firing.

Most Eskom power stations do have fixed fire protection in the air heaters – a manually operated deluge fire protection system – as part of the station installation. This type of system must be provided by the air heater OEM as part of the air heater. Upon activation, the fire alarm system shall sound a local alarm, and transmit an alarm to the unit and main control rooms. Clear alarm response procedures for air heater fires are critical for the system to be operated effectively in a fire situation.

The Eskom Position Paper – Air Heater Fire Protection and Detection and Fan Vibration Minimum Requirements [36] gives guidance on the Eskom requirements for fire protection and detection in air heaters.

NFPA 850 [93] gives the required recommendations.

6.1.4.6 Fire Protection System Measures – Scrubbers, Scrubber Buildings, and Exhaust Ducts

Scrubbers are the main component for flue gas desulfurization (FGD) processes, which are frequently used to maintain low sulphur emissions. Auxiliary equipment associated with the FGD process is often enclosed in scrubber buildings. Exhaust ducts provide a flow path from the scrubber outlet to the stack. Fires have occurred in scrubbers with combustible lining, combustible packing, or both. The fires occurred during outages and were caused by cutting and welding. Attempts to manually fight the fires were not successful since smoke and heat prevented access to the scrubber. Where scrubbers were in buildings, there was extensive smoke and heat damage to the building. Fires can also occur in ductwork.

Typically, the materials used to construct a scrubber and its associated buildings should be constructed of non-combustible materials.

NFPA 850 [93] gives the required recommendations.

Bulk materials handling structures and equipment that form part of FGD installations shall have fire protection system measures as per section 6.1.3.3 of this document.

6.1.5 Turbines and Associated Sub-systems

6.1.5.1 General

The fire protection objective is to minimize, to the greatest practical extent, the frequency and severity of fires and explosions in the turbine-generators and associated subsystems. The evaluation of what measures are 'practical' shall be based on the need for safe, efficient, and reliable operation of the turbine-generator and associated subsystems, as well as the cost effectiveness of the fire protection requirements. These measures shall be evaluated during the Fire Protection/Detection Assessment process.

Where the designer requires further information on the protection measures to be provided to the turbine and internal combustion engine generators and its associated equipment reference should be made to NFPA 850 [93]. All areas of Steam Turbines and Electric Generators that are subject to oil spray fires shall be protected according to the more stringent water density and nozzle spacing requirements of FM Global Data sheet 7-101 [107].

In general, for coal fired power stations the turbine area is considered as the worst-case fire scenario for the power station due to the multiple systems that must be considered activating in a single fire event. For this reason, it is critical to always have an overview the various systems and carefully consider adding water spray systems (deluge systems) in this area to limit the fire water flow and pressure requirements in this area.

6.1.5.2 Fire Protection System Measures - Oil Systems

Oil systems associated with turbines should use a listed fire-resistant oil. Where it is not possible to use a listed fire-resistant oil, equipment should be protected with a fixed fire protection system.

Any oil systems that could cause oil flow, oil spray or oil accumulation should be protected by automatic fixed fire protection systems. For turbines this typically includes hydraulic control oil, lubrication oil and hydrogen seal oil systems for steam turbines.

Typically for oil systems - water spray fire protection systems in accordance with NFPA 15 [69] is most effective. Automatic sprinkler systems or foam-water suppression in accordance with NFPA 13 [68] or NFPA 16 [70] can also be considered.

Where oil lines are installed below the turbine operating floor, they should be protected with an automatic sprinkler system wherever the accumulation of oil may occur (typically this includes all areas beneath the turbine operating floor). Actual coverage should be assessed during the Fire Protection/Detection Assessment process. Any system should be designed to an operating density of 12.2mm/min over a maximum area of $464m^2$.

A fixed fire protection system shall be supplied to protect the hydraulic control system including reservoirs and emergency stop, intercept and reheat valves.

Any cabling provided that is associated with the lube oil pump system shall be protected from exposure to fire. The protection afforded should be rated to provide one (1) hour protection from all adjacent areas. Alternatively separate cable routes for AC and DC cabling may be considered.

Where bulk oil reserves and handling equipment are provided, they should ideally be separated from the main generator area and installed within a separate room or enclosure. This room or enclosure shall have dedicated fixed fire protection installed – typically in the form of an automatic sprinkler or deluge system. See section 5.9 of this document for more information.

All areas beneath the turbine-generator operating floor that are subject to oil flow, oil spray or oil accumulation, should be protected by and automatic sprinkler system. The most appropriate form of suppression installed should be evaluated as part of the Fire Protection/Detection Assessment process and take into consideration any obstruction caused by equipment, its supporting structure, or associated pipework. Suppression coverage shall include all areas beneath the operating floor in the turbine building. The system shall be designed to have a minimum operating density of 12.2mm/min over a minimum application area of $464m^2$.

6.1.5.3 Fire Protection System Measures– Steam Turbine Generator Bearings

Turbine-generator bearings shall be protected with an automatic closed-head sprinkler system utilizing directional nozzles or a water spray system. Double-knock systems are generally used in Eskom to prevent accidental discharge. Open-head system controlled by Multiple Jet Control (MJC) valves is also widely used for this application however the location of the frangible bulb sprinkler head/s which operates the system should be carefully considered to ensure they are located directly in the path of heat generated from a fire incident for the specific turbine bearing.

The system shall be designed to provide a flow density of 10.2mm/min over all bearings that are to be protected.

6.1.5.4 Oil Pipe Galleries

All oil piping serving the turbine-generator shall be designed and installed to minimize the possibility of an oil fire in the event of severe turbine vibrations. Piping design and installation shall consider the following passive protective measures:

- Welded construction.
- Guard pipe construction with the pressure feed line located inside the return line or in a separate shield pipe drained to the oil reservoir and sized to handle the flow from all oil pumps operating at the same time.
- Route oil piping clear of or below steam piping or hot metal parts.
- Insulation with impervious lagging on steam piping or hot metal parts under or near oil piping or turbine bearing points.
- Non-combustible coverings (flange guards) around the flange to reduce the possibility of oil spraying onto hot surfaces.

6.1.6 Auxiliary Equipment and Other Structures

6.1.6.1 Cooling Towers

The cooling towers referred to include cooling towers related to auxiliary cooling on power station as well as HVAC cooling towers. It specifically refers to cooling towers of combustible construction or those in which the fill is of combustible material. NFPA 214 [84] and FM Data Sheet 1-6 [97] provides details for fire system measures that should be applied to these types of systems.

Eskom specific requirements for natural draft cooling towers at coal fired power stations are documented in an Eskom FPDA report - 474-11867 Coal Fired Power Station Natural Draft Cooling Towers Fill Replacement Fire Protection / Detection Assessment Report [37].

6.1.6.2 Auxiliary Boilers

The measures incorporated within Section 6.1.4 of this guidance document should be incorporated within any area where auxiliary oil-fired boilers are provided. During the Fire Protection/Detection Assessment process the similarities between the two areas identified should be determined to ensure the level of protection afforded to the auxiliary boiler areas is commensurate with the hazard posed and the associated risks with this area are adequately controlled.

6.1.6.3 Bulk Sulphur Tanks and Associated Equipment

There are no specific fire protection system measures stipulated for bulk sulphur in NFPA 850 [93].

SO_3 conditioning plants are utilised on coal fired power stations as part of flue gas control in association with electro-static precipitators. The plant consists of:

- Common Liquid Sulphur Off-loading, Storage and Distribution.
- Unitized SO_3 Skids and Injections Systems.

NFPA 655 [90] provided details of fire protection measures for this type of plant. Sulphur systems associated equipment utilised in Eskom must be evaluated from a fire protection perspective regarding its type, quantity, location (as an exposure hazard to plant equipment or where the sulphur plant is exposed to other power station type of hazards and risks), and usage for the business.

Material Safety Data Sheets of any chemical or gas utilised on power stations must be utilised as part of the emergency response measures for the applicable areas.

6.1.6.4 Bulk Ammonia Tanks and Associated Equipment

There are no specific fire protection system measures stipulated for bulk ammonia in NFPA 850 [93].

Ammonia on coal fired power stations are generally utilised for chemistry control in the units (boiler dosing). Ammonia is fatal to humans in large concentrations, but ammonia is generally regarded as a non-flammable.

Material Safety Data Sheets of any chemical or gas utilised on power stations must be utilised as part of the emergency response measures for the applicable areas.

6.2 HYDROELECTRIC POWER STATIONS

The requirements stipulated also includes pumped-storage power stations. Section 3 to Section 5 of this document must be read in conjunction with the sections below. NFAP 850 [93] shall apply accordingly.

6.2.1 General

As with the coal fired power stations the hydroelectric generating plant should be divided into separate fire compartments to restrict the spread of fire through the plant. The provision of effective fire compartmentation, in tandem with dedicated fire protection, detection and HVAC systems assists with safeguarding occupants working within the power station, whilst also providing a means for limiting the impact upon property and equipment, and the ability to generate power.

Where identified, areas should be separated by approved fire barriers, fire resistant construction, or spatial separation as detailed within Section 4.1 of this Standard. As most of the Eskom hydro power station equipment is in underground caverns, fire protection and life safety systems are critical.

Unattended hydro-electric plants, or plants that are operated with minimal staffing, require fire protection measures to be provided that are capable of being operated automatically, or remotely, from the area to be protected. User intervention to operate any system cannot be relied upon in these circumstances. Additionally, any emergency response team, or local fire service intervention, may be limited due to the remote location of hydro power plants, and the limited availability of trained staff to tackle any fire.

These factors should be taken into consideration during the Fire Protection/Detection Assessment process (FPDA) to determine whether any additional Fire Protection measures should be incorporated into any design to take into consideration the potential for a delayed response.

Consideration to the method for activating any protection system should be taken into consideration. It may not be possible to manually operate any system therefore the design should take into consideration the likelihood of false alarms occurring due to the method of activation chosen. This review should also take into consideration the effects of unnecessary discharge of water over equipment due to the method chosen for activation of systems. Typically, water-based suppression systems shall be actuated via standard response sprinkler heads operating at a temperature of 68°C. The actual operating method, and most suitable method for the area and/or equipment to be protected, should be assessed during the Fire Protection/Detection Assessment process.

The guidance provided within the Fire Detection and Life Safety Design Standard [6] should be considered when designing the fixed protection system, and the most appropriate method for its activation.

6.2.2 Fire Protection System Measures - General

Section 5 of this standard gives guidance on fire protection system measures which must be considered for general areas applicable to Hydro Power Stations. These areas include:

a) General Buildings and Facilities
b) Electronic Equipment Installations
c) Cable Concentrations, Cable Spreading Rooms, and Cable Tunnels
d) Switchgear Rooms
e) Battery Rooms
f) Substations And Switchyards
g) Transformers
h) Pumps, Generators and Compressors
i) Storage And Handling of Combustible / Flammable Liquids – including Lubrication Oil and Hydraulic Control Oil

NFPA 850 [93] refers to specific risk considerations and hazard protection for hydro power station which are –

- Protection of turbine bearings.
- Protection of generator pit and windings.

6.2.3 Fire Protection System Measures - Underground Oil Insulated Transformers

Where it is required that transformers be installed within an underground cavern, Section 5.7 of this document is to be referenced. Apart from the required fire protection measures and remedial action taken to deal with the direct consequences of an oil transformer fire, the following factors should also be considered when specifying the scope of underground transformer fire protection:

6.2.3.1 HVAC

The HVAC system should be designed such that in the event of a transformer fire, the ventilation extraction system is able to provide:

- Isolated and dedicated air extraction of the transformer area. This will ensure that smoke is extracted to the surface via the shortest possible route and will not allow smoke to contaminate other areas.
- Sufficient air extraction flow rates to accommodate the anticipated worst case smoke volume generation rate.

6.2.3.2 Escape Routes

Due to the high risk posed by the oil-filled transformers it must be ensured that, as far as possible, the station emergency escape routes do not go near or past the transformer installations.

6.3 WIND TURBINE GENERATING FACILITIES

This section identifies the fire and explosion risks that exist at wind turbine generating facilities (often referred to as wind farms) and provides guidance for the protection of these facilities to mitigate the risk.

Most wind farms consist of a series of tower mounted wind turbine generators (WTGs) with electrical outputs connected to an electrical distribution system synchronised to the power utility grid. A WTG is a complex machine composed of a tubular tower (up to 130 m high) with the nacelle, hub and rotor blades situated at the top. The nacelle contains the generator that is connected to the hub and rotor blades via a gearbox. Direct current (DC) produced by the generator is fed via power cables to the transformer which converts it to alternating current (AC) and feeds it to the facility substation from where power is fed via high voltage distribution lines to the grid. Access to the nacelle is usually provided via an internal ladder, although lifts are also found in some designs.

As the design of WTGs can vary (e.g. the transformer may be located with the generator in the nacelle, or at the base of the tower), some recommendations may be more appropriate to some designs than others. It is however expected that most recommendations will apply. It is up to the users of this document to evaluate the WTG-specific hazards and associated risks, and to apply the recommendations as appropriate to mitigate the risks to an acceptable level within a cost-benefit framework.

Given that these installations are often located remotely and are operated without on-site personnel, the emphasis of fire safety is on the prevention of fire through design. Additional fire suppression measures may be required depending on the outcome of the Fire Protection/Detection Assessment process.

NFPA 850 [93] recommendations for wind turbine generating facilities applies.

6.3.1 General – Risks and Causes of Fires

Wind turbines differ from traditional power generation systems in that fire in the nacelle often leads to total loss of the WTG. Service interruption can be as long as 12 months in the case of total damage to the nacelle.

A wind farm’s central electrical substation is particularly risk sensitive as it represents a single point of failure where, if damaged by fire, it could result in all connected wind turbines to be disconnected from the power grid at the same time.

The falling debris from a fire in a WTG has a high potential to lead to bushfires if the surrounding area is not adequately cleared from vegetation. In the cases where bushfires ensued, the loss not only concerns the direct property loss of the wind farm, but also the costs associated firefighting and damage and consequential loss caused by the bushfire.

Damage resulting from lightning strikes is among the most frequent causes of fire given the exposed location (often located at higher altitudes) of WTGs and the elevated hub heights. The risk of fire increases particularly when a lightning protection system is either absent or badly designed, installed or not properly maintained.

Along with lightning, overheating of electrical components because of overloading, earth fault/short circuiting and arc welds are among the highest causes of fire.

Mechanical failures resulting in sparks or hot surfaces coupled with leaks form lubricating and hydraulic oils will cause fires.

6.3.2 General – Fire Risk Prevention

Section 3 gives guidance on generic fire risk prevention measures that must be followed as part of any design. This relates to “Design Safeguards” and “Administrative Control” that must be implemented over the lifecycle of a plant from conception to de-commissioning. Some specific concepts that are applicable include –

a) Lightning and surge protection specifically tailored for the specific project.
b) Protection of electrical systems to switch them off when electrical faults occur.
c) Hot work.
d) Equipment monitoring and maintenance.
e) No smoking.
f) Qualified and trained operating and maintenance personnel.
g) Separation of ignition sources and combustibles.
h) Minimise combustible materials.
i) Emergency response plan (ERP) to limit the loss following a fire.
j) Standard Operating Procedures (SOPs) in case of fire.
k) Regular emergency response exercises.

6.3.3 Fire Protection System Measures

Section 3 to Section 5 of this document must be read in conjunction with the sections below. Given the geographical remoteness of the typical wind farm, the emphasis should be on the prevention of fire by design and passive measures with the addition of fire suppression equipment to be guided by the FPDA process.

Adequate separation should be provided between the following as determined by the FPDA process:

- Adjacent WTGs, taking into consideration the geographical topography.
- Adjacent structures (transformers, substation etc.)
- Adjoining properties and exposures.
- Closest residential buildings.

Owing to risk associated with flying debris, the prevailing wind direction and speed and direction of rotation of WTGs should be considered when establishing separation distances.

Determination of the need for automatic fire detection and/or extinguishing systems should be based on the facility design and outcome of the Fire Protection/Detection Assessment.

The suitability and installation of fire detection and automatic fire extinguishing systems for the nacelle should be done by the OEM of the wind turbines. Automatic fire extinguishing systems for the wind farm facility should be considered for the protection of specific equipment, complete rooms, or a combination of both.

Fire detection and protection systems need to be constantly monitored to ensure its operational reliability especially considering the remote location of the installations, and the operation of the plant without permanent on-site personnel. Automatic notification of equipment malfunction and system defects (leakage etc.) should be given to provide early indication of potential system faults.

6.4 SOLAR POWER FACILITIES

This section identifies the fire and explosion risks that exist at solar power generating facilities and provides guidance for the protection of these facilities to mitigate the risk.

Solar power converts sunlight into electricity using either photovoltaic (PV) or concentrated solar power (CSP) / solar thermal power. While solar energy is an environmentally safe form of energy generation, it still poses fire risks. It is necessary to be aware of the risks and proper fire protection solutions.

NFPA 850 [93] recommendations for solar power generation applies. The fire system design approach and fire risk control measures as stipulated in Section 3 to Section 5 of this document must be read in conjunction with the sections below.

6.4.1 Concentrated Solar Power (CSP)

Most large-scale solar power plants are concentrated solar power plants (CSP), which use solar energy to power conventional steam turbines. Therefore, CSP plants have the same fire hazards as many conventional power plants.

CSP plants use a series of lenses, mirrors, or heliostats and tracking systems to condense sunlight into a narrow beam of light. Solar plants have numerous options for technology that condenses the sunlight into a beam: Concentrating Linear Fresnel Reflector, Stirling Dish, Linear Parabolic Reflector/Parabolic Troughs, Solar Dish, or Solar Power Tunnel. The intense beam of light created is then used to provide heat to power a conventional steam turbine. The concentrated beam of sunlight is used as a heat source to warm the heat transfer fluid (HTF), molten salt, or steam generator to power the steam turbine. The steam turbine is connected to a generator, which produces the energy.

As the design of solar power facilities can vary (e.g. depending on the type of solar technology is utilised), some recommendations in this guideline may be more appropriate to some designs than others. It is however expected that most recommendations will apply. It is up to the users of this document to evaluate the specific hazards and associated risks with solar power plants and to apply the recommendations as appropriate to mitigate the risks to an acceptable level within a cost-benefit framework.

6.4.1.1 General

In general, the major hazards associated with solar generating plants are as follows:

- Release of large quantities of combustible heat transfer fluid (HTF).
- Shielded fires involving large quantities of HTF in the heater.
- Lubricating and control oil fires.
- Switchgear and cable fires.
- Transformer failure fires.
- Veld fires exposing the facility.

A determination should be made about the damage that could be caused by a release of the HTF. Spacing and design of critical equipment and structures should be such to limit damage in the event of a fire exposure in both the solar field and power generation areas.

In a HTF type plant, the solar field has its own fire hazards. The concentrated sunlight created from the solar field is used to bring the HTF to a high temperature. The HTF flows from the solar field to a standard steam turbine. The HTF is generally a form of oil and can be very combustible. The HTF introduces a fire hazard to the solar field.

The HTF flows until it reaches the heat exchanger which can be another potential problem area. The steam turbine uses lube oil to keep it moving smoothly. Fires can ignite within the turbine underfloor, exciter, lube oil piping, or the turbine bearings.

The next stage in solar energy generation is the generator, which produces the energy. The generator contains lube oil, and/or hydrogen which can fuel a fire from the slightest spark.

Cooling towers are often thought of as fire resistant because they are usually wet; however, cooling towers contain hidden dry areas and are completely dry during maintenance. Cooling tower materials often include combustible materials. The heat source in a cooling tower fire can come from outside sources, such as a fire from another part of the plant that has spread or internal sources, such as maintenance welding, overheated bearings, or electrical failures.

6.4.1.2 Fire Protection System Measures

NFPA 850 [93] gives details on recommended fire protection system measures for CSP specific hazards and risk which includes -

- HFT piping and pumping and associated equipment.
- HFT heater protection.
- Steam generator and other equipment structural support passive and active fire protection.

Hydrants should be placed strategically about the solar field to provide coverage of all HTF piping associated with solar collection assemblies and HTF supply and distribution piping. This will help in early manual firefighting and exposure control.

An automatic listed fire protection system should be provided for the following areas based on the FPDA process (where the hazard is lubrication oil or hydraulic oil, a listed fire-resistant fluid is an acceptable alternative to fixed fire protection):

- Lubrication systems
- Hydraulic control systems
- Electrical equipment rooms, including control, computer, communications, cable trays, and tunnels etc., in accordance with Section 5.

6.4.2 Photovoltaic (PV) Solar Powered Panel Installations

Photovoltaic panel installations have a unique risk to life safety in that when fire fighters arrive at a burning building, one of their first tasks is to disconnect utilities to the structure. However, this is not possible with solar systems since the PV system inverter can hold a charge and send electricity back up to the solar panels. The panels themselves will continue to produce power as long as the sun is shining and possibly even at night when bright lights are present.

Thus, the conduit leading from the PV panels to an inverter remains live with direct current even after the main service panel has been shut-off. The fire services must fight a fire in the presence of high DC voltage and current and can be subject to electric shock. During a fire on a building with a photovoltaic system, DC cable insulation might melt and cause a DC flash arc. The same can happen if a photovoltaic system is disconnected incorrectly. DC arcs are not only an ignition source themselves, but an additional life safety threat to fire fighters.

Other possible risks of photovoltaic systems for manual firefighting are:

- Solar panels may block key points and pathways that fire fighters would otherwise use on a roof.
- The added weight of a solar panel array may lead to roof collapse if the integrity of the structure is already compromised by fire.
- Potentially toxic fumes from decomposed products of the panels.
- Falling objects from the roof top or wall (e.g., broken glass).

All components of a photovoltaic system exposed to sunshine and other exterior elements of weather need to have highly durable characteristics, and certain materials that have traditionally performed well in this regard (i.e., certain types of plastics), do not necessarily have good fire-resistant characteristics. The solar panels themselves typically contain limited plastics, but it is the frames, mounting systems, cables and boxes that can add to the combustible loading of an installation and eventually to the combustibility of the entire roof.

As a result, the combustibility of a planned photovoltaic installation needs to be evaluated case by case. Fire test results for the panels alone are not enough as an increasing number of mounting systems made from plastics are on the market. There are no harmonized standards for solar cables (cables used in solar installations); however, fire test results and flame-retardant characteristics of the cables need to be considered too.

6.4.2.2 General

Photovoltaic systems are subject to electrical faults like any other electrical installation such as arc faults, short circuits, ground faults and reverse currents. These faults and other failures of the system, including cable insulation breakdowns, rupture of a module, and faulty connections, can result in hot spots that can ignite combustible material in their vicinity. Wrongly installed or defect DC/AC inverters have been the reason of several photovoltaic fires as well.

In the worst case, faulty conditions on the photovoltaic system will not only result in a hot spot, but also a DC arc. Arcing has been found to be the main reason of larger rooftop fires on commercial buildings starting on PV systems and have gained a lot of attention.

Any disconnection or faulty connection of current carrying wire can cause an electric arc, which is the continuation of current flow through air. An arc-flash can occur when there is sufficient amperage and voltage and a path to ground or to a lower voltage. Any electric installation is exposed to the risk of arcs, but solar installations are particularly sensitive to this exposure because of the continuous DC current and the high currents (>10 A) and voltages (300-1000 V) involved. DC arcs do not self-extinguish and can reach temperatures as high as 3000°C (5400°F). Arcs at this temperature can melt metal, which can fall as slag and ignite nearby combustible materials. Three types of arcing can take place – serial arc, parallel arc, and ground arc.

Safely disconnecting a PV system in a fire situation should ideally result in DC currents and voltages reduced to levels which are no longer hazardous to fire fighters. However, this would require isolation of each individual module and currently, there is no economically feasible solution for such an isolation tool. The so called “fireman’s switch” has been launched on the German market. Additional isolators can be installed between strings / arrays and the inverter at roof top level to at least de-energize the main conduit leading from the roof to the inverter. These switches can be remotely actuated from a safe location.

Proper labelling of all components and live equipment, as well as adding information and documentation of the PV system to the emergency response plan and providing fast access to qualified electricians familiar with the installation are other key factors in supporting manual firefighting.

In general, the major hazards associated with PV generating plants are as follows:

- Electrical fires associated with failed PV module connections or string cabling.
- Hydraulic oil fires associated with the hydraulic oil systems used for multi-plane tracker positioning of the PV modules.
- Inverter, switchgear, and cable fires.
- Transformer failure fires.
- Veld fires exposing the facility.

6.4.2.3 Fire Protection System Measures

Photovoltaic systems in general and on commercial / industrial buildings are a relatively new fire risk and there are no proven, standard protection concepts currently available. “Fire” protection for photovoltaic systems is not a classical “fire extinguishing issue” but rather a matter of preventing fires from happening in the first place by protective devices and high installation standards, minimizing the combustible loading should they happen, and avoiding unnecessary hazards for the fire services.

Before installing photovoltaic systems on high value commercial and industrial properties, a FPDA must be conducted to determine if the fire risk can be minimized or if there is a potential for a catastrophic loss.

The following list consists of system design elements in rigid photovoltaic systems and loss prevention programs that can be used for minimising the fire risk of photovoltaic installations.

a) Only PV modules which comply with national / international standards for electrical performance and safety should be used.
b) Modules should have the approval / listing of a national / internationally recognized testing laboratory.
c) Mounting systems and frames should be non-combustible.
d) Accessibility for firefighting should be considered.

e) Installation cabling type, fire performance and routing.
f) Inverter accessibility and mounting.
g) Disconnect requirements.
h) DC arc detection and elimination.
i) Pre-emergency plans and drawings for the fire department / emergency response teams should include the fire hazard of the photovoltaic system and the disconnection means.
j) Inspection, testing, and maintenance done by qualified professionals.
k) Grounding, overcurrent protection, lightning protection.

6.5 NUCLEAR POWER STATIONS

6.5.1 General

Nuclear power plants have the same general fire hazards and risk as many conventional power plants. Additional aspects that must be understood include nuclear safety and radioactive release.

The goals and performance objectives / criteria for fire protection of a nuclear power plant include –

- Nuclear safety
- Radioactive release
- Life safety
- Plant damage / business interruption

6.5.2 Fire Protection System Measures

Fire protection system measure recommendations as per NFPA 805 [92] and the International Guidelines for the Fire Protection of Nuclear Power Plants [115] shall apply. Section 3 to Section 5 of this document must be taken into consideration in determining site fire risk control measures.

6.6 BATTERY ENERGY STORAGE SYSTEMS

An energy storage system (ESS) is defined as one or more devices, assembled and capable of storing energy to supply electrical energy at a future time to the local power loads, to the utility grid, or for grid support. There are four types of ESS which includes:

- Electrochemical – Consists of a secondary (rechargeable) battery, electrochemical capacitor, flow battery of hybrid battery-capacitor system that stores electrical energy and any associated controls or devices that can provide the stored electric energy upon demand.
- Chemical – Consists of hydrogen storage. The hydrogen generator supplies hydrogen for storage, and fuel cell power system provides electric energy upon demand.
- Mechanical – Consists of mechanical means to store energy like through compressed air, pumped water or fly wheel technologies, associated controls and systems. It can be used to run an electric generator that provides electric energy upon demand
- Thermal – Consists of a system that uses heated fluids like air to store energy along with associated controls and system. These can be utilized to run an electric generator that provides electrical energy upon demand.

A battery energy storage system (BESS) is an electrochemical ESS. The purpose of a BESS application in a power system can include - frequency regulation, load following, voltage support, transmission congestion relief, renewable capacity firming, electrical energy time shift, power quality enhancement, peak shaving, electric bill management, etc.

6.6.2 General

The Eskom Standard, Battery Energy Storage Systems for Grid-scale Applications [32] sets out to describe the technical requirement for a complete BESS system and associated plant for Eskom.

The battery technology that is selected for as BESS system requires careful consideration. The most critical fire hazard aspect to consider in terms of the selected battery technology is “Thermal Run-Away”. Thermal run-away is the condition when an electrochemical cell increases its temperature through self-heating in an uncontrollable fashion and progresses when the cell’s heat generation is at a higher rate than it can dissipate, potentially leading to off-gassing, fire, or explosion.

There have been various fires across the world in BESS systems. This is mainly linked to thermal run-away in lithium-ion batteries. Fire events have occurred during every stage of project implementation, even in some cases before the BESS system was even commissioned. Emergency response measures in a fire event is critical.

6.6.3 Fire Protection System Measures

Fire protection system measures shall be incorporated though product quality, design, plant layout, quality installation and inspection testing and maintenance. An inherently safe design, integrated as part of the systems is critical as very little from a fixed fire protection perspective can be done to control a fire once thermal run-away has started in BESS systems.

The following resource developed through the Electrical Power Research Institute (EPRI) gives significant insight into all aspects that must be incorporated to prevent a fire from starting as well as to control a fire that have started in an ESS –

- Energy Storage Integration Council (ESIC) Energy Storage Reference Fire Hazard Mitigation Analysis [118].

Fire protection system measure recommendations as per NFPA 855 [94], UL 9540 [116] and UL 9540A [117] shall apply. Section 3 to Section 5 of this document must be taken into consideration in determining site fire risk control measures.

There are various fixed fire protection methods with various suppression mediums (including gaseous an aerosol) that have been provided with the battery units that come with BESS systems. Some OEMs have also provided these units without any fixed fire protection indicating that the system is designed and built (inherently safe with passive measures) to only loose one unit in a fire event. An important consideration is also if the fixed fire protection has been certified for that OEM for thermal run-away of the batteries or if the fixed fire protection consideration is for a fire events other than thermal run-away.

Fire protection system measure requirements for batteries located indoor on outdoor should consider the following –

a) Location – remote location or location near other exposures.
b) Size, separation and means of egress.
c) Maximum stored energy.
d) Elevation and enclosure (e.g. walk in units).
e) Clearance to other exposures and vegetation control.
f) Smoke and fire detection.
g) Fire control and suppression (e.g. availability of water supply).
h) Thermal run away.
i) Explosion control – explosion prevention, deflagration venting.

All of this said, it is important to take specific project requirements into consideration. This includes the fact that battery technologies, chemistry, design, and configuration are different from OEM to OEM.

7. AUTHORISATION

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8. REVISIONS

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9. DEVELOPMENT TEAM

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11. ANNEXURE A: SEPARATION DISTANCE REQUIREMENTS - EXAMPLES

11.1 SCOPE

This section provides guidance on the methods available for the evaluation of separation distances between buildings, major equipment, activities, and processes to limit exposure to radiant heat.

Application of the three design approaches discussed in Section 3 (Deemed to Satisfy, Code-Compliant or Fire Engineered) is illustrated through various Examples.

11.2 APPLICATION

The first step in determining separation distances is to determine what the design objective is. If the design objective aligns with the objectives typically found in prescriptive codes or standards (e.g. to determine the required spatial separation between buildings or structures to prevent fire spread via radiant heat), a DTS or code-prescriptive design approach could possibly be used. If this is not possible or desirable, a fire engineered design approach will have to be adopted. Situations where a prescriptive approach (DTS or code-compliant) may not be suitable include:

- Where there is no guidance in industry standards or codes for the particular application;
- The recommended separation distances in industry standards and codes cannot practically be met;
- The application under consideration is more hazardous than assumed by the industry standards and codes;
- The application under consideration is considerably less onerous than assumed in the industry standards and codes and a reduction in separation distance is desirable;
- The risk is higher (high value or important structure) than implicit in the industry standards and codes;
- The conditions and assumptions inherent in the prescriptive guidance cannot be met (e.g. the separation distances may be based on the availability of an attending fire brigade).

Application of the three design approaches is illustrated by way of Examples in Section 11.4 through to Section 11.6.

11.3 OBJECTIVES

The objectives of allowing for spatial separation between buildings, equipment, people and plant could involve any of the following:

- Meet code requirements for building approval purposes;
- Prevent building-to-building fire spread;
- Prevent/limit damage to plant or equipment exposed to radiant heat from a possible fire (process equipment, electrical cables etc.);
- Prevent harm to people that could possibly be exposed to radiant heat (plant operators required to perform essential functions, escape routes to be kept tenable etc.);
- Allow for manual fire-fighting activities to be performed;

It is therefore important that the objectives of allowing for spatial separation are clearly understood to enable an informed decision to be made about the adequacy of the provisions.

A disadvantage of following a DTS or rational code-prescriptive design approach is that the objectives are sometimes not clearly defined and the user could be uncertain whether the recommended distances relate to limiting exposure to radiant heat or whether there are other practical reasons. Another problem could be that there could be uncertainty about the basis of the guidance, e.g. what endpoint criteria (e.g. the maximum heat flux) are considered acceptable. As a result, there often are conflicting recommendations between documents from various sources, and the designer is faced with the problem of deciding which source to use. Regardless of source, once selected, all the guidance contained in that document or suite of documents needs to be followed exactly as there is often an inter-dependence between the fire safety features/systems and construction detail. The main advantages of following a code-prescriptive approach are the simplicity of use, and the knowledge that the guidance is generally accepted in industry as best practice.

The advantage of a fire engineered approach is that the exposure hazard and associated consequences are quantified, thereby allowing an informed decision to be made. The main disadvantage is that a high level of fire engineering knowledge is required to perform the analyses. Time constraints and the complexity of modelling required could be additional drawbacks.

11.4 EXAMPLES - DEEMED TO SATISFY DESIGN

11.4.1 Example 1 – Building Separation

Problem statement

It is proposed to construct a new office building on a power station site. An open area adjacent to a warehouse has been identified as a possible location. In order to determine whether the area is large enough to accommodate the office building, it is necessary to determine the required separation distance between the warehouse and the office building.

The warehouse is used for the storage of lubricating oil in 220 L drums. It is a steel framed building with sheet metal cladding, is 50 m long by 25 m wide and has a height of 6 m. It is not sprinkler protected.

The proposed office building is 30 m long by 12 m wide and consist of two storeys. It has 300 mm thick brick cavity external walls (15 mm plaster + 110 mm solid clay brick + 50mm cavity + 110 mm solid clay brick + 15 m plaster). The eaves height is 6 m. The largest window area per elevation is in the longer side of the building and consists of 6 no. equally spaced windows (2 m wide by 1.5 m high) per floor. There is no fire separation between the lower and upper floors.

Solution

SANS 10400-T [61] provides a DTS approach that is amenable to this problem and will therefore be followed. Note that SANS uses the term “Safety distance” for separation distance.

Step 1: Determination of safety distance from warehouse

The warehouse is classified as a J1 occupancy in terms of SANS 10400-T Table 6 [61].

The external wall of the warehouse does not have a fire resistance and is classified as a Type N wall (SANS 10400-T Clause 4.2.1 (c)). As such, the total wall area of the largest elevation is considered as an opening:

$$\mathrm{A} = 50 \text{ x } 6 = 300 \text{ m}^2$$

From SANS 10400-T Table 2, under High Fire Load, we find the safety distance to the notional boundary to be 11.0 m.

Table 2 — Safety distances

1	2	3	4
Area of openings in elevation	Low fire load $\leq$ 25 kg/m^2 (timber equivalent)	Moderate fire load > 25 kg/m^2; < 50 kg/m^2 (timber equivalent)	High fire load $\geq$ 50 kg/m^2 (timber equivalent)
	Occupancy class		
	A1, A2, A3, A4, A5, B3, C2, D3, D4, E1, E2, E3, E4, G1, H1, H2, H3, H4, H5, J3, J4	B2, C1, D2, F1, F2, F3, J2	B1, D1, J1
m^2	Minimum safety distances m		
Type F wall (no openings)	1,0	1,5	2,0
< 5	1,0	1,5	2,0
5	1,5	2,0	2,7
7,5	2,0	2,2	3,5
10	2,4	2,5	3,7
30	3,8	4,6	6,2
50	4,5	5,5	7,3
70	5,0	6,0	8,0
90	5,3	6,4	8,6
110	5,5	6,7	9,0
130	5,7	7,0	9,3
150	5,9	7,2	9,6
170	6,1	7,4	9,9
190	6,2	7,5	10,1
210	6,3	7,7	10,3
230	6,4	7,8	10,5
250	6,5	8,0	10,6
270	6,6	8,1	10,8
290	6,7	8,2	10,9
310	6,8	8,3	11,1
330	6,9	8,4	11,2

Step 2: Determination of safety distance from office building

The office building is classified as a G1 occupancy in terms of SANS 10400-T Table 6 [61].

From SANS 10400-T Table 13 [61], it is seen that the external brick cavity wall of the office building is deemed to have a fire resistance in excess of 240 minutes. The wall can therefore be regarded as a type FR wall as it exceeds the 30 minute fire resistance requirement of SANS 10400-T Table 1 for a G1 occupancy.

As the floors are not fire separated, the area of all the openings in the elevation should be considered in the safety distance calculation.

$$A = 2(6 \text{ x } 2 \text{ x } 1.5) = 36 \text{ m}^2$$

From SANS 10400-T Table 2 [35], we see that 36 m^2 lies between 30 m^2 and 50 m^2. Opting to use the formula (for Low Fire Load) provided in Table 2 rather than interpolating, we find the safety distance:

$$D = 2.75 \log(A) - A^{-0.5} = 2.75 \log(36) - 36^{-0.5} = 4.1 \text{ m}$$

Step 3: Separation distance between buildings

The separation distance between buildings is therefore the sum of the two calculated safety distances = 15.1 m.

11.4.2 Example 2 – LPG Tank Separation

Problem statement

It is proposed to install a 5,000 L bulk LPG tank as close as possible to the building where the LPG will be used. What is the closest allowable distance between the tank and the building?

Solution

Requirements for the installation of bulk LPG storage tanks in excess of 500 L is given by SANS 10087:3 [51] (as refer to by SANS 10400-T Clause 4.53.1.1 [61]).

Step 1: Safety distance

Referring to SANS 10087:3 Table 1 below, a safety distance of 7.5 m is found.

Table 1 — Safety distances

1	2	3	4	5	6	7
Water capacity of storage vessel L	**Minimum safety distances** m					
	From above-ground storage vessel to points of transfer[a]	**From above-ground storage vessel to buildings and property boundaries**	**From buried and mounded storage vessel to buildings, property boundaries and points of gas release**	**From sealed surface equipment to building and property boundaries**	**From open flame equipment to building and property boundaries**	**Between above-ground LPG storage vessels**
500 – 2 250	5,0	5,0	3,0	3,0	5,0	¼ of sum of diameters of adjacent storage vessels
2 251 – 9 000	7,5	7,5	5,0			
9 001 – 67 500	9,5	9,5	7,0			
67 501 – 135 000	15,0	15,0	15,0			
135 001 – 265 000	15,0	22,5	15,0			
> 265 000	15,0	30,0	15,0			

[a] For points of transfer or filling points see clause 15 and figure 3.

11.4.3 Example 3 – Diesel Tank Separation

Problem statement

An emergency generator is to be installed at a power station. The generator is to be supplied with diesel from 28,000 L tanks installed in a 6.0 m x 6.0 m bund. It is not proposed to protect the bund with an automatic foam fire suppression system.

The proposed location of the diesel tank is 10.0 m away from an important building housing a control room. Is the tank far enough from the building?

Solution

Step 1: Determine classification of diesel

Guidance for the installation of diesel tanks with a capacity less than 200 m^3 is given in SANS 10131 [55].

SANS 10131 classifies petroleum products in terms of their closed-cup flashpoints as follows:

3.9
class
class of petroleum product, based on the following classification:
a) class 0: liquefied petroleum gas;
b) class I: liquids, subdivided as follows:
- class IA: liquids that have a closed-cup flash point of below 23 °C and a boiling point of below 35 °C;
- class IB: liquids that have a closed-cup flash point of below 23 °C and a boiling point of 35 °C or above;
- class IC: liquids that have a closed-cup flash point of 23 °C or above, but below 38 °C;
- class II: liquids that have a closed-cup flash point of 38 °C or above, but below 60,5 °C;
- class IIIA: liquids that have a closed-cup flash point of 60,5 °C or above, but below 93 °C;
- class IIIB: liquids that have a closed-cup flash point of 93 °C or above

From manufacturer's information, diesel is seen to have a flashpoint of approximtely 55°C. It is therefore a Class II liquid.

Step 1: Determine safety distance

From SANS 10131 Table 2 (see below), the safety distance to an important building is found to be 1.5m. Therefore the proposed location of the diesel tank at 10.0 m away is acceptable.

Table 2 — Minimum safety distances for tanks with class I, II and IIIA liquids at an operating pressure of 17,2 kPa or less

1	2		3	
Individual tank capacity m^3	**Minimum safety distance from the boundary of a property that is built on or can be built on, including the far side of a public road** m		**Minimum safety distance from the near side of a public road, or from the nearest important building on the same property** m	
	Class I liquids	**Class II or IIIA liquids**	**Class I liquids**	**Class II or IIIA liquids**
1,001 to 2,200	3	1,5	1,5	1,5
2,201 to 45,000	4,5	3,0	1,5	1,5
45,001 to 85,000	6	4,5	1,5	1,5
85,001 to 200,000	9	6	3	3

11.5 EXAMPLES – CODE COMPLIANT DESIGN

11.5.1 Example 4 – Transformer separation

Problem

An oil-insulated transformer contains 22,000 L of non-fire-resistant transformer oil. The transformer is installed outdoors in a containment bund 12.0 m long x 7.0 m wide x 0.3m high. What is the minimum distance between the tank and an important building on the site?

Solution

Step 1: Find alternative Standard

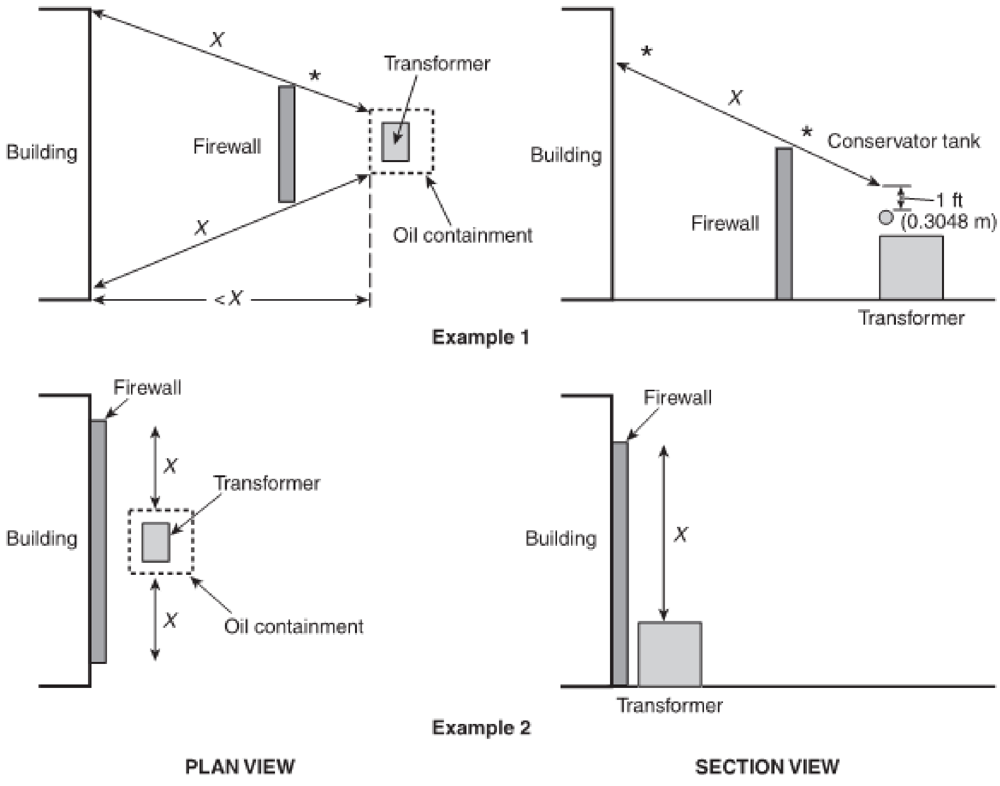
There is no SANS Standard that specifically addresses transformers. As such, it is proposed to perform a rational design by using an internationally accepted Standard as alternative. NFPA 850 [93] has been identified as containing guidance on separation distances between transformers and structures.

Step 2: Determine separation distance

Refering to NFPA 850 Table 5.1.4.3 (see below), the recommended separation distance is 15.0 m.

Table 5.1.4.3 Outdoor Oil-Insulated Transformer Separation Criteria

Transformer Oil Capacity		Minimum (Line-of-Sight) Separation Without Firewall	
gal	L	ft	m
<500	<1,890	See 5.1.4.2	
500–5000	1,890–18,925	25	7.6
>5000	>18,925	50	15



X: Minimum separation distance from Table 5.1.4.3.
*: See A.5.1.4.3.

FIGURE 5.1.4.3 Illustration of Oil-Insulated Transformer Separation Recommendations.

Figure 2: NFPA 850 outdoor transformer separation recommendations.

11.5.2 Example 5 – Building Separation

In this example, the building separation problem given in Example 1 is calculated according to the method presented in NFPA 80A [81].

Whereas the calculation method presented in SANS 10400-T is based on the distance to a notional boundary between buildings (necessitating calculations to be performed for both buildings), the method in NFPA 80A calculates the required separation distance between buildings, i.e. the greater of the separation distance calculated for either building is the required separation distance. The separation distance between the buildings is determined in a way to protect the exposed building and its contents from igniting due to piloted ignition. Determination of separation distances are based on the assumption that neither of the buildings is fitted with means of protection against fire by, for example, sprinklers or fire resistant glazing.

As the warehouse represents the severest hazard, the calculation is performed for the warehouse. The fire is assumed to penetrate the exterior walls of the warehouse within 20 minutes, giving 100% openings in the exposing wall. The width and height of the exposing fire are therefore the same as the façade dimensions, i.e. 50 m x 6 m and 25 m x 6 m respectively.

Step 1: Determine fire severity

The warehouse can be assumed to have a severe fire severity, as the fire load is likely to exceed 74kg/m^2 (wood equivalent), the minimum value listed in NFPA 80A Table 4.3.5.2(a) to be considered as presenting a severe hazard. This can be demonstrated as follows by calculating the minimum litres of oil required to achieve this value:

Multiplying the fire load of 74kg/m^2 by the floor area, the equivalent mass of wood is found:

Fire load = 25m x 50m x 74kg/ m^2 = 92,500 kg

As wood has a heat of combustion of approximately 20,000 kJ/kg, the fire load energy in the building is 92,500kg x 20.0MJ/kg = 1,850,000 MJ. From Table 8 Section 11.6.1.2 (of this document) it is seen that transformer oil has a heat of combustion of 46,400 kJ/kg. The equivalent kilogram of oil is then 1,850,000/46.4 = 39,700 kg. Taking the density of the oil as 880 kg/m^3, this equates to approximately 205 no. of 220 L drums – a number than can easily be accommodated in the building.

Step 2: Guide number

In order to find the appropriate guide number g from NFPA 80A Table 4.4, the ratio between the height and width of the exposing fire needs to be calculated.

W/H = 50/6 = 8.33

Interpolation in Table 4.4 gives the guide number g, as follows:

g = 8.01

Note that NFPA 80A Table 4.4 already is based on a critical incident radiation of 12.5 kW/m^2 and therefore, no further modifications needs to be done with regards to ignition criteria.

The separation distance between the buildings can now be determined as explained below:

D = g x lesser dimension of either the width or height + 1.5 m = 8.01 x 6 + 1.5 = 49.9 m.

It is important to note that the method of determining separation distances in NFPA 80A contemplates Fire Brigade intervention. At locations where Fire Brigade intervention can not be guaranteed within reasonable time, NFPA 80A recommends that the separation distance be extended by multiplying by a factor of up to three.

This result is vastly different to the 15.5 m calculated by the SANS method.

Possible reasons for this could be:

- The SANS method assumes the exposure risk to a building located beyond the notional boundary to be dependent of the size of openings in the façade. Combustibles inside the exposed building could in reality be ignited through any size opening. As an example, the SANS method would have required two similar warehouses to be located 22 m apart.

- SANS Table 2 considers a high fire load to be one that is equal or greater than 50kg/m^2 (wood equivalent). This value however lies within the moderate fire severity grouping of NFPA 80A. SANS 10400 Table 2 therefore significantly underestimates high fire loads (in this case by more than 50%).

Separation distances should be determined using both methods with consideration being given to the worst case result.

11.6 EXAMPLES – FIRE ENGINEERED DESIGN

11.6.1 Applicable Theory

In the following sections, models for calculating the radiative heat flux emitted from buildings fires and fires in the open are presented.

Due to the complexity involved in calculating the radiation from bush fires, gas and dust explosions, deflagrations, fire balls and BLEVE's, these fire phenomena are not discussed. Specialist fire engineering advice should be sought.

11.6.1.1 Thermal Radiation Limits

A performance-based approach to separation distances involves the estimation of the distance from a fire where the calculated heat flux is below a specified value. This value is typically referred to as the acceptance criterion, or heat flux damage limit (HFDL) and depends on the specific objective (preventing harm to people, damage to equipment etc.).

Recommended thermal radiation limits from various sources are given in the tables below. Note that different documents may list slightly different values.

Table 6: Typical thermal heat flux damage limits (Reference 1)

Radiation intensity [kW/m^2]	Effect
1.2	Received from the sun at noon in summer.
2.1	Minimum to cause pain after 1 minute.
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds' exposure (at least second degree burns will occur).
12.6	• Significant chance of fatality for extended exposure. High chance of injury. • Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure. • Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure.
23	• Likely fatality for extended exposure and chance of fatality for instantaneous exposure. • Spontaneous ignition of wood after long exposure. • Unprotected steel will reach thermal stress temperatures which can cause failure. • Pressure vessel needs to be relieved, or failure would occur.
35	• Cellulosic material will pilot ignite within one minute's exposure. • Significant chance of fatality for people exposed instantaneously.

Table 7: Typical thermal heat flux damage limits (Reference 2)

B Design guidance: API RP 510: 1990

Thermal radiation intensity (kW/m^2)	*Limit*
15.6	Intensity on structures where operators are unlikely to be performing and where shelter is available
9.5	Intensity at design flare release at locations to which people have access and where exposure would be limited to a few seconds for escape
6.3	Intensity in areas where emergency actions lasting up to 1 minute may be required without shielding but with protective clothing
4.7	Intensity in areas where emergency actions lasting up to several minutes may be required without shielding but with protective clothing
1.6	Intensity at design flare release at locations where people are continuously exposed

D Design and assessment guidance – BS 5980: 1990[b]

Thermal radiation intensity (kW/m^2)	*Limit*
37.5	Intensity at which damage is caused to process equipment
25	Intensity at which non-piloted ignition of wood occurs
12.5	Intensity at which piloted ignition of wood occurs
4.5	Intensity sufficient to cause pain to personnel unable to reach cover in 20 seconds, though blistering of skin (first degree burns) unlikely
1.6	Intensity insufficient to cause discomfort for long exposures

In most instances where damage to equipment is concerned, a simple radiation damage threshold value as listed above may not be adequate and detailed heat transfer analyses may be required taking into consideration the exposure time and geometry and properties of the material at risk.

11.6.1.2 Heat Release Rate of Fire

Most radiation calculations require that the total heat release rate (HRR) of the fire to be known or estimated.

For ordinary combustibles (non-liquids), there are numerous methods for estimating the HRR of the fire. These methods are not discussed here as ordinary combustibles will seldom be the subject of a separation distance assessment in the context of power stations. In contrast, flammable liquids are stored on site in large quantities and could be the source of large pool fires.

For flammable liquids, the HRR of the fire remains essentially constant once the flame has spread across the liquid pool. The HRR is a function of the mass burning rate $\dot{m}''$, the effective heat of combustion Δh_{eff} of the liquid and the pool area A_f as follows:

$$\dot{Q}_t = \dot{m}''\Delta h_{eff} A_f$$

Equation 1

where $\dot{Q}_t$ = total heat release rate of fire, [kW]

$\dot{m}''$ = mass burning rate of fuel, [kg/s]

Δh_{eff} = effective heat of combustion, [kJ/kg]

A_f = area of pool, [m^2]

Note that the effective heat of combustion Δh_{eff} is less than the net heat of combustion Δh_c (which is determined by oxygen bomb calorimeter) and accounts for incomplete combustion. However, as large–

scale measurements of the effective heat of combustion are not readily available, the net heat of combustion is conservatively used, implying that the combustion efficiency is 100%.

The mass burning rate of liquid fuels are given by:

$$\dot{m}'' = \dot{m}''_{\infty}[1 - e\,(-k\beta D_f)]$$

Equation 2

where $\dot{m}''_{\infty}$ = asymptotic mass burning rate as the pool diameter increases to infinity, [kg.m^{-2}.s^{-1}]

$k\beta$ = mean beam length corrector-flame attenuation coefficient of fuel, [m^{-1}]

D_f = flame diameter, [m]

The above pool burning constants are given in the table below for a few common liquid fuels.

Table 8: Pool Burning: Empirical Constants for a Number of Common Hydrocarbon Fuels [112], [113]

Liquid	Δh_c [kJ kg^{-1}]	$\dot{m}''_{\infty}$ [kg m^{-2} s^{-1}]	$k\beta$ [m^{-1}]
Gasoline	43,700	0.055 (±0.002)	2.1 (±0.3)
Kerosene	43,200	0.039 (±0.003)	3.5 (±0.8)
Transformer oil, hydrocarbon	46,400	0.039	0.7
Fuel Oil (heavy)	39,700	0.035 (±0.003)	1.7 (±0.6)
Crude Oil	42,600	0.060	0.62
No. 2 Diesel Fuel	39,700	0.035	

The SFPE Handbook of Fire Protection Engineering discusses various methods for estimating the surface area of an unconfined fuel spill. For simplicity, the diameter of an unconfined spill will be estimated by assuming that the liquid depth is approximately 13 mm [112], giving the following equation:

$$D_s = 10\sqrt{V}$$

Equation 3

where D_s = spill diameter, [m]

V = volume of liquid spill, [m^3]

11.6.1.3 Emitted Radiation

The emissive power of a flame can be expressed as:

$$E_f = \varepsilon_f \sigma (T_f^4 - T_a^4) = \frac{\chi_r \dot{Q}}{PH_f}$$

Equation 4

where: E_f = emissive power of flame, [kW/m^2]

ε_f = emissivity of flame

σ = Stefan-Boltzmann constant = 5.67x10^{-11} kW/m^2

T_f= temperature of the surface, [K]

T_a= ambient temperature, [K

$\dot{Q}$ = total heat release rate (HRR) of fire, [kW]

χ_r = radiative fraction (fraction of energy lost via radiation)

P = perimeter of flame, [m]

H_f = height of flame, [m]

From this equation it is seen that the emissive power of a fire can be estimated if either:

a) the emissive power is approximated by an empirical correlation, or

b) the flame emissivity and average flame temperature; or

c) the radiative fraction, HRR and flame surface area are known.

Models employing method (a) are usually associated with large hydrocarbon fires. Method (b) is used for calculating the radiation emitted from building openings, and method (c) is used in models for unconfined fires.

11.6.1.4 Flame Emissivity

Radiation emitted from flames depends on the type of fuel and the size of the fire. The radiation comes primarily from the glowing soot particles in the flame, except for clean burning fuels like methanol where the thermal radiation is emitted from the carbon dioxide and water vapour produced by the combustion process. The emissivity of a flame can be expressed as:

$$\varepsilon_f = 1 - \exp\,(kL)$$

Equation 5

where: k = effective emission coefficient and is fuel dependent, [m^{-1}]

L = effective beam length, [m]

The effective beam length is typically taken as the diameter of the flame, D_f. From Equation 5 it is seen that as the fire diameter becomes large, $\varepsilon_f \rightarrow 1$.

Typical values for the effective flame emission coefficient are given in the table below.

Table 9: Radiative Properties for Soot Particles

Fuel	k [m^{-1}]	Flame temperature [K]
Diesel Oil	0.43	
Furniture (assorted)	1.13	
Petrol (gasoline)	2.0	1240
Wood cribs	0.8	1732

11.6.1.5 Radiative Fraction

In general, the radiative fraction χ_r (fraction of total energy radiated) depends on the type of fuel and the size of the fire. It can vary from as low as 0.15 for low soot producing fuels such as alcohols, to 0.60 for high soot-producing fuels. The radiative fraction initially increases with fire diameter, before decreasing when the fire diameter becomes very large. For very large fires (greater than several meters in diameter), large amounts of soot tend to escape from the combustion zone to congregate around the flames. These relative cool soot particles absorb a considerable amount of radiation, and can reducing χ_r significantly.

Some values for χ_r are given in the table below for relatively small fires.

Table 10: Radiative Fraction for Various Fuels

Fuel	χ_r
Methyl Alcohol	0.16
Heptane	0.33
Kerosene	0.35
Polyurethane	0.59
Polystyrene	0.59
PMMA	0.31
Wood (Douglas Fir)	0.38
Wood (Red Oak)	0.37

The decrease in radiative fraction with increasing fire diameter is shown in the figure below.

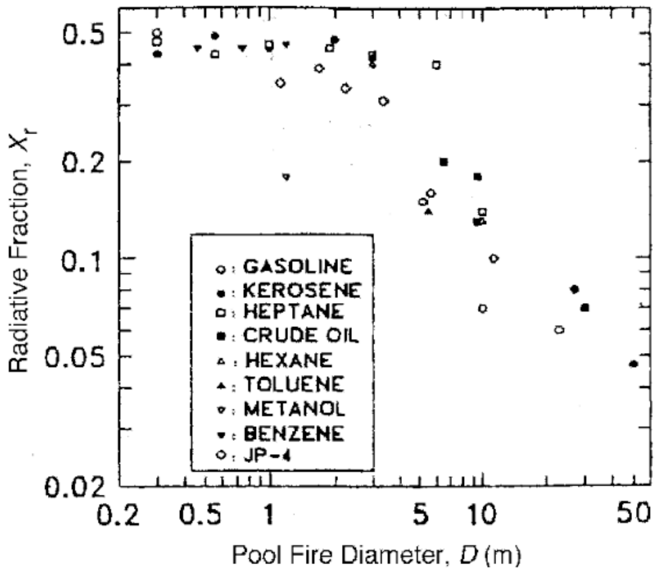


Figure 3: Radiative fraction as function of pool diameter for various hydrocarbon fuel fires

The radiative fraction of large hydrocarbon fuel fires can be estimated from the following empirical correlation [112]:

$$\chi_r = \chi_{r\,max} e^{-kD_f}$$

Equation 6

where $\chi_{r\,max}$ = 0.35, k = 0.05 m^{-1} and D_f is the flame diameter.

11.6.1.6 Radiation Received

The amount of radiation from a fire reaching a target surface depends on the shape and position of the flame relative to the target, as well as the orientation of the target surface. This is expressed as a view factor, F (also called a shape or configuration factor).

The radiative heat flux from a fire received at a target can therefore be expressed as:

$$\dot{q} = \tau F E_f$$

Equation 7

Where: $\dot{q}$ = heat flux received at target, [kW/m^2]

F = view factor (portion of target surface visible to flame)

τ = atmospheric transmissivity

11.6.1.7 Atmospheric Transmissivity

Radiation adsorption by the atmosphere over long lengths can be significant if the flame emits radiation in the spectral absorption bands of the carbon dioxide and water vapour. This effect is usually negligible for sooty flames so that $\tau \approx 1$.

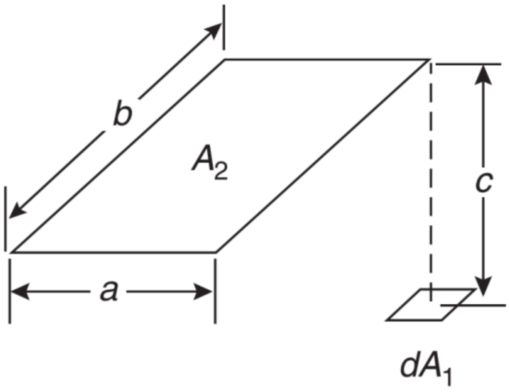
It is however important when the target is screened from the fire by a water curtain, a technique sometimes used to mitigate against radiation exposure.

11.6.1.8 View Factor

In order to facilitate the calculation of the view factor, the flame shape is usually approximated as either a rectangle (flat sheet) or cylinder.

<u>Rectangle</u>

The view factor for a plane element parallel (V) and perpendicular (H) to a rectangle with the normal of the element passing through the corner of the rectangle is given by:

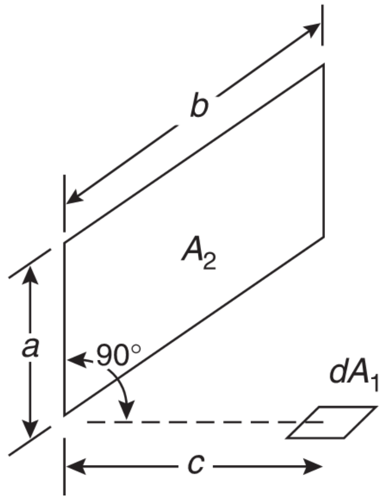


$$F_V = \frac{1}{2\pi}\left(\frac{X}{1+X^2}\tan^{-1}\frac{X}{\sqrt{1+X^2}} + \frac{X}{1+Y^2}\tan^{-1}\frac{X}{\sqrt{1+Y^2}}\right)$$

$$X = \frac{a}{c} \qquad Y = \frac{b}{c}$$

Equation 8

The view factor for a plane element perpendicular (H) to a rectangle with the normal of the element passing through the corner of the rectangle is given by:



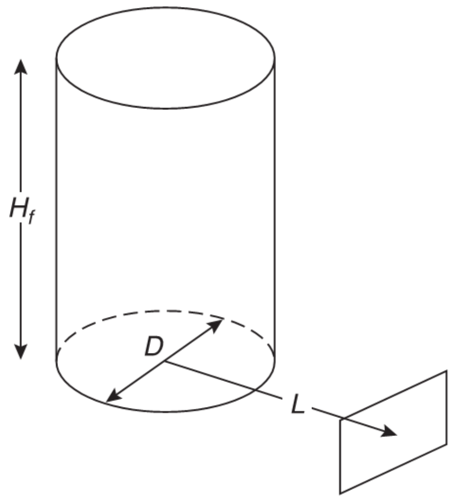
$$F_H = \frac{1}{2\pi}\left(\tan^{-1}\frac{1}{Y} - \frac{Y}{\sqrt{X^2+Y^2}}\tan^{-1}\frac{1}{\sqrt{X^2+Y^2}}\right)$$

$$X = \frac{a}{b} \qquad Y = \frac{c}{b}$$

Equation 9

<u>Cylinder</u>

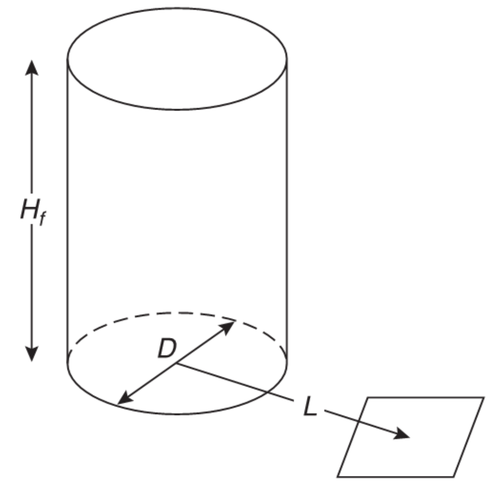
The view factor from a planar element to a cylinder with finite length, and with the normal to the element passing through the axis at the bottom of the cylinder is given by:



$$F_V = \frac{1}{\pi S}\tan^{-1}\frac{h}{\sqrt{S^2-1}} - \frac{h}{\pi S}\tan^{-1}\sqrt{\frac{(S-1)}{(S+1)}} + \frac{Ah}{\pi S\sqrt{(A^2-1}}\tan^{-1}\sqrt{\frac{(A+1)(S-1)}{(A-1)(S+1)}}$$

Equation 10

where A,S and h are defined in Equation 12 below.



The view factor from a planar element to a cylinder with finite length, and with the normal to the element passing through the axis at the bottom of the cylinder is given by:

$$F_H = \frac{(B - 1/S)}{\pi\sqrt{B^2 - 1}} \tan^{-1} \sqrt{\frac{(B + 1)(S - 1)}{(B - 1)(S + 1)}} - \frac{(A - 1/S)}{\pi\sqrt{A^2 - 1}} \tan^{-1} \sqrt{\frac{(A + 1)(S - 1)}{(A - 1)(S + 1)}}$$

Equation 11

where A,B, S and h are given by Equation 12:

$$A = \frac{h^2 + S^2 + 1}{2S} ; B = \frac{1 + S^2}{2S}$$

$$S = \frac{2L}{D} ; h = \frac{2H}{D}$$

Equation 12

Maximum View Factor

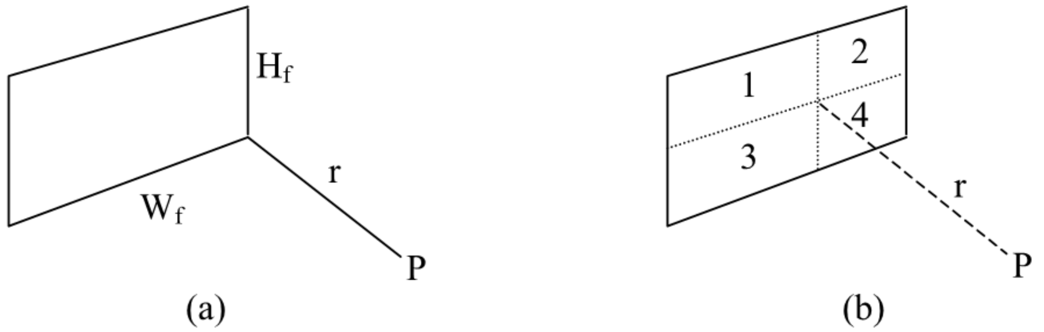
As the maximum heat flux at the target is not necessarily oriented parallel or orthogonal to the flame, the maximum view factor needs to be calculated from:

$$F_{max} = \sqrt{F_H + F_V}$$

Equation 13

Additive Properties

The applicability of the equations for the view factors given above may at first seem limited as it is given to relative to a corner of a rectangle or the base of a cylinder. However, as view factors are additive, the above equations can be used for a wide range of applications by the judicious selection of rectangles and cylinders. The additive property requires that the view factors for each contributory part be calculated from the same receiver, P, as shown below.



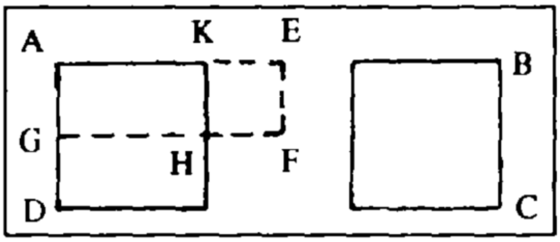
$$F_T = F_1 + F_2 + F_3 + F_4$$

Equation 14

Where: F_T = *total view factor,*

F_n = *view factor for part n*

To illustrate the concept, consider a building with two identical windows in the façade as shown below.



The maximum view factor for both windows will lie in line with point F. As such, the total view factor can be calculated from:

$$F_T = 4(F_{AGEF} - F_{KHFE})$$

<u>View Factor Simplification</u>

If a fire perimeter is irregularly shaped, cylinders or flat plates can be used as surrogates for the perimeter provided that they completely block the view of the fire from the observer. The view factor for a flat plate or cylinder can be used to simplify the calculation as shown in Figure 4.

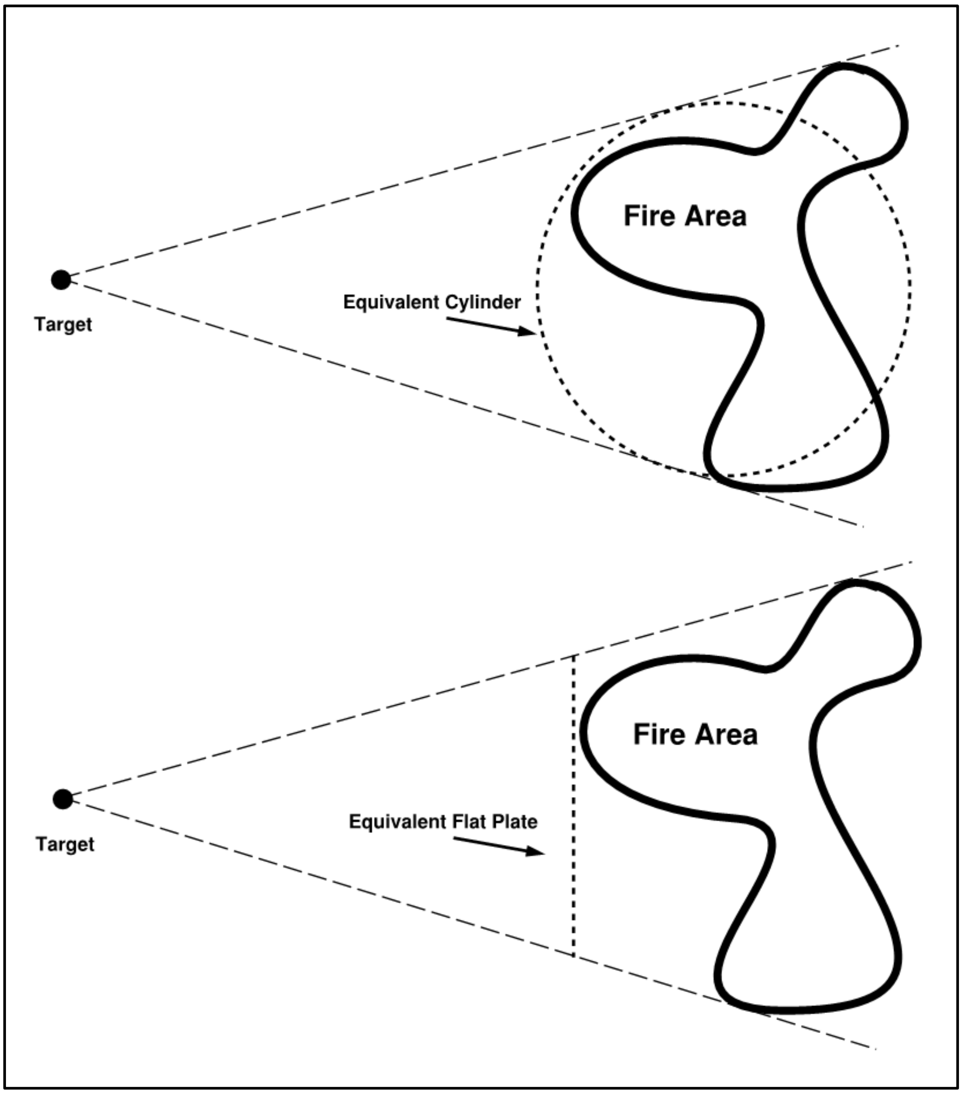


Figure 4: Diagram showing how a cylinder or flat plate is used to simplify a view factor calculation.

11.6.1.9 Flame Characteristics

The diameter of a fire can be estimated from:

$$D_f = \sqrt{\frac{4A_f}{\pi}}$$

Equation 15

where D_f = diameter of fire, [m]

A_f = surface area of a non-circular fire, [m^2]

The flame length for a free-burning fire can be estimated from the Heskestad correlation:

$$H_f = 0.235\dot{Q}^{2/5} - 1.02D$$

Equation 16

where H_f = height of flame, [m]

$\dot{Q}_t$ = total heat release rate (HRR) of fire, [kW]

D_f = diameter of fire, [m]

11.6.1.10 Radiation Emitted from Building Fires

11.6.1.10.1 Compartment Temperature

Building codes require that large buildings be compartmented into smaller areas with fire-rated construction in order to limit the maximum possible size that a fire could possibly reach. External walls are often also required to be fire-rated to prevent fire spread between buildings. Where unprotected openings occur in fire-rated external walls, fire spread between buildings is possible as a result of thermal radiation emitted through window and door openings.

The highest level of thermal radiation emitted through window openings is found when the whole of the compartment is involved in fire and the compartment temperature is high. An enclosure fire can either be fuel controlled or ventilation controlled, depending on the availability of oxygen for combustion. A ventilation-controlled fire occurs when the fire size is limited by the amount of air that can flow through openings into the compartment. For relatively high fuel loads, maximum compartment temperatures of around 1040°C has been measured, which represents a maximum radiation intensity of 168 kW/m^2. For low fuel loads (25 kg/m^2 wood equivalent), the compartment temperature is typically around 800°C, which represents a radiation intensity of 84 kW/m^2. These values have been used in the derivation of the separation distances in several prescriptive building codes.

When undertaking a fire engineered approach, it is usually necessary to estimate the maximum compartment temperature that can be expected during a fully involved compartment fire. It is therefore necessary to have an understanding on the factors that influence the maximum post-flash over compartment fire temperature. The compartment temperature depends on the fuel load, the heat loss to the compartment bounding surfaces, and the compartment openings which influence ventilation (air supply for combustion) and the convective heat loss associated with the outflowing smoke.

There are various methods available for estimating the maximum compartment temperature. One such equation is the Law correlation (BS EN 12101-3 [114]) which has been derived from experimental measurements of the maximum compartment temperature recorded for a large number of wood-crib fires in small-scale compartments:

$$T_{comp} - T_a = 6000\frac{[1 - \exp(-0.10\eta)]}{\eta^{0.5}}[1 - \exp(-0.05\psi)]$$

Equation 17

where: $\eta = \frac{A_T}{A_w h^{0.5}}$,[m$^{-1/2}$]

$\psi = \frac{L}{(A_w A_T)^{0.5}}$,[kg/m^2]

T_{comp} = compartment fire temperature, [K]

T_a = ambient temperature, [K]

A_T = total internal surface area (floor, ceiling and walls minus area of openings), [m^2]

A_W = sum of wall opening area (windows and doors), [m^2]

h = height or weighted average height of openings on walls, [m]

L = fire load [kg, wood equivalent] (heat of combustion of wood is taken as 16 MJ/kg)

Note that the above equation is independent of time, and provides an estimate of the maximum temperature that can be expected in a post-flashover compartment fire. Other methods are available for estimating the compartment temperature as a function of time. These may be required if it is desirable to match the maximum compartment temperature with the fire-resistance period of the bounding construction. These methods are outside the scope of the current discussion and expert advice should be sought if such an analysis is required. Equation 17 should however suffice for general design.

Note that Equation 17 is only applicable to compartments with wall openings, i.e. no ceiling/roof openings.

11.6.1.10.2 Radiation Received

By combining Equation 4 and Equation 7, the thermal radiation emitted from numerous openings in a building façade can be calculated at a target point P from:

$$\dot{q} = F_T \tau E_f = F \tau \varepsilon_f \sigma (T_f^4 - T_a^4)$$

Equation 18

As the flames inside the compartment are optically thick, the emissivity of the opening is $\varepsilon \approx 1$. If the openings are fitted with fire-resistant glazing or the glazing is drenched with water, the emissivity can conservatively be taken as 0.5. As discussed earlier, the atmospheric transmissivity is $\tau \approx 1$ under normal atmospheric conditions.

The view factor is the total view factor from all the openings.

11.6.1.10.3 Calculation Procedure

The above equations can be used in a spread sheet to calculate the required separation distance. This usually will involve an iterative process, depending on the number and size of the openings and whether the openings are in the same plane. The procedure is as follows:

1. Define heat flux damage level (HFDL) depending on objectives (e.g. 12.5 kW/m^2 for piloted ignition of ordinary combustibles).
2. Calculate the maximum post-flashover compartment temperature from Equation 17.
3. Select a trial separation distance, and use the view factors for a rectangular emitter (Equation 8 and Equation 9) and the additive property of view factors (Equation 14) to calculate the total view factor for various combination of openings (e.g. perform one calculation at the centre of the largest opening, another calculation considering 2,3 and more openings) to ensure that the location of the point with the highest view factor is identified.
4. Calculate the radiative heat flux received from Equation 18 and compare with the HFDL.
5. If the calculated radiative heat flux > HFDL, increase the separation distance and repeat from step 3.

11.6.1.10.4 Flames Issuing from Roofs

In buildings where the fire compartment ceiling/roof is not fire-resistant, there is the possibility that flames may spread out through the roof. Estimating separation distances for these situations are complex and falls outside the scope of this document and expert fire engineering advice should be sought.

11.6.1.11 Radiation from Small Unconfined Fires

Radiation from relatively small fires (where soot production is not excessive so that the flame is visible throughout its height) can be estimated from either the point-source model, or by considering the flame to be a cylinder. The models various are discussed below.

11.6.1.11.1 Point-Source Model

In the point-source model, the radiation from the fire is assumed to originate in a point located at the mid-height of the flame as shown in the figure below.

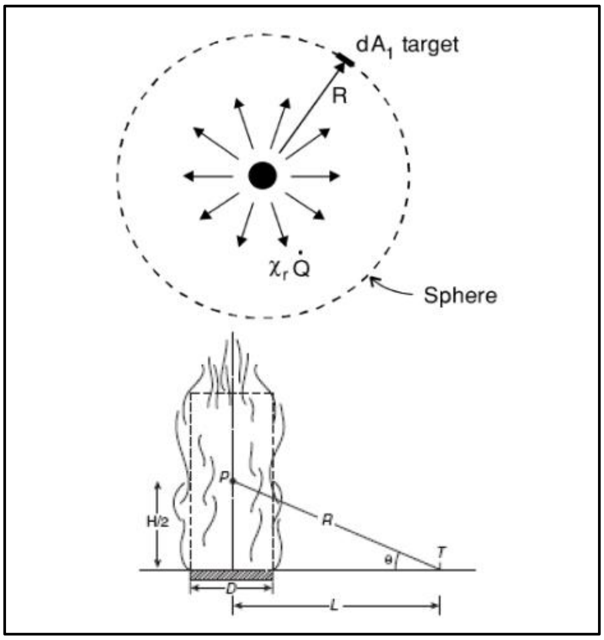


Figure 5: Diagram showing radiation from point-source Model.

The radiation is emitted in a hemisphere and can be calculated from:

$$\dot{q}_r = \frac{\chi_r \dot{Q}_t L}{4\pi R^3}$$

Equation 19

Where: $\dot{q}_r$ = radiation heat flux, [kW/m^2]

χ_r = fraction of heat radiated, [typically 0.35]

$\dot{Q}_t$ = total heat released by fire, [kW]

L = horizontal distance to fire, [m]

R = radial distance from centre of fire to point of interest, [m]

Although the point-source model is generally considered accurate at distances greater than twice the fire diameter (L > 2D), there are some experimental evidence that suggests that it is also applicable closer to the fire. This model is used in the BRANZ zone model to estimate the ignition of adjacent objects.

The radiative heat fraction for most fires encountered in buildings is typically around 0.35.

11.6.1.11.2 Cylindrical flame Model

Another model that is often used to estimate the heat flux at a target is the cylindrical flame model.

This model requires the following steps to be performed:

1. Define heat flux damage level (HFDL) depending on objectives (e.g. 2.5 kW/m^2 for occupant tenability).
2. Calculate the fire diameter and flame length from Equation 15 and Equation 16 respectively.
3. Calculate the perimeter of the fire from the effective diameter, $P = \pi D_f$.
4. Estimate the radiative fraction (or use 0.35), and use the total HRR to calculate the emissive power of the flame from Equation 4.
5. For a transmissivity of 1, calculate the radiative heat flux at the target from Equation 7, using the cylindrical view factor equations Equation 10, Equation 12 and Equation 13.
6. If the calculated radiative heat flux > HFDL, increase the separation distance and recalculate the view factors.

It should be noted that the cylindrical flame model is sometimes used in conjunction with an estimate of the average flame temperature. However, as the flame temperature varies with flame height and distance from the axis it is difficult to estimate an average flame temperature. Furthermore, reported values for flame emissivity vary significantly. As such, this approach is not recommended as it is not based on energy conservation principles and does not necessarily ensure that the calculated flame emissive power reconciles with the radiative fraction of the HRR.

11.6.1.12 Radiation from Large Hydrocarbon Pool Fires

Much of the thermal radiation from large soot-producing hydrocarbon pool fires is emitted from the luminous flames visible near the base of the fire. The flames above the luminous base are usually obscured by thick smoke as shown in Figure 6.

The most popular models used for the calculation of the thermal radiation from large pool fires are:

a) Point-source
b) Shokri and Beyler
c) Mudan and Croce
d) McGrattan et al.

The point-source model is considered accurate in the far field, but is considered too conservative within a few fire diameters. The other models (b, c and d) are cylindrical flame models and differ in the treatment of the flame emissive power and flame height.

The model of McGrattan et al. [112] is recommended here because of its conservatism, simplicity of use and the flexibility it provides in assessing the effectiveness of manmade radiation barrier walls in blocking radiation from reaching the target. This model considers the all the thermal radiation to emanate from the luminous flame zone. E_f is regarded as the emissive power of the luminous flame zone, and H_{Lum} is the height of this luminous zone which is lower than the flame height predicted from Equation 16.

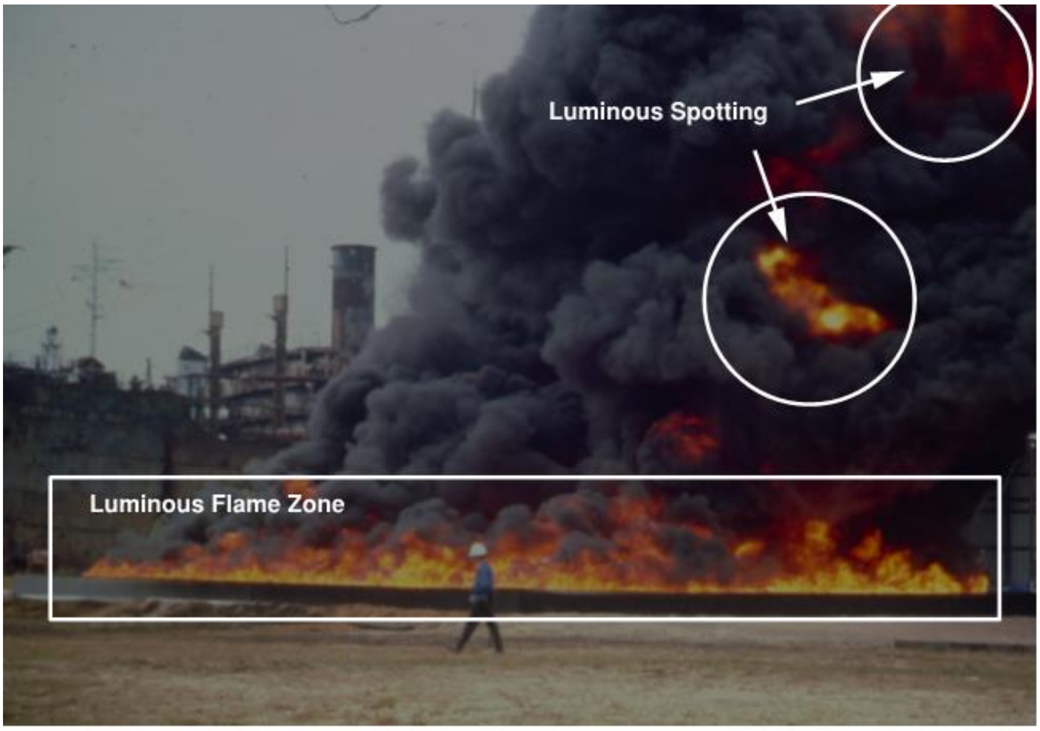


Figure 6: Large hydrocarbon pool fire showing luminous flame region near the base of the fire [112].

The height of the luminous zone is found by rearranging Equation 4:

$$H_{Lum} = \frac{\chi_r \dot{Q}_t}{PE_f} = \frac{\chi_r \dot{q}_f'' A_f}{PE_f}$$

Equation 20

where: E_f = emissive power of flame, [kW/m^2]

$\dot{Q}_t$ = total heat release rate (HRR) of fire, [kW]

χ_r= radiative fraction (fraction of energy lost via radiation)

P = perimeter of flame, [m]

H_{Lum} = height of luminous flame zone, [m]

$\dot{q}_f''$ = heat release rate of fire, [kW m^{-2}]

A_f = area f fire, [m^2]

A constant emissive power (E_f) of 100 kW/m^2 is adopted for the luminous flame zone since it represents an upper bound of the emissive power of most hydrocarbon pool fires. Making use of the correlation for the decrease in radiative fraction with increasing fire diameter (Equation 6), the height of the luminous flame zone H_{Lum} is then found from the equations below:

$$H_{Lum} = \frac{0.35e^{-0.05D_f} D_f \dot{q}_f''}{400} \quad \text{for} \quad D_f \leq 20 \text{ m}$$

$$H_{Lum,max} = 6.4x10^{-3} \dot{q}_f'' \quad \text{for} \quad D_f > 20 \text{ m}$$

Equation 21

where $\dot{q}_f$ = the heat release rate per unit area (HRRPUA), [kW/m^2]

D_f = effective diameter of the fire, or the shortest side of a rectangular fire if the aspect ratio of the longest side to the shortest side exceeds 2.5, [m]

The HRRPUA for hydrocarbon fires can be estimated from Equation 1 and Equation 2 and the values in Table 8.

With the height of the luminous portion of the flame defined, as well as the effective fire diameter or perimeter, the view factor can be determined from equations Equation 10, Equation 12 and Equation 13.

Where the spill is confined to a rectangular dike and the aspect ratio of the longest dimension to the shortest dimension exceeds 2.5, it is not appropriate to assume the fire to be cylindrical with an effective diameter D_f. In these instances, the fire perimeter is to be used to calculate the view factor.

11.6.1.13 Radiation Barrier Walls

Although the methodology has been designed to be conservative, it is not conservative when the effectiveness of a barrier in blocking thermal radiation is assessed. This is because the model considers the radiative energy output to be concentrated near the base of the fire rather than distributed over the entire height of the fire.

For example, measurements in Japan of a 20 m diameter crude oil fire showed that 85 % of the radiant energy of the fire was emitted at heights lower than 20 m. The remaining 15 % of the radiant energy was emitted mainly by hot black smoke at higher levels, and by occasional luminous bursts of flame. The HRRPUA for crude oil is approximately 2,000 kW/m^2, thus, the luminous flame height for a 20 m diameter pool fire is 6.4 x10^{-3}(2000) =12. 8 m. In this context, a radiation barrier 13 m in height would be expected to block all of the thermal radiation. To remedy the situation, it is suggested that for the purpose of evaluating a radiation barrier, the emissive power of the flame be reduced by half, from 100 kW/m^2 down to 50 kW/m^2. The flame height is then doubled to ensure that the same value for the product $H_f E_f$ is maintained.
In brief, measurements of the emissive power of the luminous band surrounding gasoline and diesel fuel fires range from approximately 50 to 100 kW/m^2. The value of 100 kW/m^2 is used in evaluating hazards to nearby structures whereas 50 kW/m^2 is used in evaluating thermal barriers. In each instance, the goal is to err on the conservative side.

11.6.2 Example 6 – Separation Distance between Transformer and Valve Station

Problem statement

The transformer in Example 4 is located 20 m from an valve station that requires access by plant personnel during a fire emergency. Is the separation distance adequate to prevent personnel from being exposed to hazardous conditions in the event of the transformer fire?

Solution:

Step 1: Determine the exposure criteria

As the main exposure hazard to personnel is radiant heat, it is necessary to determine a safe design limit.

As the exposure time of personnel is expected to last several minutes, a conservative thermal radiation limit of 1.6 kW/m^2 is adopted (refer Table 7).

Step 2: Selection of large hydrocarbon pool fire model

There are various models that can be used for estimating the radiant heat flux emitted by pool fires. The model of McGrattan et al. [112] is used here.

Step 3: Calculation

The effective fire diameter for the square bund can be calculated for the 6.0 m x 6.0 m bund from Equation 15:

$$D_f = \sqrt{\frac{4A_f}{\pi}} = \sqrt{\frac{4(36)}{\pi}} = 6.77 \text{ m}$$

The mass burning rate of the transformer oil can be calculated from Equation 2:

$$\dot{m}'' = \dot{m}''_{\infty}\left[1 - e\,(-k\beta D_f)\right]$$

From Table 8, transformer oil is seen to have an asymptotic mass burning rate $\dot{m}''_{\infty}$ of 0.039 kg.m^{-2}.s^{-1}, a $k\beta$ of 0.7 m^{-}1 and a heat of combustion Δh_{eff} of 46,400 kJ.kg^{-1}. The mass burning rate is therefore:

$$\dot{m}'' = 0.039[1 - e\,(-0.7(6.77))] = 0.039\ kg.m^{-2}s^{-1}$$

The total heat release rate of the fire is therefore from Equation 1:

$$\dot{Q}_t = \dot{m}''\Delta h_{eff}A_f = 0.039(46{,}400)(36) = 65{,}146 \text{ kW}$$

The heat release rate per unit area $\dot{q}''_f$ is:

$$\dot{q}''_f = \frac{Q_t}{A_f} = \frac{65{,}146}{36} = 1{,}810 \text{ kW.m}^{-2}$$

The height of the luminous zone for a fire less than 20 m in diameter is given by Equation 20:

$$H_{Lum} = \frac{0.35e^{-0.05D_f}D_f\dot{q}''_f}{400} = \frac{0.35\exp\big(-0.05(6.77)\big)6.77(1810)}{400} = 7.64 \text{ m}$$

Considering the flame as a cylinder and calculating the view factor to a vertical element at the base of the cylinder:

From Equation 12:

$$S = \frac{2L}{D} = \frac{2(20)}{6.77} = 5.908$$

$$h = \frac{2H}{D} = \frac{2(7.64)}{6.77} = 2.257$$

$$A = \frac{h^2 + S^2 + 1}{2S} = \frac{2.257^2 + 5.908^2 + 1}{2(5.908)} = 3.470$$

$$B = \frac{1 + S^2}{2S} = \frac{1 + 5.908^2}{2(5.908)} = 3.039$$

Calculating the view factor to a vertical element at the base of the cylinder from Equation 10:

$$F_V = \frac{1}{\pi S}\tan^{-1}\frac{h}{\sqrt{S^2-1}} - \frac{h}{\pi S}\tan^{-1}\sqrt{\frac{(S-1)}{(S+1)}} + \frac{Ah}{\pi S\sqrt{(A^2-1}}\tan^{-1}\sqrt{\frac{(A+1)(S-1)}{(A-1)(S+1)}}$$

$$= \frac{1}{\pi(5.908)}\tan^{-1}\frac{2.257}{\sqrt{5.908^2-1}} - \frac{2.257}{\pi(5.908)}\tan^{-1}\sqrt{\frac{(5.908-1)}{(5.908+1)}}$$

$$+ \frac{3.470(2.257)}{\pi(5.908)\sqrt{(3.470^2-1}}\tan^{-1}\sqrt{\frac{(3.470+1)(5.908-1)}{(3.470-1)(5.908+1)}} = 0.0425$$

The heat flux at 20 m is therefore from Equation 7 (E_f = 100 kW/m^2 as per Equation 21):

$$\dot{q} = \tau F E_f = 100(1)(0.0425) = 4.25\ \text{kW}$$

This exceeds the tenability limit of 1.6 kWm^{-2} and we conclude that the separation distance is not adequate. Thus either the transformer needs to be moved further away or a radiation barrier wall needs to be constructed between the valve station and transformer.

Performing the view factor calculations in a spread sheet, the heat flux at the target can be plotted as a function of distance from the fire as shown in Figure 7 below.

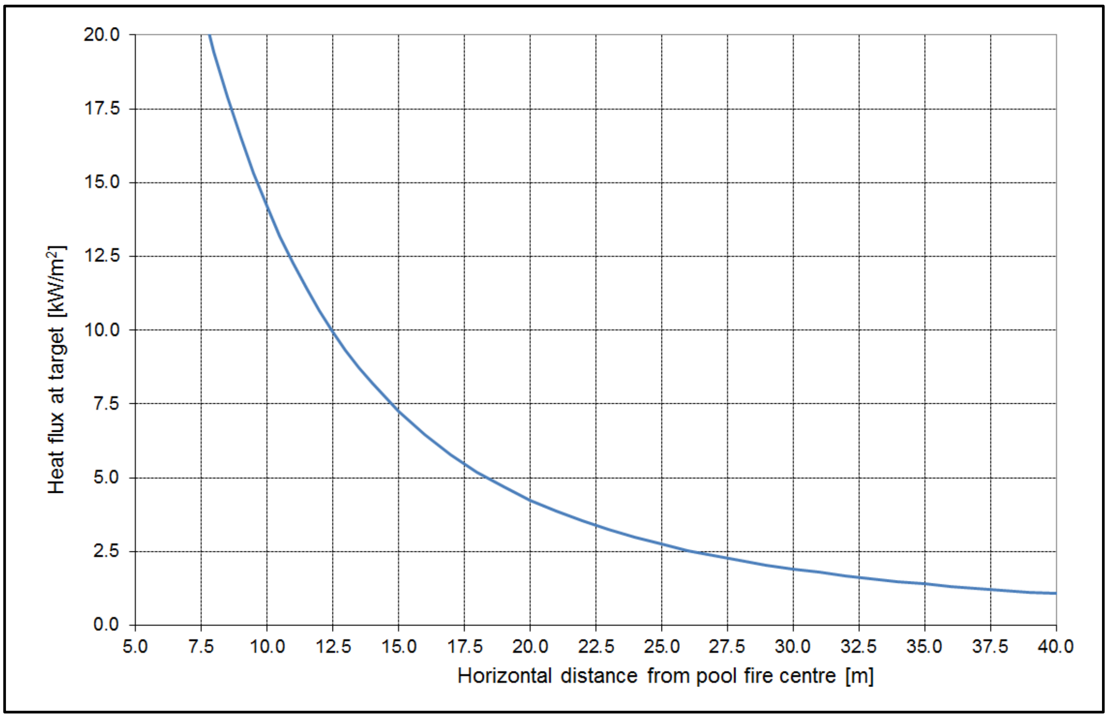


Figure 7: Heat flux at ground level at target as a function of distance from the fire. (option 1)

From the figure it is seen that the heat flux is 1.6 kW/m^2 at a distance of 33.0 m from the fire.

It is interesting to compare the prediction of this model against the NFPA 850 [93] value as determined in Example 4.

Building separation distance in NFPA 80A [81] (and in the UK) is based on a heat flux of 12.5 kW/m^2 which is generally accepted to be the lowest heat flux below which piloted ignition of cellulosic materials is unlikely to occur.

Considering that the maximum heat flux will be at the centre height of the flame, Figure 7 cannot be used as the heat flux shown has been calculated at the base of the cylinder. To get the heat flux at the centre height of the cylinder, the additive property of view factors can be used by using half the flame height in determining the view factor from Equation 10 and Equation 12, and then multiplying the result by 2.

Performing the calculations for a height H of 7.64/2 = 3.82 m, the graph shown in Figure 8 is obtained. From the graph it is seen that the heat flux is 12.5 kW.m^{-2} at a distance of 12.5 m. This compares favourably to NFPA 850 [93] requirement of 15.0 m in this instance.

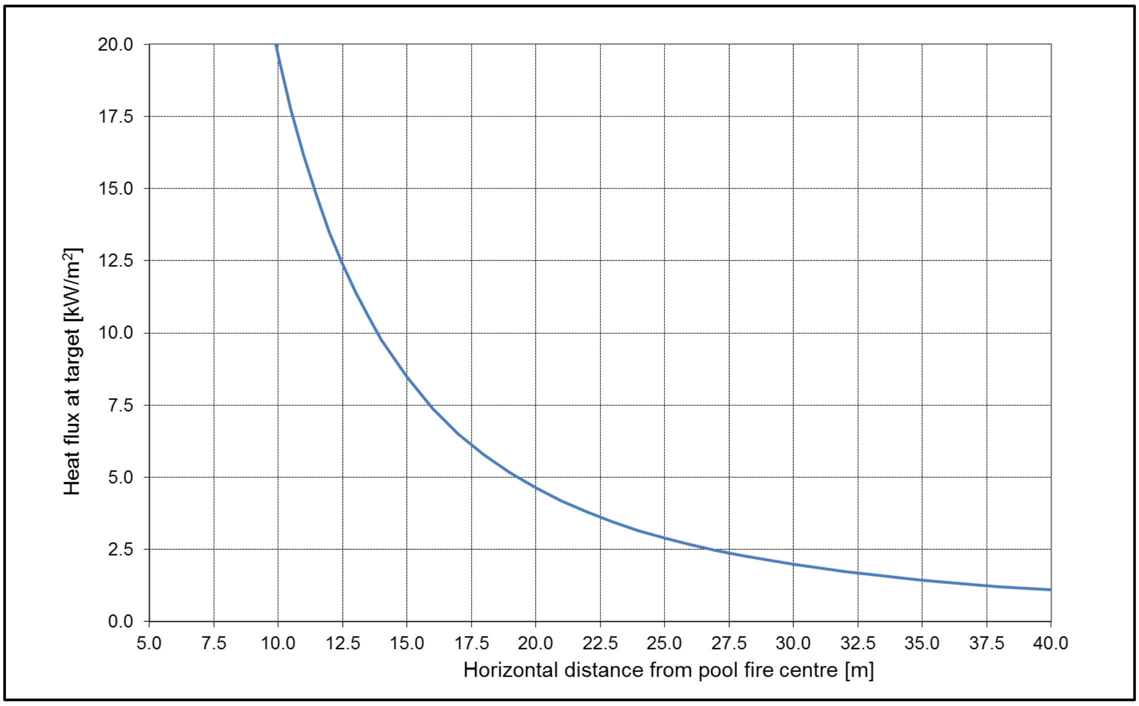


Figure 8: Heat flux at ground level at target as a function of distance from the fire. (option 2)

11.6.3 Example 6 – Separation Distance between Buildings

In this Example, the separation distance between the buildings in Example 1 is calculated from fire engineering principles.

For a fully involved post-flashover compartment fire, Equation 17, would typically be used to estimate the compartment fire temperature. However, as this equation is based on a fully involved compartment fire, it cannot be used in this instance as the walls and roof do not have any fire resistance and can as such be expected to collapse during the fire (to some degree at least). This would cause large vents to open up which will vent heat from the building.

Therefore, one option is to consider the building as a large open fire. For normal cellulosic materials, the point source model would typically be a candidate method. However, as the building houses primarily lubricating oil, the fire is more likely to resemble a large open hydrocarbon fire. The large hydrocarbon pool fire model of McGrattan will therefore be used.

The effective fire diameter for the building can be calculated from Equation 15 based on the building floor area:

$$D_f = \sqrt{\frac{4A_f}{\pi}} = \sqrt{\frac{4(25)(50)}{\pi}} = 39.89 \text{ m}$$

The mass burning rate of the transformer oil can be calculated from Equation 2:

$$\dot{m}'' = \dot{m}''_{\infty}\left[1 - e\,(-k\beta D_f)\right]$$

From Table 8, transformer oil is seen to have an asymptotic mass burning rate $\dot{m}''_{\infty}$ of 0.039 kg.m^{-2}.s^{-1}, a $k\beta$ of 0.7 m^{-}1 and a heat of combustion Δh_{eff} of 46,400 kJ.kg^{-1}. The mass burning rate is therefore:

$$\dot{m}'' = 0.039[1 - e\,(-0.7(39.89))] = 0.039\ kg.m^{-2}s^{-1}$$

The total heat release rate of the fire is therefore from Equation 1:

$$\dot{Q}_t = \dot{m}''\Delta h_{eff} A_f = 0.039(46.4)(50)(25) = 2{,}262 \text{ MW}$$

The heat release rate per unit area $\dot{q}''_f$ is: $\dot{q}''_f = \frac{Q_t}{A_f} = \frac{2{,}262(1000)}{(25)(50)} = 1{,}810 \text{ kW.m}^{-2}$

The height of the luminous zone for a fire more than 20 m in diameter is given by Equation 20:

$$H_{Lum,max} = 6.4x10^{-4}\dot{q}''_f = 6.4x10^{-3}(1{,}810) = 11.6\ m$$

Considering the flame as a two cylinders, each with a height equalling half the luminous flame height, the view factor at the midpoint of the flame is then twice the value calulated from Equation 10.

As combustibles could potentially be ignited inside the office building as a result of radiation received through the windows, it is appropriate to adopt a limiting radiation level of 12.5 kW/m^2. The corresponding view factor can be found from by rearranging Equation 7:

$$2F = \frac{\dot{q}}{\tau E_f} = \frac{12.5}{1.0(100)} = 0.125 \quad =\gg \quad F = 0.063$$

Using Excel and plotting Equation 10 as a function of distance (refer to Figure 9), the separation distance corresponding to a view factor of 0.063 is seen from Figure 9 to be 43.7 m. This corresponds well with the value of 49.9 m calculated in Example 5 using NFPA 80A.

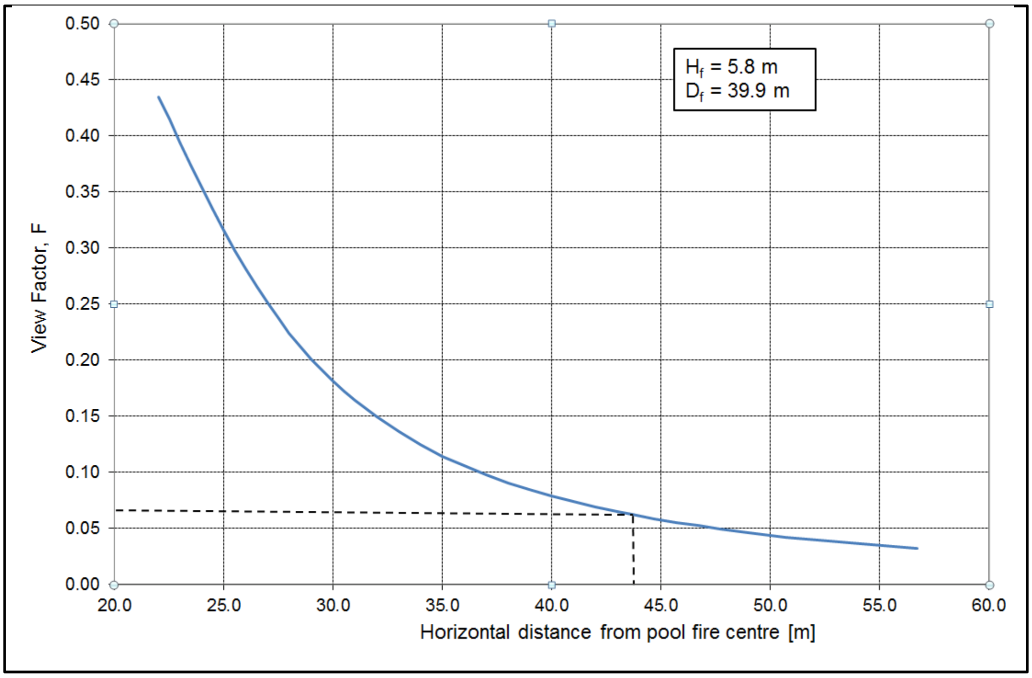


Figure 9: View factor at base of cylinder as a function of distance from the fire.

Performing the calculations to confirm:

$$S = \frac{2L}{D} = \frac{2(43.7)}{39.9} = 2.19$$

$$h = \frac{2H}{D} = \frac{2(5.8)}{39.9} = 0.291$$

$$A = \frac{h^2 + S^2 + 1}{2S} = \frac{0.291^2 + 2.19^2 + 1}{2(2.19)} = 1.343$$

$$B = \frac{1 + S^2}{2S} = \frac{1 + 2.19^2}{2(2.19)} = 1.323$$

Calculating the view factor to a vertical element at the base of the cylinder from Equation 10:

$$F_V = \frac{1}{\pi S}\tan^{-1}\frac{h}{\sqrt{S^2 - 1}} - \frac{h}{\pi S}\tan^{-1}\sqrt{\frac{(S-1)}{(S+1)}} + \frac{Ah}{\pi S\sqrt{(A^2 - 1}}\tan^{-1}\sqrt{\frac{(A+1)(S-1)}{(A-1)(S+1)}}$$

$$= \frac{1}{\pi(2.19)}\tan^{-1}\frac{0.291}{\sqrt{2.19^2 - 1}} - \frac{0.291}{\pi(2.19)}\tan^{-1}\sqrt{\frac{(2.19-1)}{(2.19+1)}}$$
$$+ \frac{1.343(0.291)}{\pi(2.19)\sqrt{(1.343^2 - 1}}\tan^{-1}\sqrt{\frac{(1.343+1)(2.19-1)}{(1.343-1)(2.19+1)}} = 0.063$$

12. ANNEXURE B: PASSIVE FIRE PROTECTION - FIRE PROOFING CHECKLISTS

Section 4.1.5 Fire Proofing refers. The following checklists give guidance on the typical information that are critical for each type of fire barrier application.

12.1 STEEL FIREPROOFING CHECKLIST

- ☐ Has the exposure been specified, i.e. cellulosic or hydrocarbon?
- ☐ Has the corrosivity of the environment been classified, i.e. C1, C2, C3, C4 or C5?
- ☐ Has the steel limiting temperature been specified (typically 550°C)?
- ☐ Is there a methodology for surface preparation (sandblasting required for intumescent paint)?
- ☐ Is the primer correct and compatible (including corrosion under cementitious fireproofing)?
- ☐ Is the fireproofing appropriate for the exposure and corrosivity environment?
- ☐ Is the topcoat compatible and suitable to protect the fireproofing?
- ☐ Are there valid, recent test data, applicable to all section sizes?
- ☐ Is there a table with fireproofing thickness per section size (intumescent and cementitious)?
- ☐ Is the testing to the correct exposure, i.e. cellulosic or hydrocarbon?

12.2 CABLE COATING CHECKLIST

- ☐ Does the specification address the scope, i.e. extent of cables to be fireproofed?
- ☐ Does the specification clarify if the requirement is for circuit integrity, or flame spread?
- ☐ Are there valid, recent test data, to an acceptable standard (IEC or similar) for the proposed product?
- ☐ Is the proposed product suitable for the exposure, i.e. internal or external, any corrosion?
- ☐ Is the application being done to the supplier’s requirements on the relevant datasheets?

12.3 PENETRATION SEALS CHECKLIST

- ☐ Does the specification address the scope, i.e. extent of areas to be sealed?
- ☐ Does the specification clarify the requirements in terms of integrity (E) and insulation (I)?
- ☐ Are there valid, recent test data, to an acceptable standard for the proposed systems?
- ☐ For any combustible services, are suitable sundry products being used to account for this?
- ☐ Was the actual service configuration tested, and if not are the tests relevant?
- ☐ Is the application being done to the supplier’s requirements on the relevant datasheets?

13. ANNEXURE C: FIRE WATER PUMPS

13.1 CONTROLS, INDICATIONS, ALARMS AND TRIPS

The following controls, indications, alarms and trips listed in Table 11 shall be functional in the fire water pump house:

Table 11: Fire Water Pump House Controls, Indications, Alarms and Trips

Controls, Indications, Alarms and Trips	Electrical Fire Pump Set	Diesel Fire Pump Set
Controls	• Stop/start buttons for each pump • Alarm Reset.	• Stop/start buttons for each pump • Alarm Reset.
Indication on control panel	• Fire alarm activated • Failure of pump to start • Pump running • Pump trip	• Fire alarm activated • Failure of pump to start • Pump running • Low oil pressure • High oil pressure
Other Indications	• Pump suction pressure • Pump discharge pressure • System Pressure • Flow switch indications	• Pump suction pressure • Pump discharge pressure • System pressure • Flow switch indications • Diesel tank level indication
Alarms	• Fire alarm • Failure of pump to start (pump failure) • Pump running • Power available • Power failure (to the main electrical supply or of any one phase only) • Failure of the control circuit (from the end of the control circuit)	• Fire alarm • Power failure (of the electrical supply to the battery charger) • Failure of pump to start • Pump running • Low oil pressure • Failure of the battery charger (from both charger outputs in parallel) • Failure of the control circuit (from the end of the control circuit)
Trips	1. The pump shall not have any automatic stopping devices	2. The pump shall not have any automatic stopping devices

The following controls, indications, alarms and trips indicated in Table 12 shall be functional in the control room:

Table 12: Control Room Controls, Indications, Alarms and Trips

Controls, Indications, Alarms and Trips	Electrical Fire Pump Set	Diesel Fire Pump Set
Controls	None	None
Indication on control panel	– Pump running – Mains failure (loss of power) – Alarm	– Pump running – Mains failure (loss of power) – Alarm
Alarms	– Pump running – Mains failure (loss of power) – Alarm	– Pump running – Mains failure (loss of power) – Alarm
Trips	The pump shall not have any automatic stopping devices	The pump shall not have any automatic stopping devices

Depended on the method used for maintaining pressure in the system, the jockey pump/header tank indications – such as “pump running” and “tank level” - must also be identified in full and indicated in the control room.

13.2 FIRE WATER PUMP STANDARD OPERATING AND CONTROL PHILOSOPHY

13.2.1 Office Blocks

A typical office block fire protection system will consist of one set of pumps:

- 1x Jockey (or make-up) Pump;
- 1x Electrically driven fire water pump;
- 1x Diesel driven fire water pump.

(In some cases, a separate hydrant pump or pumping system may be provided.)

The role of the Jockey Pump is to maintain the water pressure within the sprinkler system, to compensate for minor leaks.

The jockey pump must be sized so as to prevent this pump from maintaining one sprinkler in operation without the main fire pump starting. However it must also have a rated capacity of not less than any normal leakage rate. This is typical a flow not exceeding 40l/min.

Stopping and starting of the Jockey Pump is controlled from the pressure switch on the auto-start arrangement. See Figure 10: Typical layout of an auto-start arrangement for office blocks.

In the event of sprinkler activation the Jockey Pump will be unable to maintain the system pressure and the set point of the second pressure switch on the auto-start arrangement will be reached causing the electrically driven fire water pump to start up.

If the electrically driven fire water pump fails to start the system pressure will continue to fall and the set point of the third pressure switch on the auto-start arrangement will be reached causing the diesel driven fire water pump to start up. As a final fail-safe a fourth pressure switch is provided on the auto-start arrangement and if its set point is reached will attempt to start the diesel driven fire water pump in the event that the third pressure switch has failed.

13.2.1.1 Starting on Pressure Drop

The jockey pump must start automatically when the pressure in the sprinkler installation has dropped to not less than 90 % of the normal pressure in the installation and must shut off automatically when the sprinkler installation pressure has reached either the jockey pump churning pressure, or 1200 kPa, whichever is lower.

The auto-starting arrangement pressure switches must be set to operate the electrically driven fire water pump (primary pump) when the pressure in the fire water main has fallen to a value not less than 80% of the pressure in the fire water main when the pump is churning or 100 kPa below duty pressure if this is above or equal to 80% of the churn pressure.

The diesel driven fire water pump (second pump) must be set to start when the pressure in the fire water main falls to a value of 100 kPa below the cut in pressure of the first pump. Two pressure switches must be provided to start the diesel driven fire water pump. The second pressure switch must be set to operate at not less than 20 kPa and not more than 50 kPa beneath the starting pressure of the primary switch. All above is as per ASIB Rules.

13.2.1.2 Example

Consider a fire water pumping system in an office block with the following characteristics:

- System normal operating pressure – 600kPa;
- Jockey Pump churn pressure - 1000kPa;
- Jockey Pump duty pressure – 750kPa;
- Electrically driven fire water pump churn pressure – 700kPa;
- Electrically driven fire water pump duty pressure – 600kPa.

Following the criteria documented we can deduce the following:

- The Jockey Pump must be set to start at equal to or more than 675kPa (90% x 750kPa)
- The Jockey Pump must be set to stop at 1000kPA (Its churn pressure which is less than 1200kPa)
- The electrically driven fire water pump must be set to start at 560kPa (80% x 700kPa and is above 500kPA (100 kPa below duty pressure)).
- The diesel driven fire water pump must have its first pressure switch set to start the pump at 460kPa (100kPa below the cut in pressure of the electrically driven fire water pump)
- The diesel driven fire water pump must have its second pressure switch set to start the pump at anywhere between 410kPa and 440kPa.

13.2.1.3 Typical layout of an auto-start arrangement for office blocks

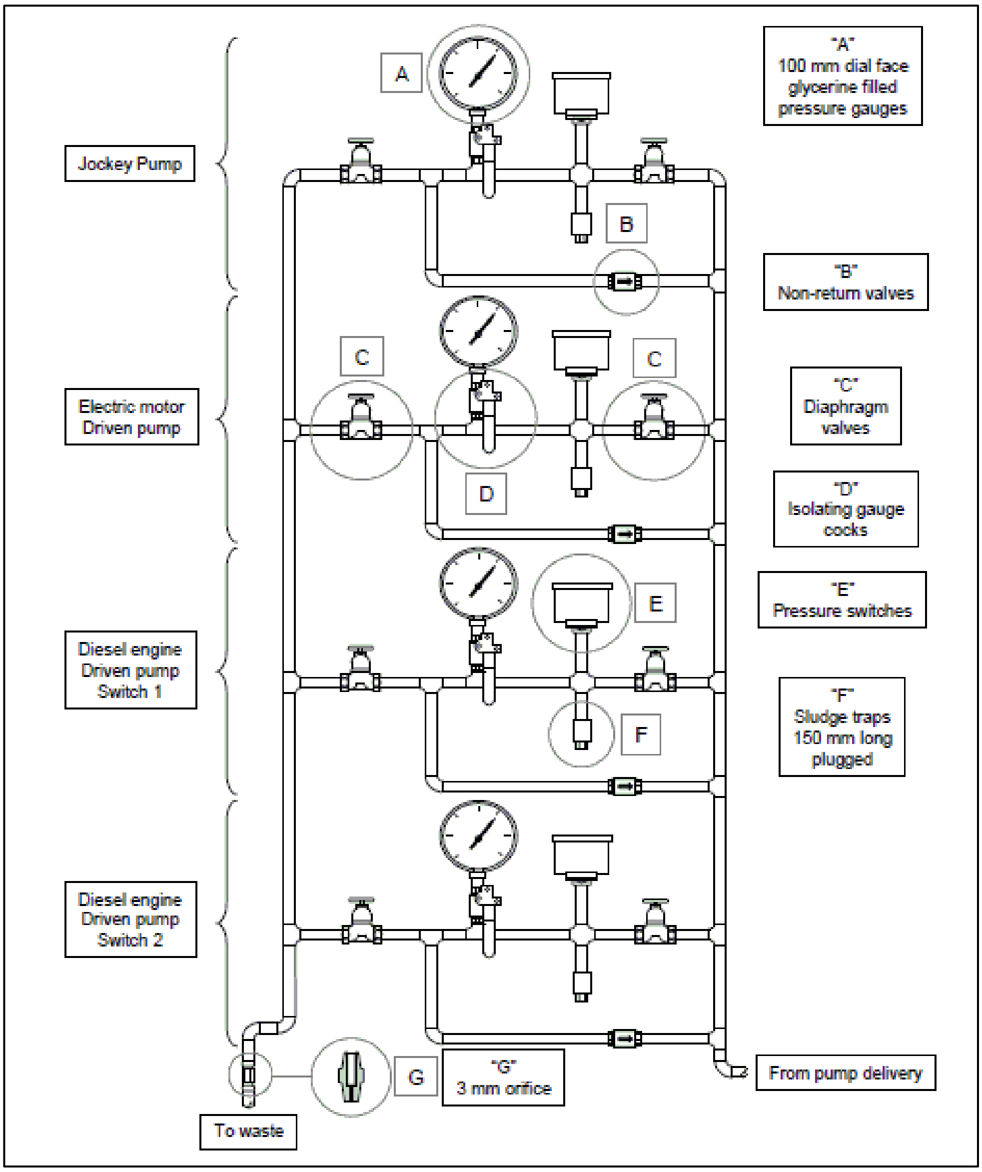


Figure 10: Typical layout of an auto-start arrangement for office blocks

13.2.2 Power Stations

A typical modern power station fire protection system will consist of three sets of pumps:

- 2x (or more) Electrically driven fire water pumps and 2x (or more) Diesel driven fire water pumps;
- 3x Fire tank water pumps;
- 3x Boiler head tank pumps.

The four fire water pumps (each rated at 50% of worst-case demand or each rated at 33% in the event of there being six fire water pumps) will typically be located in a fire pump house, with the electrically driven fire water pumps being in a separate, 2 hour fire rated, room to the diesel driven fire water pumps. These pumps will take suction from the fire main tank and discharge into the fire water ring main.

The three fire tank water pumps (two pumps operating and one on standby), will be typically located in the SSB (Service Station Building) and will take suction from filtered potable water tanks, which will usually be located in the water treatment area. The combination of these pumps will fill and maintain the water level of the fire main tank.

The three boiler head tank pumps (two pumps operating and one on standby), typically also located in the SSB, will take suction from the fire main tank and fill up six elevated fire head tanks; one fire head tank per unit boiler house. The elevated boiler head tanks will discharge into the auxiliary bay fire header and maintain the fire ring mains under a static pressure of around 900 kPa.

In the event of a small fire or minor hydrant usage, the water in the boiler head tanks will be used to satisfy the demand, with the boiler head tank pumps coming into operation to keep the boiler head tanks filled with water.

As the water demand required to fight the fire increases the boiler head tank pumps will no longer be able to keep the boiler head tanks filled and these tanks will start to empty. Once these tanks have emptied the pressure in the fire ring water ring main will start to drop and the set point of the first pressure switch on the auto-start arrangement will be reached causing the first electrically driven fire water pump to start up.

If the electrically driven fire water pump fails to start or if the system pressure continues to decrease the set point of the second pressure switch on the auto-start arrangement will be reached causing the second electrically driven fire water pump to start up. The pump controller may also be configured to start the second electrically driven fire water pump automatically between 5 and 10 seconds after the first electrically driven fire water pump starts on pressure drop. This is allowable in terms of NFPA 20 [71].

If the electrically driven fire water pumps fail to start the system pressure will continue to fall and the set point of the third pressure switch on the auto-start arrangement will be reached causing the first diesel driven fire water pump to start up. If the first diesel driven fire water pump fails to start or if the system pressure continues to decrease the set point of the fourth pressure switch on the auto-start arrangement will be reached causing the second diesel driven fire water pump to start up.

As a final fail-safe a fifth pressure switch is provided on the auto-start arrangement and if its set point is reached will attempt to start the diesel driven fire water pumps if the third and fourth pressure switches have failed.

13.2.2.1 Starting on Pressure Drop

In terms of ASIB Rules, the jockey pump must start automatically when the pressure in the sprinkler installation has dropped to not less than 90 % of the normal pressure in the installation and must shut off automatically when the sprinkler installation pressure has reached either the jockey pump churning pressure, or 1200 kPa, whichever is lower. As the newer power station as well as the new build power stations do not use a jockey pump, instead relying on elevated fire head tanks in the boiler houses, a slightly modified method of determining the starting pressures of the fire water pumps is required.

The auto-starting arrangement pressure switches must be set to operate the electrically driven fire water pump (primary pump) when the pressure in the fire water main has fallen to a value not less than 80% of the pressure in the fire water main when the pump is churning or 100 kPa below duty pressure if this is above or equal to 80% of the churn pressure.

The subsequent pumps must be set to start when the pressure in the fire water main falls to a value of 100 kPa below the cut in pressure of the previous pump. Two pressure switches must be provided to start the last diesel driven fire water pump. The second pressure switch must be set to operate at not less than 20 kPa and not more than 50 kPa beneath the starting pressure of the primary switch.

13.2.2.2 Example

Consider a fire water pumping system in a power station with the following characteristics:

- System normal operating pressure – 1000kPa;
- Electrically driven fire water pump churn pressure – 1000kPa;
- Electrically driven fire water pump duty pressure – 960kPa.
- Elevated fire head tank low level – 900kPa
- Elevated fire head tank high level – 920kPa

Following the criteria documented we can deduce the following:

- The first electrically driven fire water pump must be set to start at 860kPa (100 kPa below duty pressure) as this is higher than 800kPa (80% x 1000kPa). *It must be noted that the starting pressure of 860kPa is a theoretical amount and, depending on the elevated fire head tank characteristics, may have to be adjusted slightly during commissioning of the system.*
- The second electrically driven fire water pump must be set to start at 760kPa (100 kPa below the set point of the first pump)
- The first diesel driven fire water pump must have its pressure switch set to start the pump at 660kPa (100kPa below the cut in pressure of the second electrically driven fire water pump)
- The second diesel driven fire water pump must have its pressure switch set to start the pump at 560kPa (100kPa below the cut in pressure of the first diesel driven fire water pump)
- The diesel driven fire water pump must have its second pressure switch set to start the pump at anywhere between 510kPa and 540kPa.

13.2.2.3 Typical layout of an auto-start arrangement for power stations

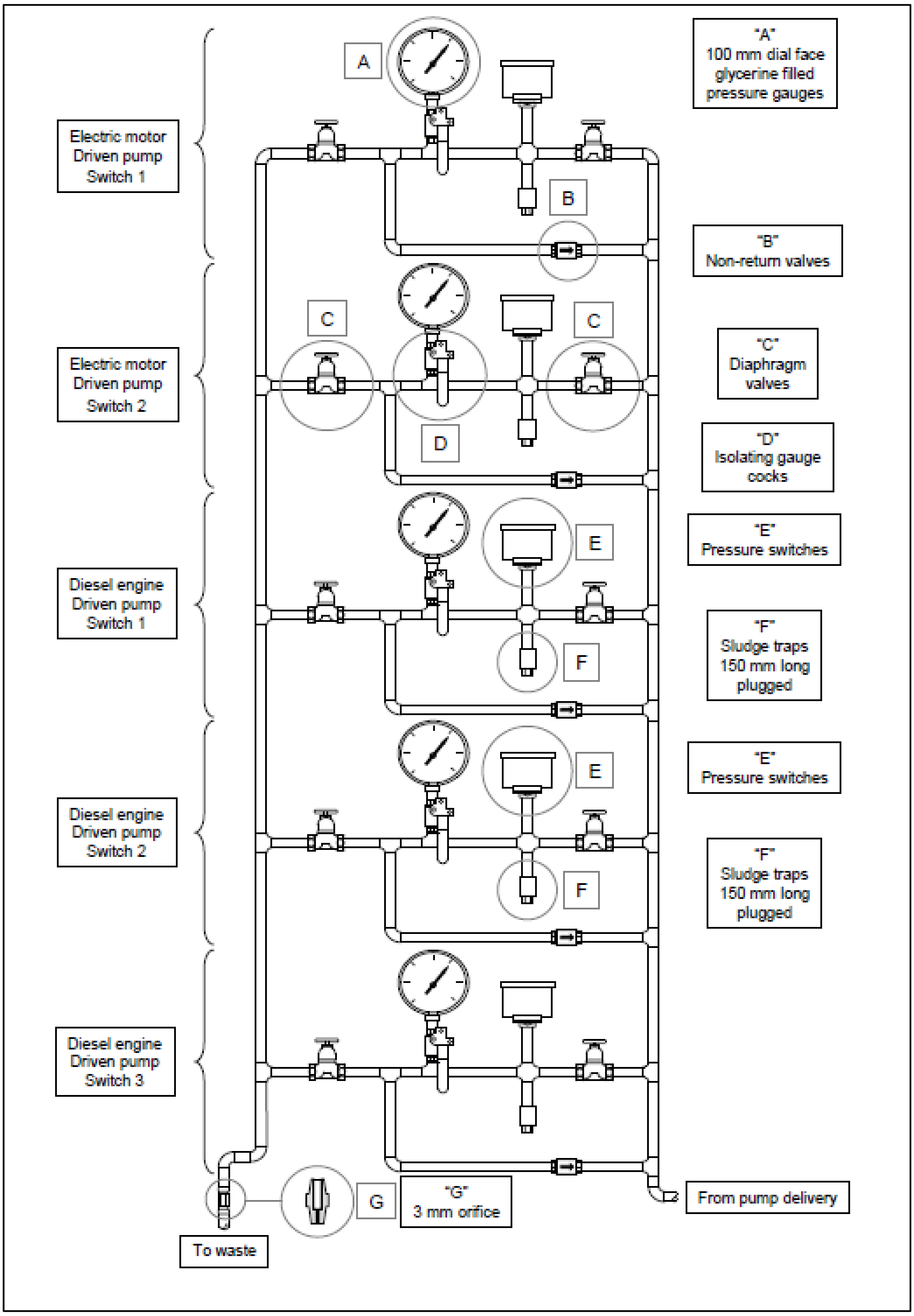


Figure 11: Typical layout of an auto-start arrangement for power stations

14. ANNEXURE D: FIRE PROTECTION SYSTEM DESIGN – CRITIAL INFORMATION

Based on the complexity of the design and the type of systems that is being provided, the following checklists gives guidance on the typical information that must be available from Eskom's side, information that could be specified as part of the requirements, the typical information that must be supplied by a detailed designer and the critical information that should be reviewed to ensure the design has taken all aspects for a fire water system into consideration.

Table 13: Information to Consider when Specifying or Designing a Water Based Fire System

Outputs	**Critical Information**
✓ Fire Protection / Detection Assessment ✓ Rational Design ✓ Coverage Drawing ✓ Concept / Basic / Detailed Design Report ✓ Process Design Report ✓ List of existing documents ✓ List of existing documents to be cancelled / updated ✓ Process Flow Diagrams ✓ Process and Instrumentation Drawing (P&ID's) ✓ Control Narrative ✓ Equipment Lists / Schedules: o Valve, Instrument, Drive and Actuator, Electrical Load, Label List ✓ Equipment Data Sheets ✓ Concept / Basic / Detailed Plant Layout Drawings ✓ Pipe and Cable Routing Drawings ✓ Water supply curve at the interface with an existing system ✓ Pipe Isometric Drawings ✓ Hydraulic Analysis ✓ Pipe Stress Analysis ✓ Design Calculations ✓ FMECA Study ✓ HAZOP Study	✓ Design approach ✓ Type of protection ✓ Spray density ✓ Fluid type ✓ No flow pressure ✓ Minimum required pressure ✓ Maximum supply pressure ✓ Supply flowrate at minimum required supply pressure ✓ Supply flowrate at maximum supply pressure ✓ Minimum nozzle pressure at minimum required supply pressure ✓ Design code ✓ Design pressure ✓ Design temperature ✓ Corrosion protection ✓ Nozzle specification ✓ Valve specification o Isolating valves, vent valves etc. ✓ Piping, pipe support and fitting specification (including corrosion protection) ✓ Flange and gasket specification
Review Considerations	
✓ Correct type of protection ✓ Water supply ✓ Piping ✓ Corrosion protection ✓ Colour coding ✓ Air accumulation ✓ Draining of the system ✓ Pipe supports ✓ Access for operating activities ✓ Access for maintenance activities	

15. ANNEXURE E: FIRE PROTECTION REQUIREMENTS – AREA AND SYSTEM

This section aims to address the most appropriate fire protection system measures and fixed fire protection technologies to use within each specific area of the Eskom asset, which will provide the best protection.

The proposed systems are combinations of codes, standards, industry best practice and experience. The Table in this annexure serves as a QUICK REFERENCE GUIDE ONLY. To provide a complete fire system solution for the specific area the information and recommendations stipulated in Sections 3 to Section 6 of this document (including the referenced standard information) that is appliable to the specific hazard / risk must be applied.

In most cases, this section provides more than one option for each area, as there will very rarely be only one option which will always be the best choice. It shall be the responsibility of the user of this document to decide which system, if any, is to be used based on the FPDA and project specific requirements.

The inappropriate selection of fire protection equipment in a power utility environment may contribute to unnecessary false alarms, slow detection times of fires, high installation and maintenance costs, increased outages and potentially unwanted ignition sources within hazardous areas representing a fire and explosion hazard. This could possibly be the cause of subsequent risk to life safety and asset loss.

A balance is also required between simple and sophisticated fire protection technology, which must be appropriate to the operating environment. A power station environment requires robust, simple fixed fire protection as far as practically possible.

Even though this document basically allows for a Deemed to Satisfy approach and a Rational Alternative Code Compliant Design, there will always be factors which cannot be accounted for and will require a Rational Fire Engineered Design. Such factors are:

- Suitability of the Fire Protection system components;
- Nature of the site, buildings and equipment;
- Environmental and atmospheric factors specific to the area such as temperatures, humidity, wind, dust, and smog, etc. Particularly in relation to how the fire protection system is to be actuated.
- Operations in the areas;
- The level of monitoring and control required for the site as a whole;
- The personnel occupying the buildings as well as using and monitoring the Fire Protection and Fire Detection systems;
- Areas not covered in the documents.

The determination of which of the approaches to use for carrying out the fire protection system selection and design is detailed in the Fire Protection/Detection Assessment [3] standard.

Table 14: Area versus System Protection

		Active Fire Protection								
Fire Protection System Measures	**Passive**	**Foam**	**Sprinkler**	**Deluge**	**Water Mist**	**Gaseous**	**Aerosol**	**Manual**	**Fire Detection**	**Smoke Ventilation**
Hazard or Risk Area										
1. General Buildings and Facilities	x		x		x	x	x	x	x	x
2. Electronic Equipment Installations	x				x	x	x	x	x	x
3. Cables (concentrations, rooms, tunnels)	x		x					x	x	x
4. Switchgear Rooms	x							x	x	x
5. Battery Rooms	x							x	x	x
6. Substations and Switchyards	x							x	x	x
7. Transformers	x			x				x	x	x
8. Pumps, Generators, Compressors	x		x	x	x	x	x	x		
9. Storage and Handling of Combustible / Flammable liquids (oil / fuel)	x	x	x	x				x	x	x
10. Fuel Handling and Storage – LPG	x			x				x		
11. Fuel Handling and Storage – Hydrogen	x			x				x		
12. Bulk Materials Handling and Storage	x		x					x		
13. Boiler Plant and Associated Equipment										
13.1. Boiler Furnace Burners	x			x				x		
13.2. Mills	x							x		
13.3. Feed Pumps	x			x				x		
13.4. Air Pre-Heaters	x			x				x	x	
13.5. Scrubbers, Scrubber Buildings and Exhaust Ducts	x		x					x	x	
14. Turbines and Associated Sub-Systems										
14.1. Oil Systems	x		x	x				x		
14.2. Bearings	x			x				x		
15. Auxiliary Equipment and Other Structures										
15.1. Cooling Towers	x							x		
15.2. Auxiliary Boilers	x			x				x		
15.3. Bulk Sulphur / Ammonia Tanks and Associated Equipment	x							x		

		Active Fire Protection								
Fire Protection System Measures	**Passive**	**Foam**	**Sprinkler**	**Deluge**	**Water Mist**	**Gaseous**	**Aerosol**	**Manual**	**Fire Detection**	**Smoke Ventilation**
Hazard or Risk Area										
16. Wind Farm -Turbine Nacelle	x						x			
17. BESS – Battery Unit	x					x	x	x	x	x