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Thesis of final studies project

Application of Passive and Active Fire Protection Systems in the Oil and Gas Industry

BEN BOUTELDJA Mohamed Sabri

BOUDERBALA M'hammed

Under the direction of:

M.M. BOUSBAI	Associate professor B at ENP	
Ms.H. MERZOUGI	Safety Engineer	at CEI HALFAOUI
Ms.H. BENRABAH	Safety Engineer	at CEI HALFAOUI

Presented and defended publicly on 29 - 06 - 2024 in front of the jury composed of:

M YOUSFI Hamid	President	Professor at ENP
M.BOUBAKEUR Mohamed	Examiner	Associate Professor A at ENP
M.KERTOUS Aboubaker	Examiner	Associate Professor A at ENP

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Mémoire de fin d'études

Application des Systèmes de Protection Passive et Active contre les incendies dans l'Industrie du Oil & Gas

BEN BOUTELDJA Mohamed Sabri

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Sous la direction de:

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Présenté et soutenu publiquement le 29 - 06 - 2024 devant le jury composé de:

M YOUSFI Hamid	Président	Professeur à l'ENP
M.BOUBAKEUR Mohamed	Examinateur	Professeur Associé A à l'ENP
M.KERTOUS Aboubaker	Examinateur	Professeur Associé A à l'ENP

ENP 2024

الملخص:
تتناول هذه الأطروحة موضوع حماية الحرائق لوحدة معالجة المحروقات. من أجل ذلك، قمنا بإجراء دراسة تقييم مخاطر الحرائق والانفجارات (FERA) باستخدام برنامج DNV Safeti 8.4 لمحاكاة سيناريوهات حقيقية للحرائق وتقدير النتائج المتوقعة.

هذه البيانات أدت إلى وضع خطة للحماية السلبية من الحرائق وفقًا لمعيار API RP 2218. تتيح هذه الخطة حماية المعدات المهمة لفترة مطولة أثناء حدوث حريق.

بالإضافة إلى ذلك، تم تقييم فعالية أنظمة الإطفاء النشطة لضمان مكافحتها بشكل مثلى للحرائق داخل بيئة وحدة المعالجة، ملتزمين بمعايير NFPA.

من خلال دمج هذه الاستراتيجيات، تقترح هذه الأطروحة خطة شاملة لحماية الحرائق لوحدة معالجة المحروقات، مع التركيز على سلامة الأفراد وتقليل الضرر المحتمل.

الكلمات الرئيسية: FERA، الحماية من الحرائق السلبية، الحماية من الحرائق، الحماية النشطة من الحرائق، النمذجة، المحاكاة، Safeti 8,4، معايير API RP ، معايير NFPA.

Résumé :
Cette thèse aborde la protection contre les incendies pour une unité de traitement des hydrocarbures. Pour ce faire, nous avons réalisé une étude d'évaluation des risques d'incendie et d'explosion (FERA) en utilisant le logiciel Safeti 8.4 pour simuler des scénarios d'incendie réels et estimer les conséquences.

Ces données ont guidé l'élaboration d'un plan de protection passive contre les incendies conforme à la norme API RP 2218. Ce plan permet de protéger les équipements critiques pendant une période prolongée en cas d'incendie.

De plus, l'efficacité des systèmes actifs de suppression des incendies a été évaluée afin de garantir qu'ils combattent de manière optimale les incendies dans l'environnement unique de l'unité de traitement, en respectant les normes NFPA.

En combinant ces stratégies, cette thèse propose un plan de protection incendie complet pour l'unité de traitement des hydrocarbures, en priorisant la sécurité du personnel et en minimisant les dommages potentiels.

Mots-clés : FERA, Protection passive contre les incendies, Ignifugation, Protection active contre les incendies, Modélisation, Simulation, Safeti 8.4, Normes API RP, Normes NFPA.

Abstract:
This thesis addresses fire protection for a hydrocarbon treatment unit. In order to do that, we realized a Fire and Explosion Risk Assessment (FERA) study using Safeti 8.4 software to simulate real fire scenarios and estimate the consequences.

This data guided the development of a passive fireproofing plan following the API RP 2218 standard. This plan allows to protect critical equipment for an extended period during a fire.

Additionally, the effectiveness of active fire suppression systems was evaluated to ensure they optimally combat fires within the unique environment of the treatment unit, adhering to NFPA standards.

By combining these strategies, this thesis proposes a comprehensive fire protection plan for the hydrocarbon treatment unit, prioritizing personnel safety and minimizing potential damage.

Keywords: FERA, Passive Fire Protection, Fire Proofing, Active Fire Protection, Modeling, Simulation, Safeti 8.4, API RP Standards, NFPA Standards.

Dedications

To my parents, Mom and Dad, who have done everything for me and to whom I shall be grateful all my life.

To my younger sister, whom I'm so grateful to have, even though I never said it.

To my grandmother and my aunts, who have always supported me.

To my friends and classmates, who made this journey sweet and with whom I shared the most beautiful memories.

To my project partner, M'hammed, whom I'm thankful for working with over the last few months.

To my two cats, who added considerable drama to my life.

– Sabri

To my loving family—Mom, Dad, and my brothers and little sister—your unwavering support and belief in me have been my greatest motivation. Thank you for always encouraging me to pursue my dreams.

To my mentors and supervisors, whose guidance and wisdom have shaped my journey. Your patience and insights have been invaluable in molding my understanding and skills.

To my teachers and professors, for sharing your knowledge and pushing me to explore new horizons. Your dedication to education has inspired me to strive for excellence.

To my classmates and friends, who have made this academic adventure unforgettable. Your camaraderie and shared experiences have made the challenges easier and the victories sweeter.

To my project partner, Sabri, thank you for being by my side throughout this journey. Your dedication, ideas, and collaboration have been instrumental in our success.

And finally, to everyone who has believed in me and supported me along the way—thank you. This achievement would not have been possible without each of you.

– M'hammed

Acknowledgments

We would like to express our sincere gratitude to Mrs. Hadjer BENRABAH and Mrs. Hind MERZOUGI for their invaluable guidance and support throughout the duration of this internship. Their expertise, patience, and encouragement have been instrumental in shaping our experience and guiding us through its various stages. We are truly fortunate to have had the opportunity to benefit from their wisdom and mentorship.

We would also like to extend our heartfelt thanks to our academic tutor, Mr. BOUSBAI M'hammed, for his unwavering support and valuable insights. His dedication to our professional growth and his willingness to share his knowledge have been invaluable resources throughout this journey.

Furthermore, we are deeply grateful to all the personnel of CEI Halfaoui for their unwavering support and professionalism. Their assistance and cooperation have greatly contributed to the successful completion of this internship.

Lastly, we would like to express our immense appreciation for the privilege of working on such a meaningful project with such exceptional mentors. Their guidance and mentorship have not only enriched our professional experience but have also inspired us to strive for excellence in all our endeavors.

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Chapter 1

Context, glossary and definition of the problem

1.1 Introduction

The scope of this chapter is to define the general context of our study, followed by defining the problem that we worked on, and presenting a glossary that contains the key terms and terminology.

1.2 General context

1.2.1 Gas treatment site

Our study was held at a gas treatment site, a project which CEI Halfaoui is currently working on. The primary objective of the site is to purify natural gas extracted from wells before it is distributed and used by consumers. This purification process removes impurities like water, carbon dioxide, and hydrogen sulfide from the raw gas.
The outcome of this process is treated natural gas and condensate, process details will be given in the following chapters.

1.2.2 Fire protection (Passive & Active)

In the high-risk world of oil and gas, fire protection is a critical safeguard. Facilities rely on a multi-layered approach, combining active and passive measures to shield personnel, equipment, and prevent infernos. Active systems take center stage, with detection systems raising the alarm and suppression systems like water, foam, or gas extinguishing flames. Passive measures build in fire resistance, using fire-rated construction materials, fire barriers to compartmentalize areas, and fireproof coatings to delay ignition. Smoke control systems further enhance safety by managing smoke movement during an incident. Regular maintenance and training for staff ensure these systems function flawlessly when called upon. [1] [12]

1.2.3 Fire Hazards Analysis (FHA)

Building effective on-site fire protection starts with properly identifying hazards and assessing fire risks. Fire Hazard Analysis (FHA) helps us analyze a facility's layout and potential dangers by quantifying fire risks through realistic simulations. This process provides a clear understanding of the severity and potential consequences of these risks. Using this data-driven approach, we can establish practical fire protection measures on-site, ensuring comprehensive safety. [2]

1.3 Definition of the problem

Our project aims to enhance fire safety at a gas treatment site, the study focuses on fire protection, and distinguishes between active and passive fire protection by addressing two safety concerns:

1.3.1 Fireproofing plan development

For passive fire protection, we created a fireproofing plan based on the API RP 2218 standard, fireproofing consists of applying materials and techniques that:

- Slow down the spread of a fire.
- Reduce heat transfer.
- Safeguard critical equipment during a fire event.

1.3.2 Firefighting system evaluation

For active fire protection, already existing fire suppression and extinguishing systems are in place, our work consisted of evaluating the conformity of these systems with the related NFPA standards (NFPA 11, NFPA 15, NFPA 17), the following points are the judged criteria in our study:

- Water supply systems.
- System capacity and discharge rates.
- System coverage.

Technical documents and sources of information

- Facility layouts & equipment data (master plans and P&IDs) to pinpoint fire risks and design the fireproofing plan.
- Operational parameters (pressure, temperature) to choose the right fireproofing materials.
- FHA results to identify specific fire scenarios the plan needs to address.

This combined approach ensures a robust fireproofing plan and verifies the existing fire suppression system's effectiveness.

1.4 Glossary

1.4.1 Oil and gas equipment categories (Production and Treatment)

Vessels

In the context of oil and gas, a vessel is a container or a structure used to store, process or transport fluids such as crude oil, natural gas, or refined products. Vessels play an important role in various stages of oil and gas operations, including production, refining, and transportation, examples include separators, pressure vessels, drums, reactors, distillation columns... [3]

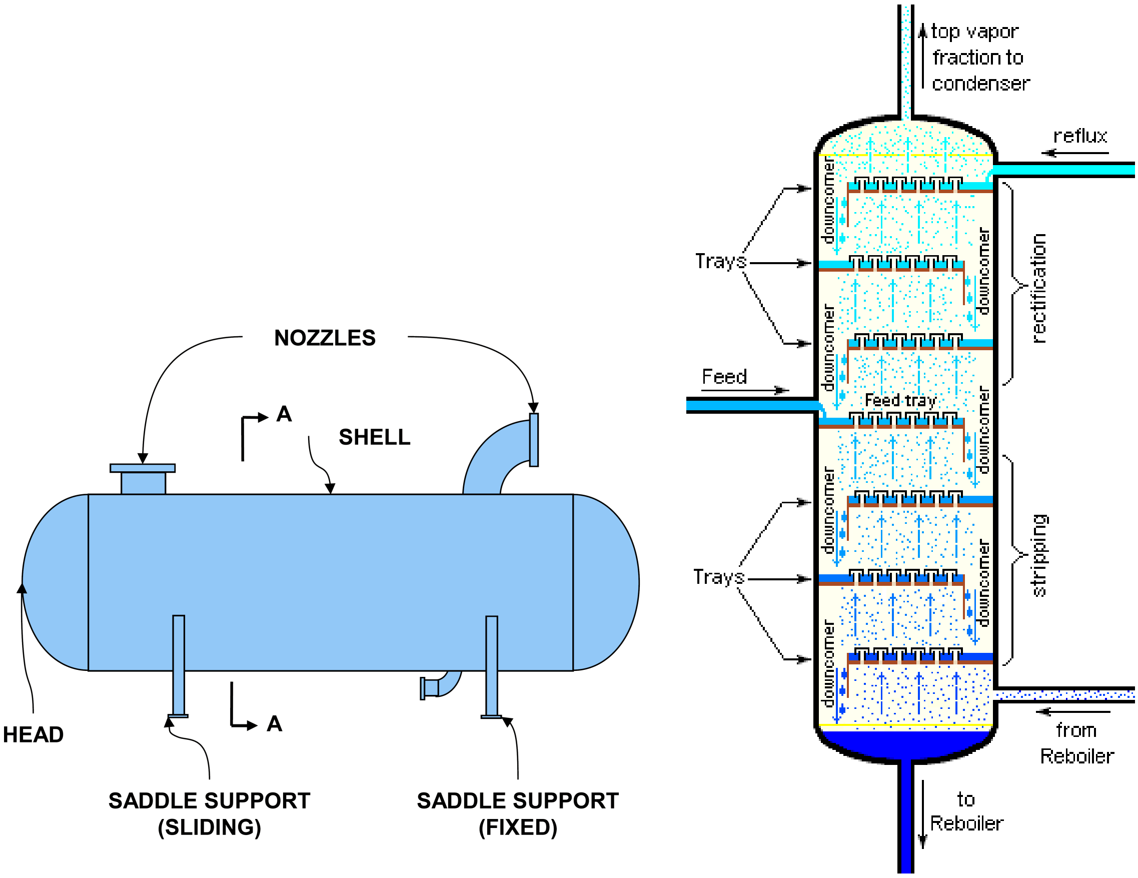

Figure 1.1: Typical components of a vessel (horizontal & vertical)

Boilers

A boiler is needed for oil and gas production because it helps to generate a high amount of steam. Steam is very important as it is needed to power some processes, such as vacuum distillation, steam distillation, stripping, and process heating. This equipment acts as a closed vessel used in converting water to steam through chemical combustion. [4]

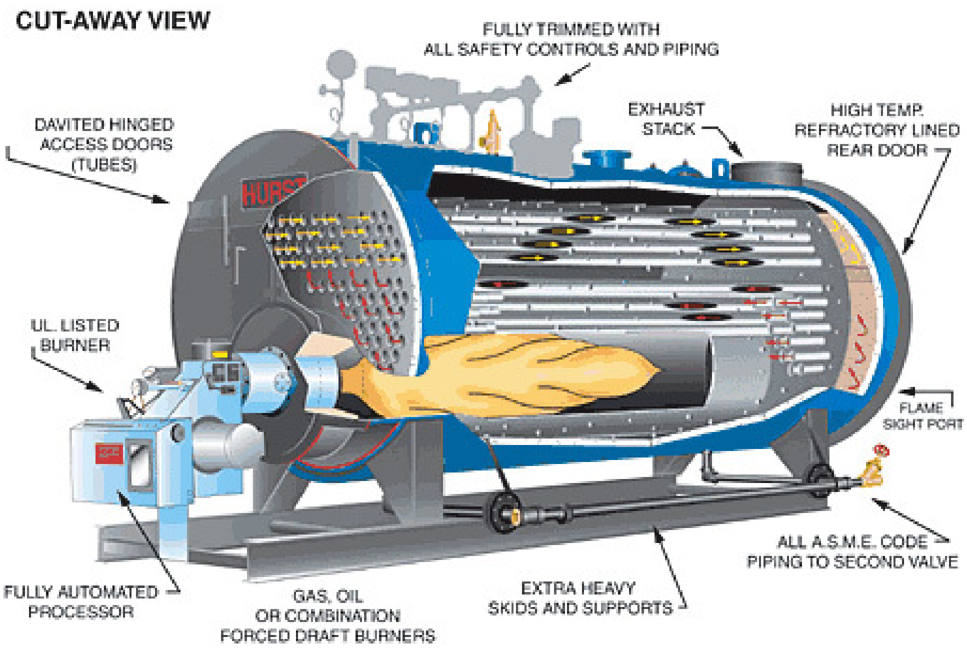

Figure 1.2: Typical components of a boiler

Air coolers

An air cooler in oil and gas cools hot fluids by transferring heat to ambient air, commonly used in refining, gas processing, and petrochemical production for its simplicity and efficiency. [5]

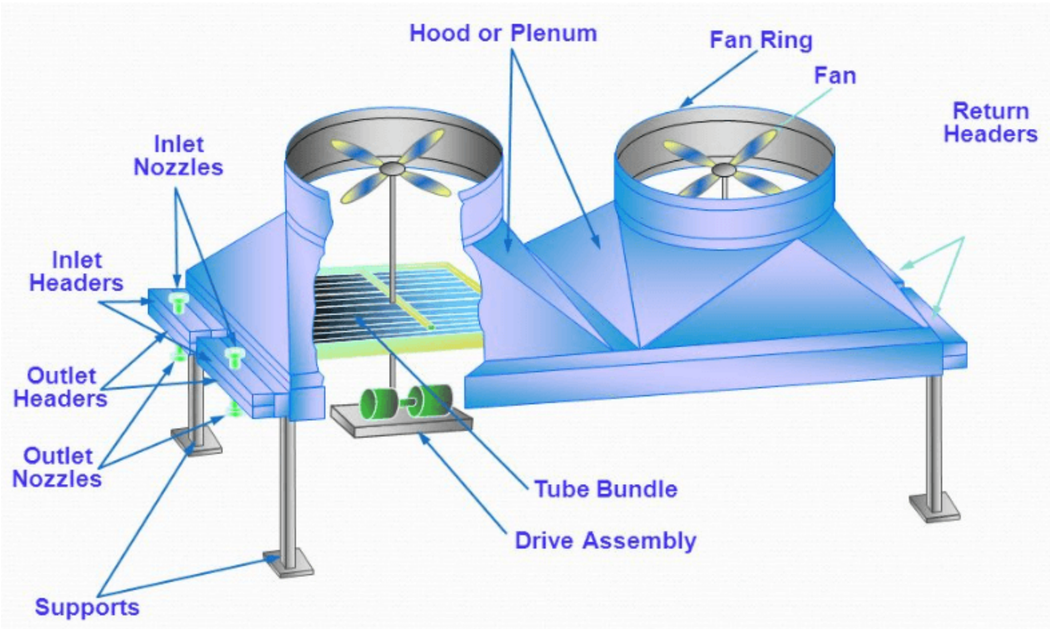

Figure 1.3: Typical components of an air cooler

PS: Depending on the usage, air coolers and boilers can be replaced with heat exchangers that we can alternate the function (heating/cooling) with the properties of the liquid (hot/cold).

Compressors

The main role of a compressor is to increase the pressure of natural gas and allow it to be transported from the production site to all desired destinations. [6]

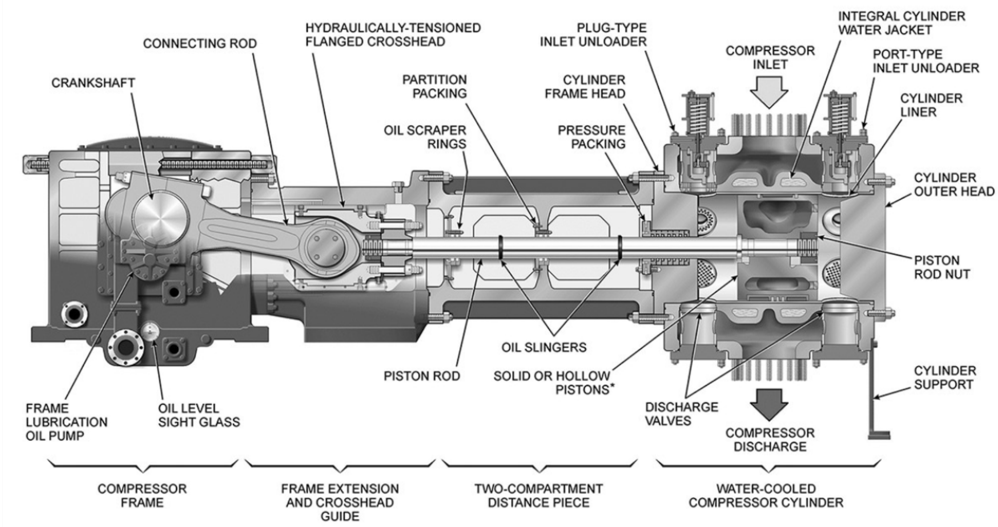

Figure 1.4: Typical components of a gas compressor

Storage tanks

A storage tank is the oil and gas industry a container used to store hydrocarbons, water or other chemical substances. These tanks are designed to safely hold substances for extended periods, providing storage and facilitating transportation as needed. [7]

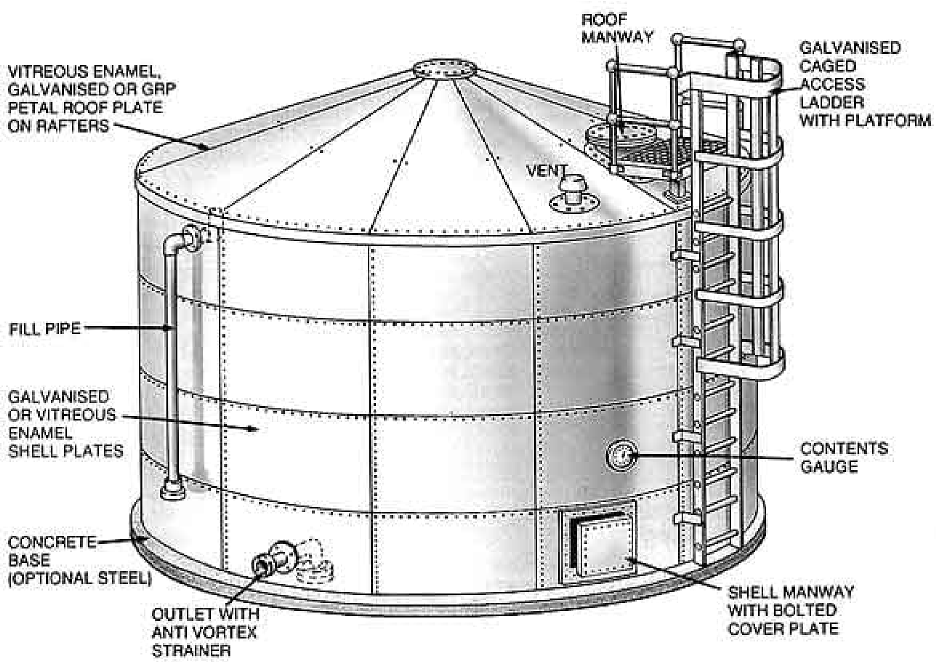

Figure 1.5: Typical storage tank components (fixed roof)

1.4.2 Equipment supports

Pipe Rack

A structural steel pipe rack is a framework used to support pipelines and convey piping across various sections of a plant or facility. These racks are typically composed of steel beams and columns, providing stability and strength to hold multiple pipes of varying sizes and weights. The design of pipe racks ensures the safe transport of fluids and gases by preventing the pipes from sagging or becoming damaged. [21]

Horizontal Leg Supports (Saddles)

Horizontal leg supports, commonly known as saddles, are structural elements used to support horizontal vessels or cylindrical equipment. Saddles are typically curved or semi-circular in shape to fit the contour of the vessel. They help distribute the load evenly and prevent deformation or damage to the vessel. Saddles are anchored to the ground or a structural foundation to ensure stability and support. [19]

Skirt

A skirt is a cylindrical support structure attached to the base of a vertical vessel, such as a reactor or storage tank. The skirt extends from the bottom of the vessel to the foundation, providing stability and support. Skirts help in distributing the weight of the vessel and its contents evenly across the foundation. They also protect the vessel from direct contact with the ground, reducing the risk of corrosion or damage. [20]

Vessel Legs

Vessel legs are the vertical supports or columns that hold up a vessel, such as a storage tank or pressure vessel, in an industrial setting. These legs are crucial for maintaining the stability and proper alignment of the vessel. They are usually made of steel or other strong materials to withstand the weight of the vessel and its contents, as well as any environmental forces such as wind or seismic activity. [19]

1.4.3 Hazardous events and fires in the oil and gas industry

Pool Fires

A flammable liquid spill with the presence oxygen and an energy source, creates a pool fire phenomenon.[12]

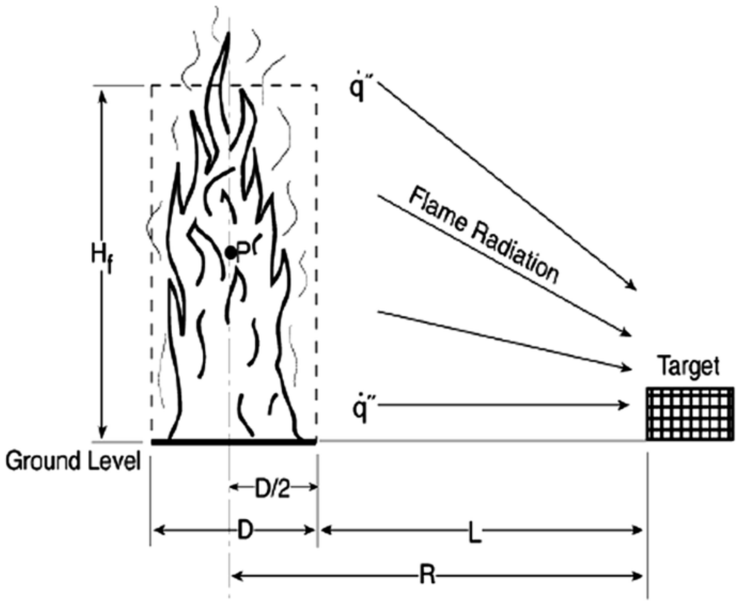

Figure 1.6: Simplified illustration of a Pool Fire

UVCE (Unconfined Vapor Cloud Explosion)

A spill of flammable liquid can evaporate, forming a gas mixture with air that becomes explosive. This explosive cloud, if it comes into contact with an energy source, can lead to an Unconfined Vapor Cloud Explosion (UVCE). Similarly, a significant release of gas without proper containment can result in the formation of an explosive gas-air mixture, also capable of causing a UVCE upon contact with an energy source. [15]

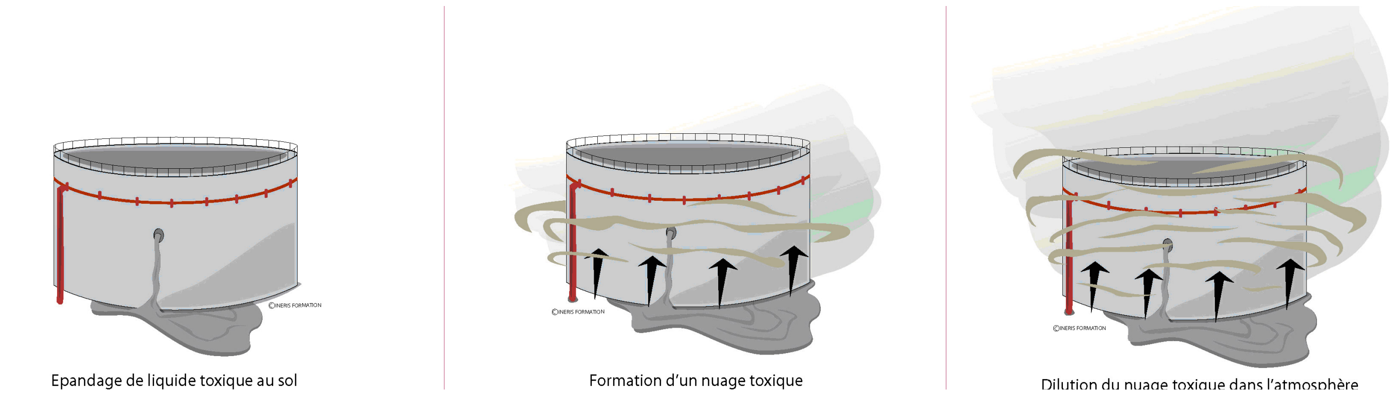

Figure 1.7: Simplified illustration of an UVCE event (before explosion)

BLEVE (Boiling Liquid Expanding Vapor)

A BLEVE occurs when a pressure container is heated, boiling the liquid inside and increasing the pressure until it explodes violently. The phenomenon is considered dangerous for its thrown debris and its heat flux. [2]

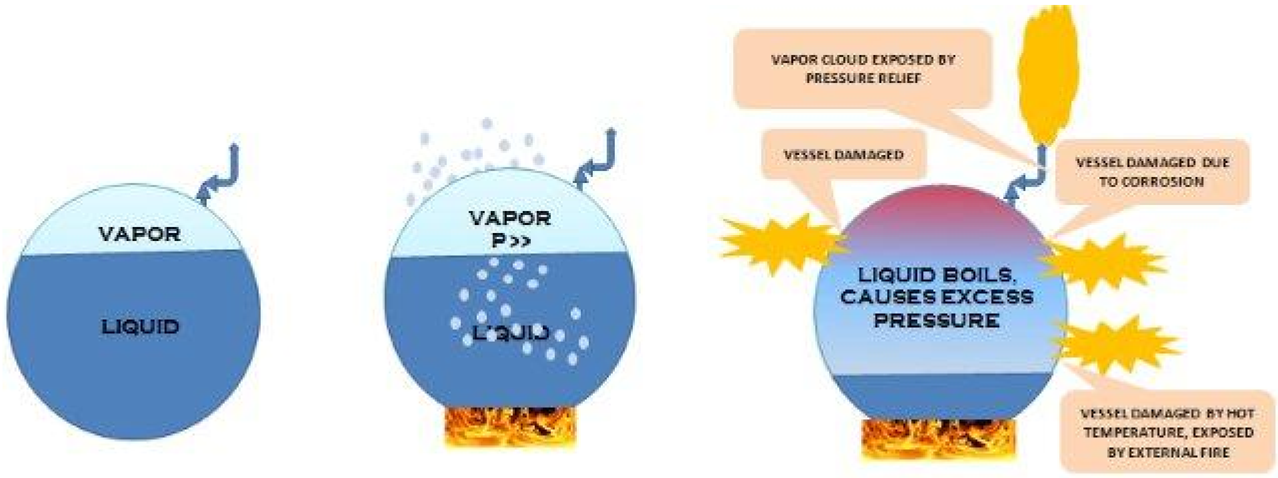

Figure 1.8: Simplified Illustration of a BLEVE phenomenon

Jet Fire

A jet fire occurs when flammable gas is released under high pressure, often as a result of a leak or rupture in a pipe or a vessel. When this gas comes into contact with a heat source, such as a flame or spark, it ignites instantly, creating a stream of fire. [12]

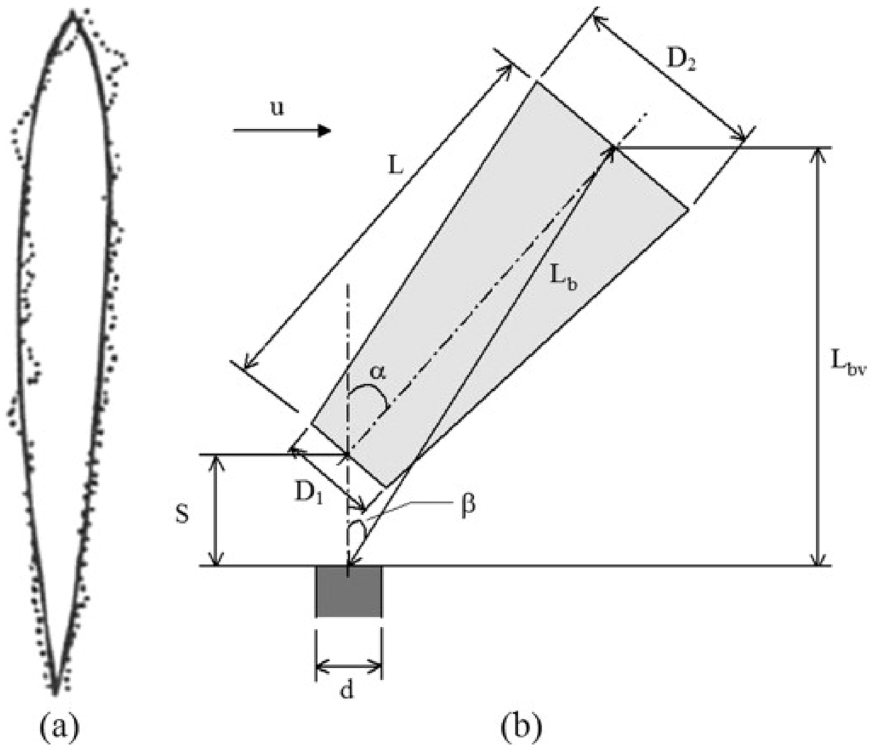

Figure 1.9: Illustration of a jet fire mechanism

Flash Fire

A flash fire is a sudden and rapid fire that occurs when flammable vapours are exposed to a heat source instantly before the formation of an explosive cloud. Flash Fires are brief (up to 5 seconds) and can reach temperatures up to 1600 °C. [15]

Figure 1.10: A small flash fire incident

Fire Ball

A fireball is a luminous sphere that forms when a mixture of flammable gases reacts with the oxygen in the air, generating rapid and intense combustion. [15]

Figure 1.11: Observed Fire Ball incident occurred from LPG vapor explosion

1.4.4 General Fire Protection context

Fire Scenario

A fire scenario is a hypothetical situation used to analyze the potential development and impact of a fire within a specific environment. It includes the ignition source, materials involved, fire growth, spread, and the expected response of fire protection systems. Fire scenarios help in evaluating fire risks, designing safety measures, and preparing emergency response plans. [12]

Fire Scenario Envelope

A three-dimensional space where equipment has the potential to release flammable or combustible fluids. These fluids can form a pool fire that sustains enough duration and intensity to cause significant property damage. [12]

System Response

System response refers to the actions and behaviors of equipment, processes, or safety systems in reaction to an event or stimulus, such as a fire or emergency situation. It includes the activation of alarms, initiation of suppression systems, isolation of hazardous materials, and other measures designed to mitigate the impact of the event and protect personnel, property, and the environment. [12][8]

Emergency Isolation

Emergency isolation refers to the rapid shutdown or separation of equipment, systems, or areas to prevent the escalation of an emergency situation, such as a fire or chemical release. This involves the activation of isolation valves, switches, or other control mechanisms to contain hazardous materials or energy, thereby minimizing the impact on personnel, property, and the environment.[12]

Class B Fires

Class B fires involve flammable liquids and gases, such as gasoline, oil, propane, and natural gas. These fires can occur in environments where these substances are present, such as kitchens, garages, workshops, and industrial facilities. Class B fires are typically extinguished using foam, dry chemical, or carbon dioxide extinguishers. [11]

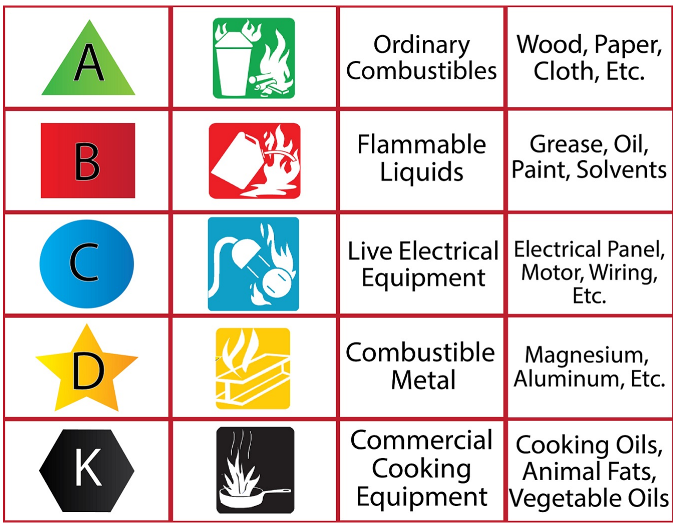

Figure 1.12: Fire Classes in the US

Low-expansion Foam

Low expansion foam is a type of firefighting foam that forms a thick blanket over the fuel surface to suppress and extinguish fires involving flammable liquids and gases. It has a low expansion ratio, meaning it produces less foam volume compared to high expansion foam. Low expansion foam is effective for controlling Class B fires by smothering the fuel and preventing vapor release. [9]

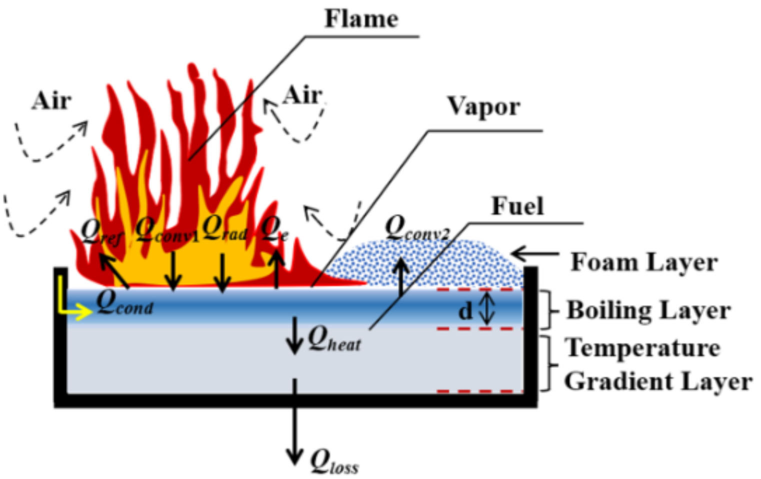

Figure 1.13: Foam blanket covering a burning fuel surface (Pool Fire)

Deluge systems

Deluge systems are specialized fire protection systems that rapidly release large volumes of water through open nozzles to suppress fires in high-hazard areas like chemical plants and oil refineries. They are effective for controlling fires involving flammable liquids and provide cooling to prevent fire spread and domino effects. [8]

Figure 1.14: Deluge system cooling a storage tank

Deluge Valve

A fire protection valve that automatically opens with a fire alarm, flooding an area with water from sprinklers. [8]

Nozzles

Nozzles are devices used to control the flow and direction of liquids or gases. They are commonly found in firefighting equipment, garden hoses, and industrial applications. Nozzles can adjust the shape, size, and velocity of the fluid stream to suit various purposes, such as spraying water, foam, or chemicals for firefighting, watering plants, or applying coatings in manufacturing processes. [8]

Figure 1.15: Medium velocity water spray nozzles

Hose systems

Hose systems are networks of flexible tubes used to convey fluids (liquids or gases) from one location to another. They are commonly used in firefighting, gardening, irrigation, and industrial applications. Hose systems typically consist of hoses, fittings, and nozzles, and can be designed for various purposes, such as delivering water for firefighting, spraying chemicals for agricultural purposes, or transporting gases in industrial processes. [10]

Hydrants

In the context of oil and gas, hydrants are fixtures located at strategic points within oil and gas facilities, such as refineries, production sites, and storage terminals. They provide a ready source of water for firefighting and emergency response activities in the event of a fire or other hazardous situation. Oil and gas hydrants are typically connected to water distribution systems within the facility and may be equipped with additional features such as foam injection systems or specialized fittings to accommodate firefighting equipment specific to the industry. They are essential for ensuring rapid and effective response to emergencies and protecting personnel, equipment, and assets within oil and gas facilities. [10]

Chapter 2

Methodology and Research

2.1 Introduction

Within this chapter, we bring closure to our exploration of NFPA and API standards and our requirement checklists, while also presenting the methodology directing our study. Here, we offer a concise glimpse into the structured approach shaping our study, with the aim of structuring our work and input data for a clear journey toward informed conclusions.

2.2 Fire protection standards

2.2.1 National Fire Protection Association (NFPA)

NFPA standards are globally recognized guidelines developed by the National Fire Protection Association to address fire prevention and safety measures. These standards encompass a broad spectrum of topics, ranging from building construction to emergency response protocols, and are continuously updated to reflect the latest advancements in technology and best practices. In our project, we relied on NFPA standards as the benchmark for evaluating foam suppression systems and water spray systems, including deluge systems. By adhering to these standards, we ensure a comprehensive and systematic approach to assessing the effectiveness and reliability of fire suppression mechanisms, thereby enhancing overall safety and risk management measures.

NFPA 11

NFPA 11 is a key standard for evaluating low-, medium-, and high-expansion foam systems used in fire suppression. In our project, focusing on oil and gas facilities, we specifically assess low-expansion foams, aligning with NFPA 11's criteria for design. This ensures a tailored evaluation process that addresses the specific needs of these facilities and maximizes the effectiveness of foam suppression systems.[9]

NFPA 15

NFPA 15 is a standard established by the National Fire Protection Association, concentrating on water spray fixed systems for fire protection. In our project, we direct our attention to NFPA 15's deluge systems, particularly concerning the design and capacity, This focus ensures that our evaluation process aligns with industry standards, specifically tailored to the requirements of fire protection in oil and gas facilities where water spray systems play a vital role in mitigating fire hazards. [8]

NFPA 17

NFPA 17, developed by the National Fire Protection Association, concentrates on the installation and maintenance of dry chemical extinguishing systems. In our study, we emphasize NFPA 17's criteria, particularly regarding the design of dry chemical extinguishing systems. By adhering to NFPA 17, we ensure that our evaluation process is in line with industry standards, specifically addressing the effectiveness of dry chemical extinguishing systems in mitigating fire risks within oil and gas facilities.

2.2.2 American Petroleum Institute (API)

The American Petroleum Institute (API) is a trade association representing the oil and natural gas industry in the United States. Founded in 1919, API develops standards and best practices for the oil and gas industry, covering a wide range of areas including exploration, production, refining, transportation, and environmental protection. API standards are widely recognized and utilized globally, providing guidelines for equipment design, manufacturing, and operation to ensure safety, reliability, and environmental responsibility within the industry. Additionally, API conducts research, advocacy, and outreach activities to promote the interests of its member companies and the broader oil and gas sector.

API RP 2218

API RP 2218, titled "Fireproofing Practices in Petroleum and Petrochemical Processing Plants," is a recommended practice developed by the American Petroleum Institute (API). It provides guidelines for fireproofing design, installation, inspection, and maintenance in petroleum and petrochemical processing facilities.[12]

API RP 2218 helps in creating a fireproofing plan by offering detailed recommendations on various aspects, including:

- **Fireproofing Materials:** It outlines suitable materials for fireproofing structures and equipment, considering factors such as fire exposure duration, temperature, and environmental conditions.
- **Design Criteria:** The recommended practice provides criteria for determining the required fire resistance rating of fireproofing systems based on the specific hazards and equipment in the facility.

- **Installation Procedures:** API RP 2218 offers guidance on proper installation techniques to ensure the effectiveness and durability of fireproofing materials and systems.

- **Inspection and Maintenance:** It establishes procedures for inspecting fireproofing systems regularly to detect any damage or degradation and outlines maintenance practices to ensure continued effectiveness.

2.3 Overall methodology

Like mentioned in the previous chapter, our work objectives consist of:

- Establish a Fire Proofing plan according to API RP 2218 standard for passive fire protection.

- Evaluate the suppression systems according to the NFPA standards for active fire protection.

In order to do so, the general methodology to follow is illustrated via the following diagram.

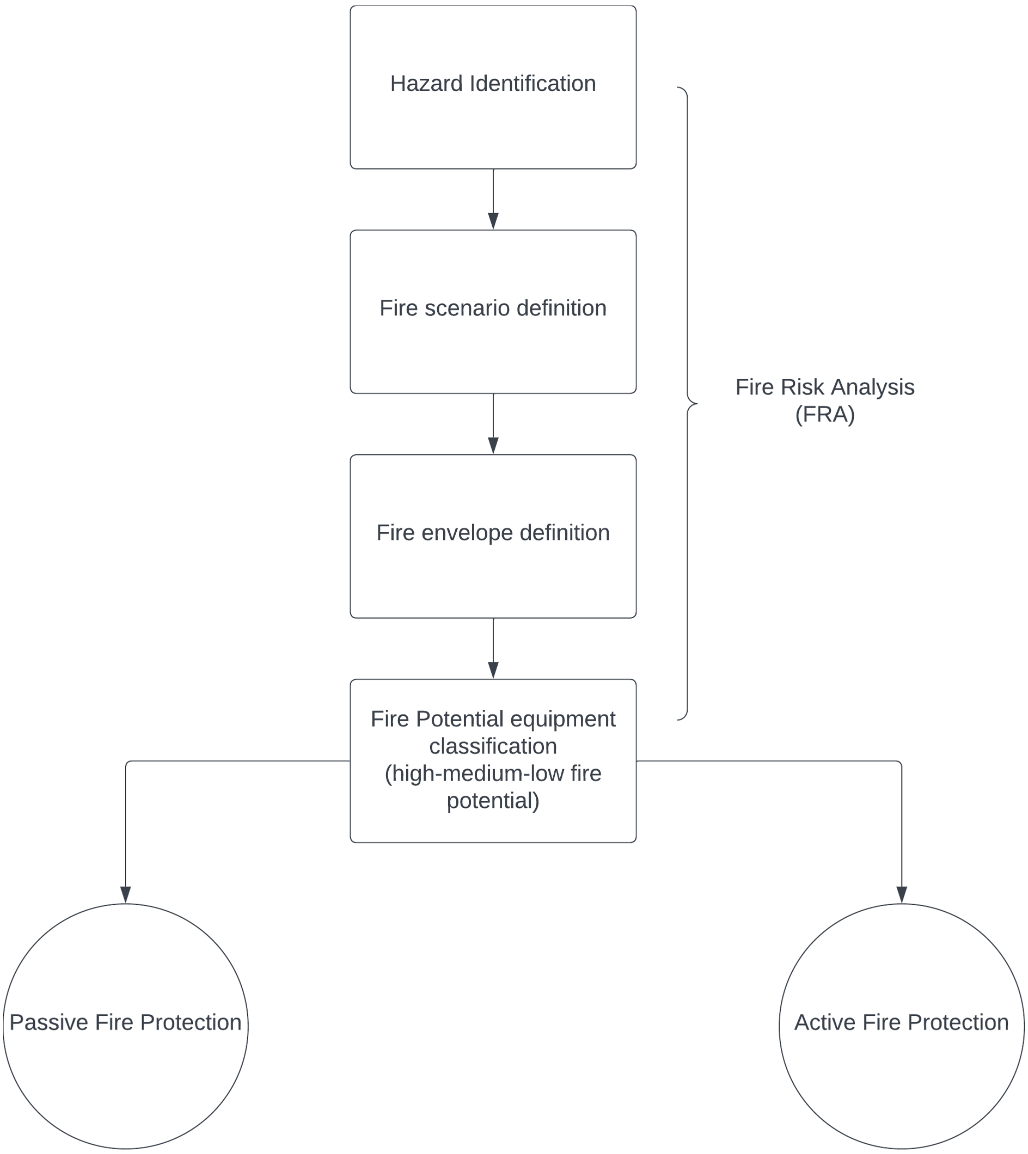

Figure 2.1: General methodology

- **Hazard Identification:** In the hazard identification phase, we proactively assess each unit at the gas treatment site, pinpointing potential dangers, their causes, and the resulting consequences. This helps us prioritize actions to prevent harm.
- **Fire scenario definition:** Fire scenario definition refines potential fire risks at the gas treatment site.[12] We create detailed descriptions of fire events using operational parameters. This includes specifying the type of fire, its location within a unit, and the operational conditions that could cause it. By outlining these possibilities, we can plan and implement effective fire protection and mitigation strategies.
- **Fire envelope definition:** The fire envelope defines the designated fire zones on the gas treatment site's master plan. This one-time exercise creates a clear picture by dividing the facility into distinct zones based on fire risk.[12] Each zone will have specific fire resistance requirements for buildings and equipment, as well as fire suppression strategies tailored to the potential hazards within that zone. This zonation approach simplifies future planning and ensures consistent fire safety measures across the entire site.
- **Fire Potential Equipment classification:** During fire risk assessment, we classify equipment at the gas treatment site based on their fire potential: high, medium, or low. This classification considers factors like the type of fuel used, operating temperatures, presence of flammable materials, and potential ignition sources. High-risk equipment receives the most stringent fire protection measures, while low-risk equipment may require minimal intervention. This categorization helps prioritize resources and ensures targeted fire safety strategies for each piece of equipment.

After following the methodology, we will have enough input data to work on Passive and Active fire protection measures.

2.3.1 Passive Fire Protection

To ensure the credibility and effectiveness of our fireproofing plan for the gas treatment site, we have adopted a methodology that strictly adheres to the American Petroleum Institute's Recommended Practice 2218 (API RP 2218) standard. This industry-recognized standard provides a robust framework for selecting, applying, and maintaining fireproofing systems specifically designed to mitigate property loss from pool fires in petroleum and petrochemical facilities. The following figure illustrates the step-by-step approach we will follow to develop a comprehensive fireproofing plan based on the valuable guidance outlined in API RP 2218.

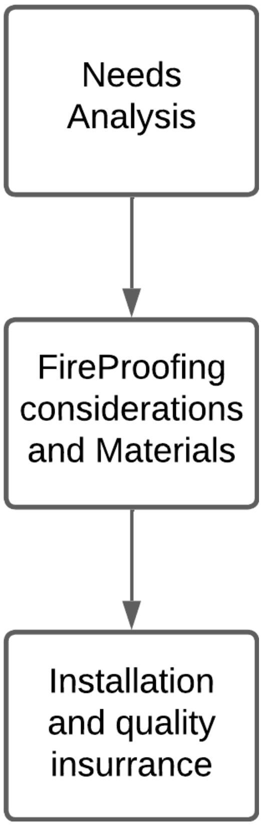

Figure 2.2: Fireproofing methodology

- **Information gathering on Location and Potential Heat Release:** The first step in passive fire protection planning is information gathering on the location and potential heat release within the facility. This involves meticulously documenting the layout of the gas treatment site, identifying the specific location of each piece of equipment. By gathering this crucial data, we can pinpoint areas of high fire risk and prioritize passive fire protection measures accordingly.

- **Estimating the duration of unabated fire:** Leveraging data from the Fire Risk Assessment (FRA), we can estimate the duration of an unabated fire at the gas treatment site. This analysis considers the time it takes for automatic and manual detection systems to activate, followed by the closure of shut-down valves. By incorporating these crucial response times from the FRA, we can create a realistic picture of how long a fire might burn before it's brought under control through isolation measures. This information is vital for designing passive fire protection systems that can withstand the anticipated heat exposure.

- **Need of Fire Proofing for exposed structures to thermal radiations:** The need for fireproofing exposed structures hinges on protecting them from thermal radiation emitted during a fire event. The Fire Risk Assessment (FRA) establishes a threshold radiation limit, the maximum amount of heat these structures can safely absorb without failure. This threshold considers the material properties and structural integrity of exposed elements. Our fireproofing analysis identifies structures exceeding this limit, highlighting areas where fireproofing measures are crucial. This targeted approach ensures optimal use of resources while safeguarding critical components from the damaging effects of thermal radiation during a fire.

- **Fire Proofing considerations:** As outlined in API RP 2218 Clause 5, fireproofing decisions for equipment supports hinge on two key factors. Firstly, we prioritize supports within the designated fire zone to mitigate direct fire impact. Secondly, fireproofing is crucial for supports where a collapse could critically damage nearby high-risk equipment. This targeted approach ensures both equipment protection and structural integrity during a fire event.

- **Fire Proofing materials:** Following API RP 2218 Clause 6, fireproofing materials and methods will be meticulously chosen to ensure optimal protection. The standard provides guidance on selecting and applying various fireproofing materials, ensuring they effectively resist the heat exposure anticipated from potential fire scenarios. This selection process considers factors like material compatibility with the protected structure, desired fire resistance rating, and ease of application within the gas treatment site environment.

- **Installation and Quality** Adhering to API RP 2218 Clause 8, both installation and quality control are critical for effective fireproofing. The standard outlines stringent requirements for qualified applicators to ensure proper installation techniques and adherence to specified application thicknesses. Additionally, rigorous quality checks are mandated to verify the integrity and fire resistance capabilities of the installed fireproofing materials. This comprehensive approach, as outlined in API RP 2218, guarantees the long-term performance and reliability of the fireproofing system in protecting the gas treatment site.

Further details about the methodology and its application will be discussed in *Chapter 4: Passive Fire Protection (Fireproofing).*

2.3.2 Active fire protection

Active fire protection measures play a crucial role in our overall fire safety strategy. To ensure their effectiveness, a thorough evaluation of fire suppression systems is paramount. This evaluation will consider factors like the type of hazards present in each zone (as defined in the fire envelope), the extinguishing agent's compatibility with those hazards, and the system's discharge capacity. By aligning these elements, we can guarantee optimal fire suppression capabilities across the entire gas treatment site.

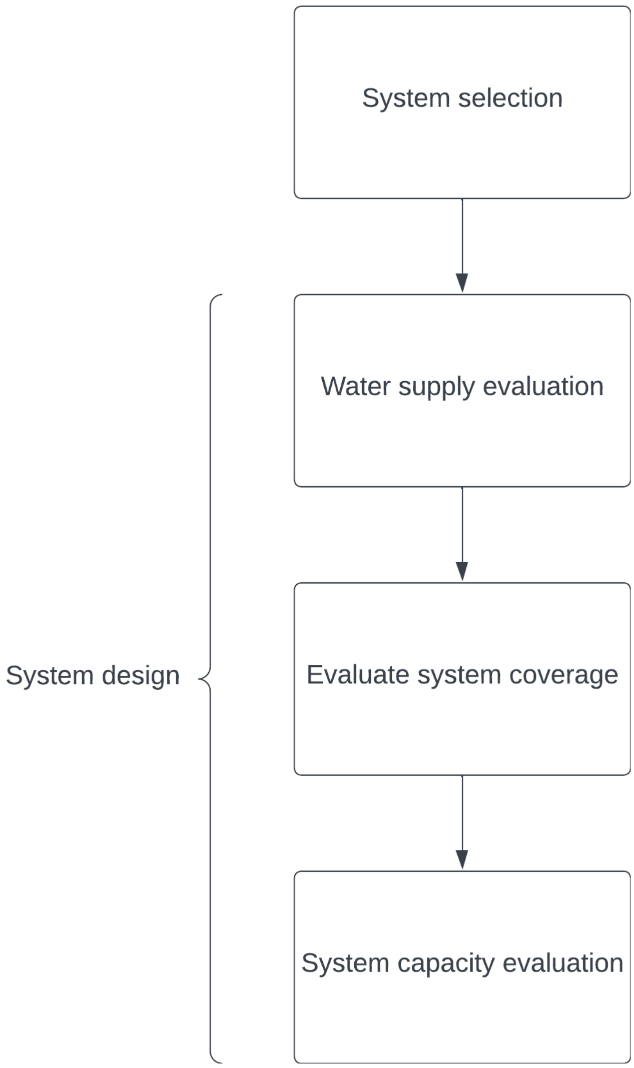

Figure 2.3: Evaluation of suppression systems methodology

- **System selection** The initial step in our active fire protection strategy involves meticulously selecting and evaluating the most suitable extinguishing systems for each zone within the gas treatment site. This process differentiates between two primary categories: foam and water-based systems. Foam systems excel at smothering hydrocarbon fires, while water systems are better suited for general fire suppression or cooling exposed equipment. By carefully assessing the specific hazards present in each zone, we can select the most effective extinguishing agent – foam or water – to ensure optimal fire suppression capabilities across the entire facility.

- **Water supply evaluation** A robust water supply is the backbone of any effective water-based fire protection system. To guarantee its adequacy, a thorough evaluation is essential. This assessment will consider factors like available water flow rate, pressure, and reliability of the source. Public fire hydrants, on-site water storage tanks, or a combination of both will be evaluated to ensure they can meet the anticipated water demand during a fire event. By verifying a sufficient and reliable water supply, we can optimize the effectiveness of water-based fire suppression systems throughout the gas treatment site.

- **Evaluate system coverage** Once the extinguishing agent (foam or water) is selected, a crucial aspect of active fire protection involves defining the system's coverage and protected areas. This entails meticulously designing the layout of sprinkler heads, foam discharge nozzles, or other extinguishing devices. This ensures comprehensive coverage throughout the designated fire zone, effectively blanketing potential ignition sources and flammable materials. By strategically placing these extinguishing devices, we guarantee a swift and impactful fire response across the entire gas treatment site.

- **System capacity evaluation** Ensuring active fire protection effectiveness requires a two-pronged capacity evaluation. First, we verify the chosen extinguishing agent (foam or water) can deliver enough volume to smother a potential fire within the designated zone. This considers fire size, agent application rate, and protected area. Second, the system's hydraulics are assessed to guarantee sufficient pressure and flow rate reach every sprinkler head or foam nozzle throughout the protected area. By evaluating these factors, we ensure the active fire protection system has the power and reach to effectively control and extinguish fires across the entire gas treatment site.

2.4 Standard's main requirements

2.4.1 NFPA 11: Foam systems

NFPA 11 covers a wide range of foam systems, our work focuses specifically on low-expansion foam systems. Here, we delved into the critical requirements for ensuring proper foam generation and delivery and requirements of the protection of equipment. This includes standards for water supply, foam concentrate, and foam proportioning. Furthermore, this section details how these systems safeguard various storage tanks, including those with fixed roofs, floating roofs, and diked/non-diked enclosures, there are also requirements for foam hose systems **(see APPENDIX I-A)**.

2.4.2 NFPA 15: Water systems

NFPA 15 dives deep into water spray fixed systems, with Appendix A acting as the core for these requirements. This section goes beyond just extinguishing fires. It emphasizes a crucial function: controlling the burning process. Appendix A outlines specific standards for designing water spray systems, particularly deluge systems, to effectively suppress flames and minimize fire intensity. Furthermore, it focuses heavily on equipment exposure protection, ensuring critical machinery and infrastructure are shielded from the damaging effects of fire and heat. Deluge systems play a key role in this protection by delivering large quantities of water to cool exposed equipment and prevent its failure **(see APPENDIX I-B)**.

2.4.3 API RP 2218: Fire Proofing requirements

Appendix I-C/D goes beyond theory and provides actionable guidance. Packed with tables, it details key fireproofing considerations for various scenarios and breaks down suitable fireproofing materials for each situation. By leveraging Appendix A-C/D, we can make informed decisions about selecting and implementing the most effective fireproofing solutions for our specific needs. **(See APPENDIX I-C** and **APPENDIX I-D)** .

Chapter 3

Fire Hazard Analysis (FHA)

Introduction

This report presents the findings of a Fire Hazard Analysis (FHA) conducted at our natural gas processing plant. Our FHA identified key fire hazards, including equipment handling combustible materials and ignition sources. Mitigation strategies and preventative measures were outlined to enhance fire safety.

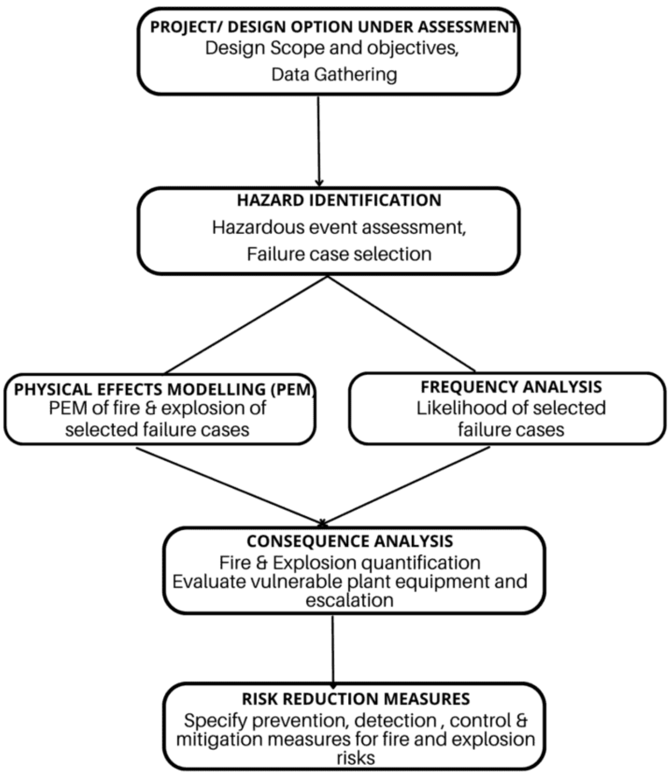

Figure 3.1: FHA methodology
[13]

3.1 Design objectives, Facility's layouts and Operational parameters

The initial groundwork for conducting a Fire Hazard Analysis (FHA) lies in gaining a deep understanding of the workspace design. This involves a meticulous assessment of the space's objectives, layout, and operational procedures. By carefully scrutinizing these elements, akin to dissecting various components, FHA can accurately identify potential fire risks. This pivotal first step enables the implementation of strong safety measures, ultimately promoting a workplace environment that is protected against fire hazards.

3.1.1 Design objectives

A gas processing plant (GPP) is designed to transform raw gas into a valuable product by separating its components, removing impurities, and meeting specific quality standards. This multi-stage process involves separating the gas stream into its constituent parts (gas, liquids, and water), purifying the gas by removing unwanted elements like H2S, Hg and CO2, preventing hydrate formation in pipelines, recovering valuable liquid hydrocarbons, and compressing the processed gas for efficient transportation. Additionally, the design should consider the treatment and disposal of byproducts like produced water and CO2 emissions to minimize environmental impact.

The site has 20 units, there are 2 types of these units: Central Processing Facilities (CPF) and Utilities Facilities.

Central Processing Facilities	Utilities Facilities
Unit 100 Receiving Facility	Unit 300 Power Generation and Heat Recovery
Unit 100 Receiving Facility	Unit 301 Hot Oil Systems
Unit 101 Intake Suppressor	Unit 302 Air for instruments and compressed air
Unit 102 H2S and Mercury Disposal	Unit 303 Nitrogen
Unit 103 CO2 Removal (amine unit)	Unit 304 Fuel Gas System
Unit 104 Gas Dehydration (TEG)	Unit 305 Torch System
Unit 105 Dew Point Adjustment	Unit 306 Incineration System
Unit 106 Condensate Stabilization	Unit 307 Drainage Systems
Unit 200/203 Gas Gauge and Export Pipeline	Unit 308 Diesel Storage System
Unit 201 Condensate Measurement, Storage and Export	Unit 309 Chemical Storage and Injection
/	Unit 400/401/403 Raw Water, Demineralized and Drinking Water Treatment
/	Unit 402 Fire Water System
/	Unit 404/406 Sewage Treatment and Production

3.1.2 Facility's layouts

The table below details the layout on a per unit basis for the Central Processing Facilities (CPF) equipment. This differs from the Utilities unit layout, which typically features heat exchangers, compressors, and various vessels.

Facility	Unit number	Unit	Equipment	Type
CPF	100	Receiving facility	HP separator	Vessels
			MP serpator	
	101	Intake facility	Air cooler	Air cooler
			Separation drum	Vessels
			Compressor	Compressor
	102	H2S and Hg removal	Hg removal vessel	Vessels
			H2S removal vessel	
	103	CO2 Removal	Amine absorber	Vessels
			Regeneration section	Heat exchangers
	104	Gas dehydration TEG	TEG stripping column	Vessels
			Heat exchanger	Heat exchanger
	105	Drew point adjustment	Turbo-expander	Compressor
			Heat exchanger	Heat exchanger
			Recompressor	Compressor
			Separator	Vessel
	106	Condensate stabilization	Flash drums	Vessel
			Stabilization columns	
			Air cooler	Air cooler
	201	Condensate storage	Storage tanks	Storage tanks
			Exportation pumps	Pumps

3.1.3 Operational parameters

Continuous control of operational parameters is vital for safe, efficient gas treatment at complex sites. These parameters, like pressure, temperature, flow rates... . Maintaining them within set limits ensures optimal contaminant removal, protects equipment, and minimizes environmental impact. **Appendix II-B** details these parameters (See **Appendix II-B**). Notably, it also includes isolatable sections, that will be discussed in the following chapter in the Needs Analysis part.

3.2 Hazard identification

Our hazard identification table focuses specifically on fire risks. This critical step involves examining potential scenarios throughout the gas processing plant that could lead to these events. Key areas of concern include leaks from flammable gas lines, malfunctions in high-pressure equipment, and the presence of ignition sources near combustible materials.**(see APPENDIX II-A)**

Interpretation:
From **APPENDIX II-A**, we can conclude the following points:

- **Primary Risks Identified**: Leaks, Loss of containment.
- **Causes of Leaks:** Aging infrastructure, Corrosion, Mechanical failures in valves or fittings.
- **Consequences:** Jet Fire, Pool Fire, UVCE (Unconfined Vapor Cloud Explosion).
- **Significant Risks:** Loss of containment, especially During maintenance activities or Improper isolation procedures during process shutdowns

3.3 Physical effects modeling

Building upon the identified fire and explosion hazards, our safety protocols incorporate physical effects modeling. This important step utilizes DNV-Phast, a sophisticated software program, to simulate the potential consequences of these events. Running simulations enables us to predict thermal radiation and the potential for flammable substance leaks. Through analysis of these simulations, we acquire valuable data guiding the design and implementation of robust safety measures. This process not only enhances the plant's overall resilience against fire and explosion events but also aids in identifying the specific equipment most in need of protection.

3.3.1 Introduction to DNV-PHAST

DNV PHAST is a software tool used for assessing and analyzing fire, explosion, and toxic release hazards in industrial settings. It enables engineers and safety professionals to simulate various scenarios involving hazardous materials, process equipment, and environmental conditions to evaluate the potential consequences of hazardous events. PHAST assists in identifying potential risks and developing effective risk management strategies to enhance safety within industrial facilities. This software caters particularly well to gas processing plant simulations.
DNV-Phast allows us to model a wide range of fire and explosion events, including:

- Jet fires
- Pool fires
- Flash fires
- Vapor Cloud Explosions (VCEs)
- Boiling Liquid Expanding Vapor Explosions (BLEVE)

By simulating these scenarios, DNV-Phast helps us predict the impact of factors like:
Pressure waves: The force generated by an explosion that can damage equipment and structures.
Thermal radiation: The heat emitted from a fire, which can ignite nearby objects and pose a risk

to personnel.
Flammable gas dispersion: The spread and concentration of flammable gas clouds after a leak, creating areas susceptible to ignition.

3.3.2 Input Parameters

Input parameters in DNV-PHAST encompass critical variables essential for accurately modeling fire and explosion scenarios within industrial environments. These parameters include factors such as process equipment specifications, material properties, release rates of hazardous substances, and environmental conditions.

Hole size

Hole sizes are chosen based on the size of the failure, aiming to manage potential on-site and off-site consequences. Small and medium holes are mainly considered for on-site risks, while medium and large holes are more important for off-site risks. According to **API RP 581**, four reject hole sizes are selected per component for better discrimination.

Equipment	**Hole sizes (mm)**				**Notes**
	Small	**Medium**	**large**	**Full bore**	
Piping	5	25	100	d	If the pipe diameter is less than 25mm, only a 5mm and full bore hole are used. If the pipe diameter is less than 25mm, 5, 25mm and full bore hole are used.
Pressure Vessels	5	25	100	d	If the pipe diameter is less than 25mm, only a 5mm and full bore hole are used. If the pipe diameter is less than 25mm, 5, 25mm and full bore hole are used.
Pumps	5	25	100	/	If the suction line is less than NPS 4, the release hole size should be the full diameter of the suction line
Compressors	/	25	100	/	OR complete rupture of the suction line, whichever is smaller

Table 3.1: HOLE sizes for types of equipment
[14]

Weather conditions

Key weather data like temperature, wind, and pressure will be included in the DNV-Phast simulations to account for their impact on fire behavior and gas dispersion

Parameter	**5D**	**2F**
	40°C	10°C
Atmospheric pressure	1.013 bara	1.013 bara
Surface temperature	40°C	10°C

Note that:

- As a conservative approach the highest distance among the both weather conditions modelled is considered for the assessment of the safety distances used for the fire zone, restricted area and impacted area definition.
- The frequency of the wind speed is as follows:
  - 20% of the time: 2m/s
  - 80% of the time: 5m/s

Material properties

At each stage of the process, the dominant component of the gas mixture will be chosen as the modeling substance, since the main component of raw natural gas is methane, the main modeling substance at the early stages of the processing will be methane, the treatment of the gas will influence on its components thus on the modeling substance on diffirent stages of the process.

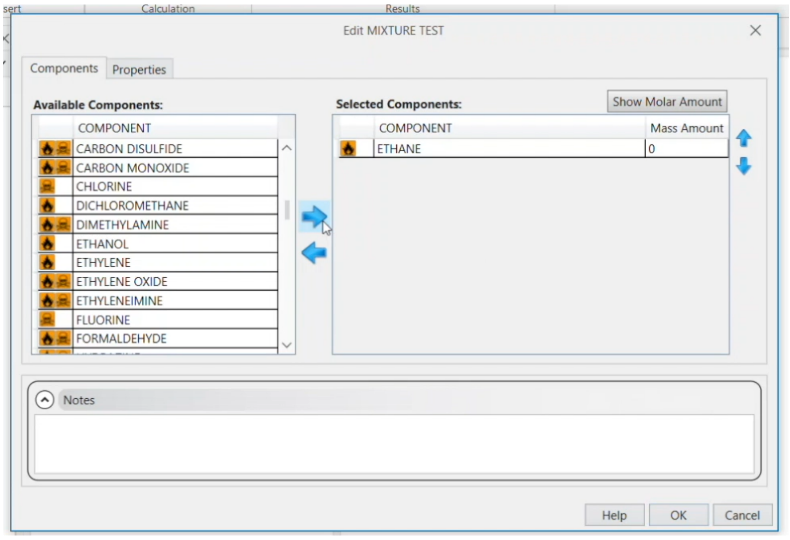

Figure 3.2: Material Properties on DNV Safeti/PHAST

Operational parameters and equipment

Similar to material properties, PHAST/Safeti focuses on key operational parameters at each process stage: pressure, temperature, flow rate, inventory mass, and volume. These parameters are crucial for safe operation, and just like the appendix provides safe material properties, there are established safe operating limits for each parameter at every process point. (See **APPENDIX II-B**)

3.3.3 Impact criteria

In our active and passive protection study we focus on Jet Fires and Pool Fires due to their continuous heat. UVCE, flash fires and explosions, although dangerous, have near-instantaneous effects,

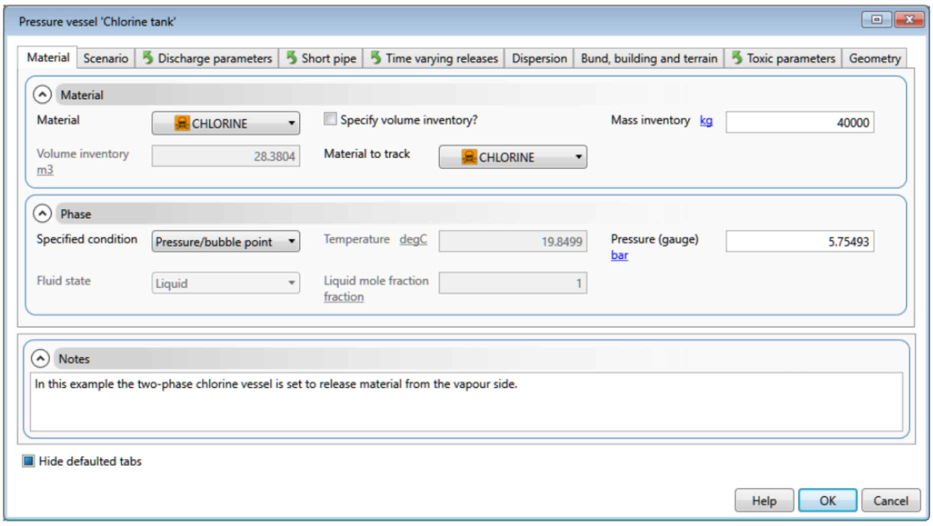

Figure 3.3: Vessel's operational parameters on DNV Safeti/PHAST

making active systems less relevant for initial mitigation.

API 581 defines radiation exposure limits to assess safety distances during jet or pool fires. A limit of 37.8 kW/m² is used for areas where component damage is a concern, while a lower limit of 12.6 kW/m² is used to prevent personnel injuries.

[14] According to API PR 2218, the critical point is reached when the material loses 50% of it strength, FOR STEEL WHEN the steel reaches 538°C, IT LOSE 50% OF ITS STRENGTH. [12] The following equivalences between the radiation temperature and the metal temperature.

TYPE OF EXPOSURE	RADIATION	
	KW/m²	Btu/hr-ft²
Unprotected structural steel failure at approximately 650°C	37.5	12,000
Unprotected steel temperature stabilizes at approximately 400°C	16.0	5,000
Maximum allowable for unprotected LPG vessel vapour space	16.0	5,000
Unprotected metal's temperature stabilizes at approximately 315°C	12.5	4,000
Exposed oil tank is expected to ignite if it is in the flammable range	12.5	4,000
Maximum allowable on unprotected steel equipment	9.5	3,000
Takes approximately 25 minutes for steel to reach 150°C	6.3	2,000
Maximum allowable on electrical cable reaches 93°C	3.2	1,000

Figure 3.4: Equivalences between the radiation temperature and the metal temperature.

Similarly, the AICHEM guidelines indicate that unprotected steel structural members can fail after exposure to 37.5 kW/m² of thermal radiation.

We opted for a radiation limit of 30 kW/m² instead of the 37.8 kW/m² threshold. This choice prioritizes a larger safety margin, ensuring components can withstand potential thermal radiation exposure without reaching the point of catastrophic failure. This allows for a wider range of scenarios where the chosen limit provides adequate protection, even under varying fire conditions

3.3.4 Isolatable sections

One major aspect of mitigating fire hazards in these areas is the installation of automatic valves, such as Shutdown Valves (SDVs) and Emergency Shutdown Valves (ESDVs). SDVs are designed to stop the flow of fluids in a pipeline during normal operations, while ESDVs are used to shut down systems during emergency conditions. These valves are typically integrated into the facility's infrastructure and are designed to automatically close upon detection of a fire. By swiftly isolating the affected section of the facility, these valves help prevent the spread of fire to other areas, minimizing potential damage and ensuring the safety of personnel.

In addition to SDVs and ESDVs, Blowdown Valves (BDVs) and Pressure Safety Valves (PSVs) may also be utilized in isolated sections of the facility. BDVs serve to safely vent pressure from the isolated section in the event of a fire or other emergency, reducing the risk of ignition and potential escalation of the situation. PSVs are designed to release excess pressure from a system to prevent over-pressurization, which could lead to equipment failure or explosions.

The isolatable sections refer to the pipe sections between two types of safety valves, such as between an SDV and a BDV, ensuring that any potential hazard can be contained and managed effectively.

№	Phase	Description	Area	From	To
CA05	G	HP Separator 100-VA-001 Gas Phase	Receiving facilities separators	SDV0103 SDV0104	SDV0101 SDV0502 SDV0102 SDV0505 PSV0101A/B
CA05	D	HP Separator 100-VA-001 Liquid Phase	Receiving facilities separators	SDV0103 SDV0104	SDV0101 SDV0502 SDV0102 SDV0505
CA06	G	MP Separators 100-VA-002/003	Receiving facilities separators	SDV0303 SDV0304	SDV0203 SDV0201 SDV0202 SDV0302 SDV0301 SDV0204
CA07	G	MP Separators gasoutlet 100-VA- 002/100- VA-003, 101-GC-001 Gas Inlet Air Cooler	Receiving facilities separators	SDV0203 ESDV2501 SDV0204	BDV0101 SDV0101 SDV0103 PSV0102A/B PV0202 ESDV0102
CA08	D	Separators FilteredLiquid outlet 100- VA-001/100-VA-002/100-VA-003, 100-MB-021 A/B, 100-MB-022 A/B, 100-MB-023 A/B, 100- MB-025 A/B, 100-GX-011	Receiving facilities separators	SDV0101 SDV0201 SDV0301	PSV1101A/B PSV0202A/B PSV0302A/B ESDV1101 BDV1101
CB01	G	Booster compressor101-KA-004, 101- VD-002, 101-GC-005, (101-UK-010 Booster compressorPackage)	Inlet Boostercompressor	SDV0101 SDV0103	BDV0201 PSV0201A/B PSV0501A/B /C SDV0501 SDV0503
CB02	G	Discharge Coalescer - Mercury& H2S removal, 101-VJ-006, 102-VW-001, 102- VW002, 102-UK-010, 102-MB-004 A/B	Inlet Boostercompressor	SDV0502 SDV0501 SDV0503 SDV0505	SDV0601 SDV0602 BDV0601 BDV0102 BDV0201 PSV0102A/B PSV0601A/B PSV0101A/B PSV0401A/B BDV0402A/B BDV0102 BDV0106 ESDV0402 ESDV0101 SDV0401A/B SDV0402A/B XV0202 XV0302 MOV0301
CD01	G	Transfer from H2Sremoval to CO2 removal	CO2 removalamine unit	ESDV0101	BDV9001 SDV0103A SDV0104

CD02	G	CO2 removal treatment 103-MB-001 A/B, 103-VJ-002, 103-CA-003, 103-VD-008	CO2 removalamine unit	SDV0103A SDV2301	SDV0101A/B BDV0101A/B PSV0101A/B BDV0102 SDV0103A PSV0201A SDV0301 BDV0301 PSV0301A/B SDV2301 SDV0801 SDV0802 BDV0801 PSV0801A/B SDV0803 SDV0804 SDV0102A/B ESD9002
CD03	G	Transfert gas treated from CO2removal to gas dehydration	CO2 removalamine unit	SDV0804 SDV0803 ESDV0402	ESDV9003
CD04	G	Fuel gas from Richamine flash drum 103- VD-011	CO2 removalamine unit	SDV1102	ESDV9001
CD05	G	CO2 from Regenerator direct condenser 103-CB-014 to VOC treatment package306-UY-005	CO2 removalamine unit	SDV1401A	SDV0001 XV0001
CE01	G	Gas dehydration,104-GA-001, 104-VD-002, 104-GA-005, 104-CA-003, 104-VJ-004	Gas dehydrationTEGunit	ESDV9003	SDV0201 BDV0102 PSV0102A/B SDV0302 SDV1601 BDV0301 PSV0302A/B SDV0401 SDV0101 SDV0102 SDV0402
CF01	G	Gas Dew pointing,105-GX-001, 105-VD-002, 105-VD-004, 104-GA-001	Gas dew-pointing	SDV0101 SDV0102	SDV0204 SDV0201 SDV0302 SDV0401 BDV0401 PSV0401A/B BDV0101 PSV0101A/B SDV0501 BDV0503 BDV0201 PSV0201A/B BDV0106 SDV0504
CF01	D	Liquid Outlet from 105-VD-004 / 105-VD-002	Gas dew-pointing	SDV0101 SDV0102	SDV0204 SDV0201 SDV0302 SDV0401 BDV0401 PSV0401A/B BDV0101 PSV0101A/B SDV0501 BDV0503 BDV0201 PSV0201A/B BDV0106 SDV0504

CF02HP	L	HP Liquid outlet from 105-VD-004 / 105-VD-002 to 105-GX-001	Gas dew-pointing	SDV0401 SDV0204	ESDV0101
CF02MP	D	MP Liquid outlet from 105-GX-001	Gas dew-pointing	SDV0401 SDV0204	ESDV0101
CF03	G	Turbo expander105-KH-003	Gas dew-pointing	SDV0202 SDV0203	SDV0302 BDV0301
CF04	G	Recompressor 105-KA-005	Gas dew-pointing	SDV0501 SDV0504	SDV0502 BDV0501 PSV0501A/B
CF05	G	Outlet Recompressor 105-KA-005 - 105-UK-010 Turbo expander / Recompressorpackage	Gas dew-pointing	SDV0502	ESDV0101 ESDV0102 BDV0502
CG01	G	Gas outlet from Condensate flash drum 106- VD-001, 106-GA-019 A/B, 106-CB-003	Condensatestabilisation and off- gas compression	ESDV1101 ESDV0201 ESDV0601 ESDV0101	SDV0102 SDV1201A SDV1201B SDV2401B SDV2401A SDV0101 PSV0101A/B BDV0101 BDV0301 SDV0301
CG01	D	Liquid outlet from Condensate flash drum 106-VD-001,106-PA-020 A/B, 106-MB-001 A/B, 106-VJ-021, 106-GC-015, 106-GA-002, 106-CB-003	Condensatestabilisation and off- gas compression	ESDV1101 ESDV0201 ESDV0601 ESDV0101	SDV0102 SDV1201A SDV1201B SDV2401B SDV2401A SDV0101 PSV0101A/B BDV0101 BDV0301 SDV0301
CG02	L	Condensate to Condensate degassing drum106-VD-016	Condensatestabilisation and off- gas compression	SDV0301	SDV1601
CG03	L	Condensate from Condensate degassing drum 106-VD-016, Pump 106-PA-017A/B	Condensatestabilisation and off- gas compression	SDV1601	ESDV1701
CG04	L	Pumped Condensate from Stabilised Condensate Pumps106-PA-017 A/B & Condensate rundown header	Condensatestabilisation and off- gas compression	ESDV1701	SDV0202 SDV0302 XV0002

CG05	G	Off Gas compressor106-KB-009, 106- GC-010 A, 106-VD-012 A, 106-GC-011 A, 106- VD-024 A, 106-KB-025 A	Condensatestabilization and off- gas compression	SDV0103A	SDV1201A PSV1201AA/AB PSV0901AA/AB PSV2401AA/AB PSV 2501 AA/AB BDV2501A XV2301 SDV2401A SDV2501A
CG06	G	Outlet Off Gas compressor 106- KB-009 / 106-KB-025 A/B	Condensatestabilisation and off- gas compression	SDV2501A SDV2501B	ESDV2501
CL01	L	Condensate truck loading until loadingarms 201-YG-011/021, 201-UJ-010/020, 201-PA-005 A/B	Condensate storage tanksand loading	SDV0301SDV0201	XV1104 XV2104 XV0504
CL02	L	Condensate storage201-RA-002 loadingmode	Condensate storage tanksand loading	SDV0202	SDV0201
CL03	L	Condensate storage201-RA-003 filling mode	Condensate storage tanksand loading	SDV0302	SDV0301
CL04	L	Off spec Condensate storage 201-RA-004	Condensate storage tanksand loading	XV0002	SDV0402
CL05	L	Condensate truckloading arm 201- YG-011	Condensate storage tanksand loading	XV1104	End of truck loading arm201-YG-011
CL06	L	Condensate truckloading arm 201- YG-021	Condensate storage tanksand loading	XV2104	End of truck loading arm201-YG-021

3.4 Results of physical effects modeling

Consequence modeling identified varying hazardous distances based on the type of incident. Details for jet fire and pool fire are provided by **APPENDIX II-C**. These distances are measured from the source of the leak (jet fire), the pool center (pool fire). To determine the maximum hazard for each fire zone, we compared these distances against predefined safety thresholds. The attachment corresponding to the greatest distance from a specific incident scenario within that zone represents the governing hazard for consequence management planning **(See APPENDIX II-C)**.

3.4.1 Jet Fire and Pool Fire contour map

The following figures illustrate the combined jet fire and pool fire contours for various units and equipment within the facility. These contours provide a comprehensive overview of potential thermal radiation hazards:

- **Blue Lines:** These represent fire envelopes, established according to API RP 2218. Thus, a separate drawing details these Fire Hazard Envelopes, considering a 6-meter buffer zone around Medium and High Fire Potential equipment (according to API RP 2218).
- **Red Lines:** These contours depict the footprints of potential jet fires, highlighting the elongated zones directly exposed to intense heat.
- **Yellow Lines:** These contours represent the pool fire footprints, indicating the areas directly impacted by hazardous thermal radiation levels from a pool fire scenario.

By analyzing these unified contours, we can effectively define fire zones throughout the facility, considering both jet fire and pool fire risks.

Unit 100, 101 & 102: Receiving, Intake and H2S/Hg removal facilities

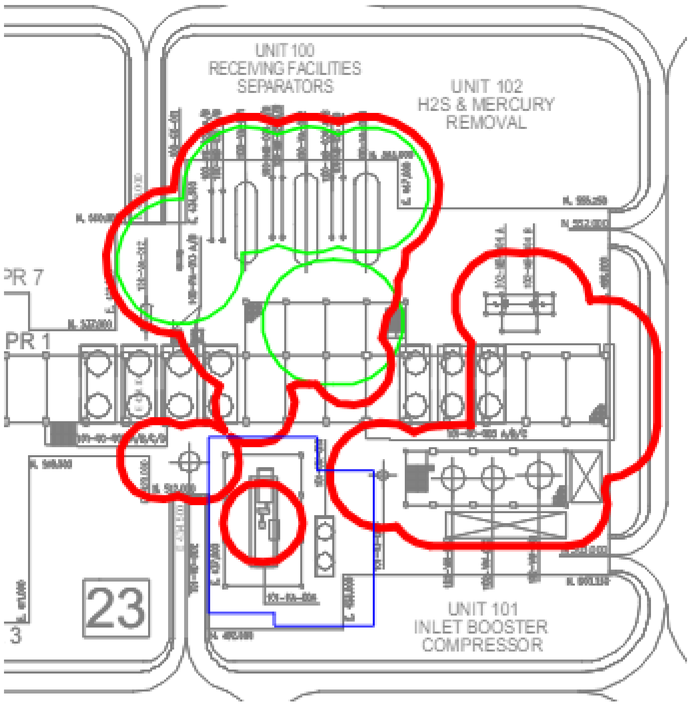

Figure 3.5: Jet Fire and Pool Fire contours (Unit 100, 101 and 102)

Unit 104, 105, 301 & 304: Gas dehydration TEG, Drew point adjustment and oil/gas systems

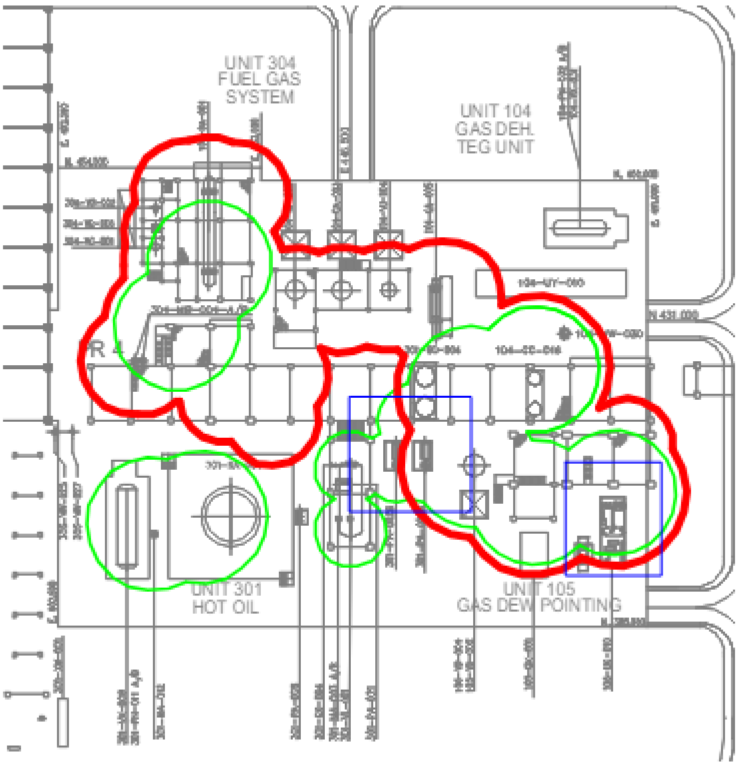

Figure 3.6: Jet Fire and Pool Fire contours (Unit 104, 105, 301 and 304)

Unit 103: CO2 removal

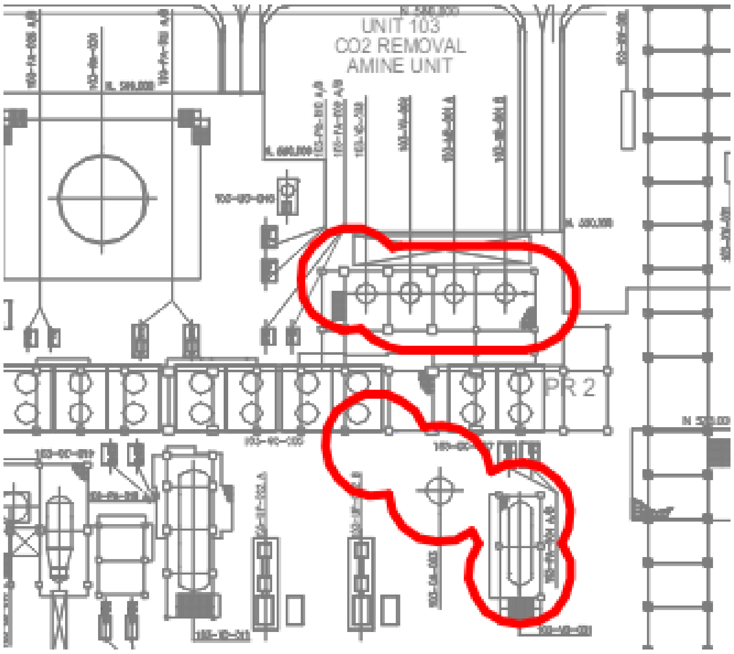

Figure 3.7: Jet Fire and Pool Fire contours (Unit 103)

Unit 106: Condensate stabilization

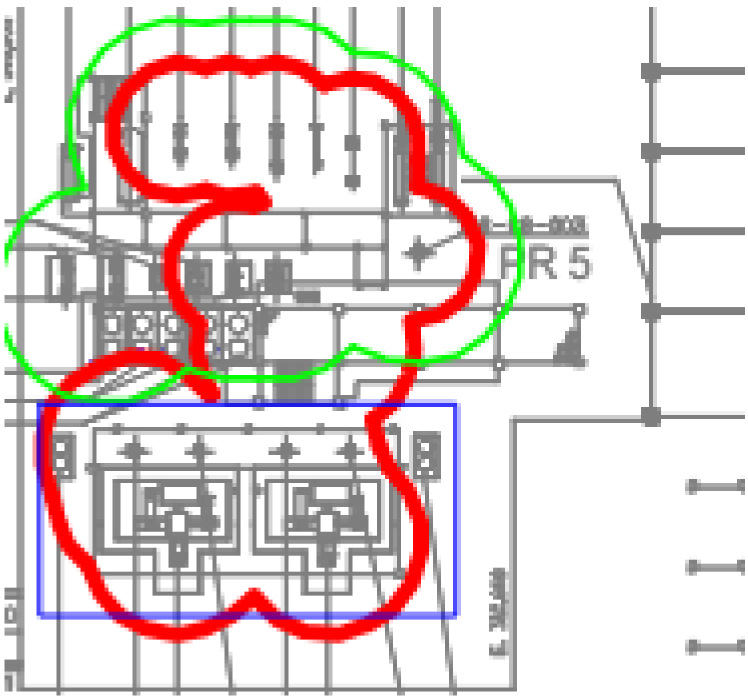

Figure 3.8: Jet Fire and Pool Fire contours (Unit 106)

3.4.2 Fire zones

Based on the combined jet fire and pool fire contours presented in the previous section, fire zones will be delineated throughout the facility. These zones will encompass all areas potentially exposed to thermal radiation hazards from both jet fires and pool fires. Each designated fire zone will be strategically equipped with a combination of active and passive fire protection measures.

Fire Zone	Type	Units
PFZ1	Process	Units 100 / 101 / 102 / 307
PFZ2	Process	Unit 103
PFZ3	Process	Units 104 / 105 / 301 / 304
PFZ4	Process	Unit 106
PFZ5	Process	Unit 200 & Manifolds
PFZ6	Process	Unit 305
PFZ8	Process	Unit 306 VOC treatment
SFZ10	Storage	Unit 201 (Condensate Storage Tanks Area)
UFZ9	Utility	Unit 300
UFZ11	Utility	Units 302 / 303 / 308 / 309 (Methanol & Glycol)/ 400/ 401/ 402/ 403

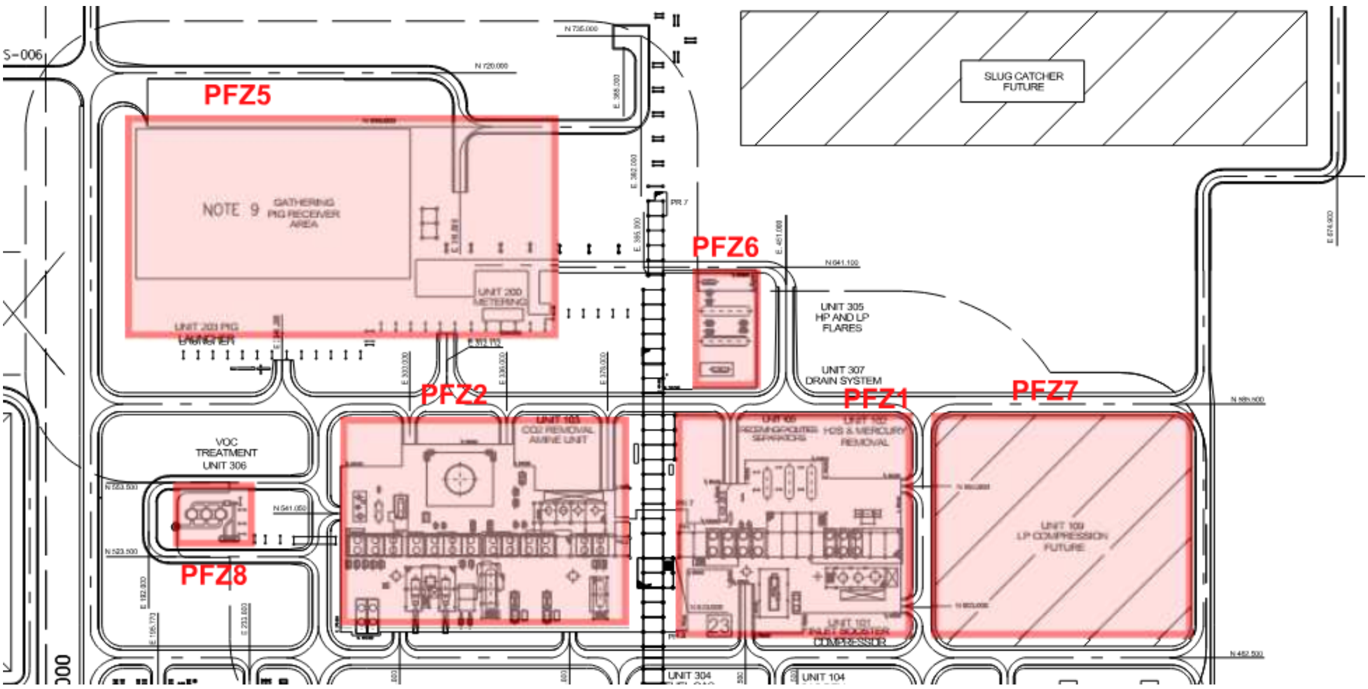

Figure 3.9: Process Fire Zones: PFZ1,PFZ2, PFZ5, PFZ6, PFZ7, PFZ8

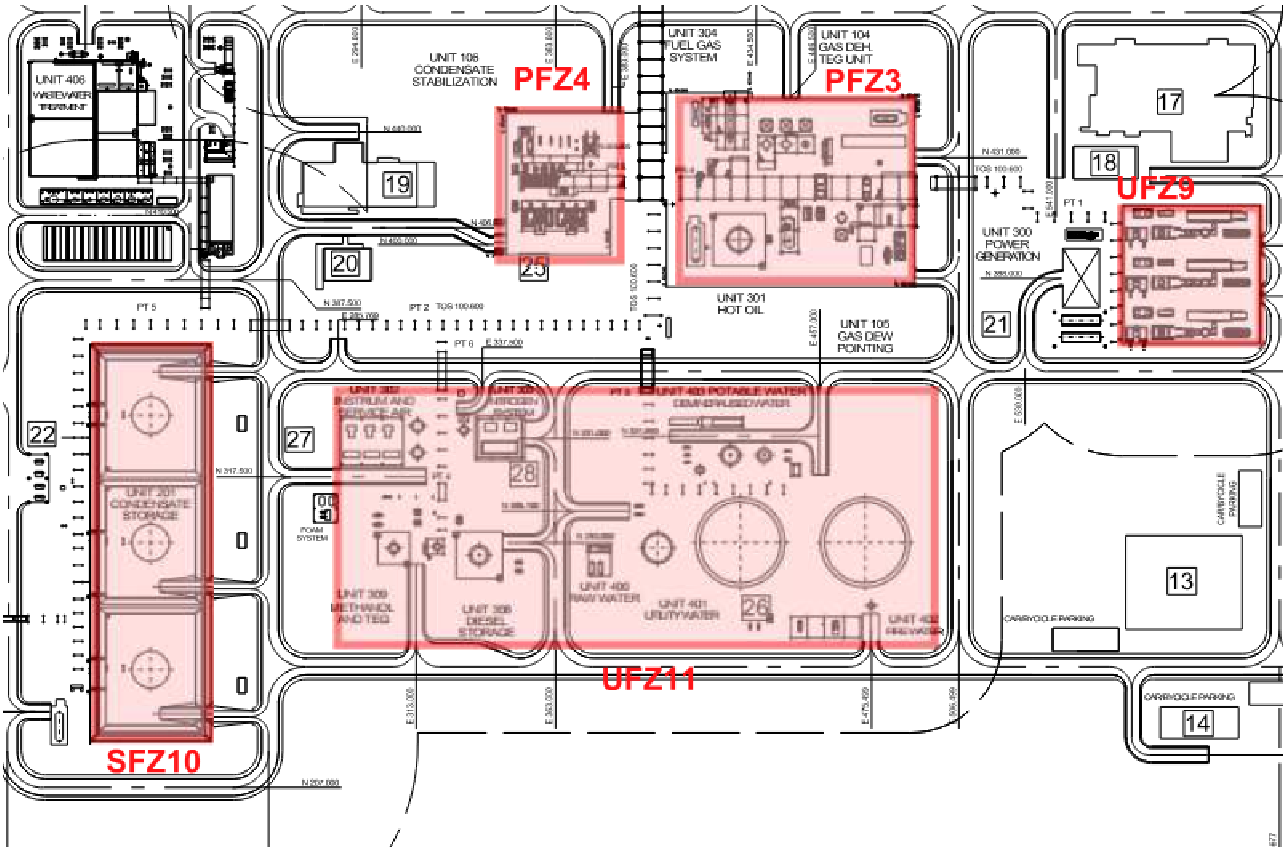

Figure 3.10: Process Fire Zones: PFZ3, PFZ4, UFZ9, SFZ10, UFZ11

3.5 Frequency Analysis

Understanding the frequency of a leak leading to ignition is essential to effectively assess risk. This chapter details the methodology used to quantify this frequency based on the analysis of the developed event tree. The calculated frequency allows informed decisions to be made regarding risk mitigation strategies and resource allocation for security measures.

3.5.1 Event-Tree

An event tree analysis was conducted to systematically explore the potential consequences of various initiating events in our process. This analysis charted the branching possibilities following an initiating event, such as a leak or equipment failure. Each branch represented a specific outcome, and the analysis identified four main consequences of concern: jet fire, pool fire, Vapor Cloud Explosion (VCE), and flash fire.

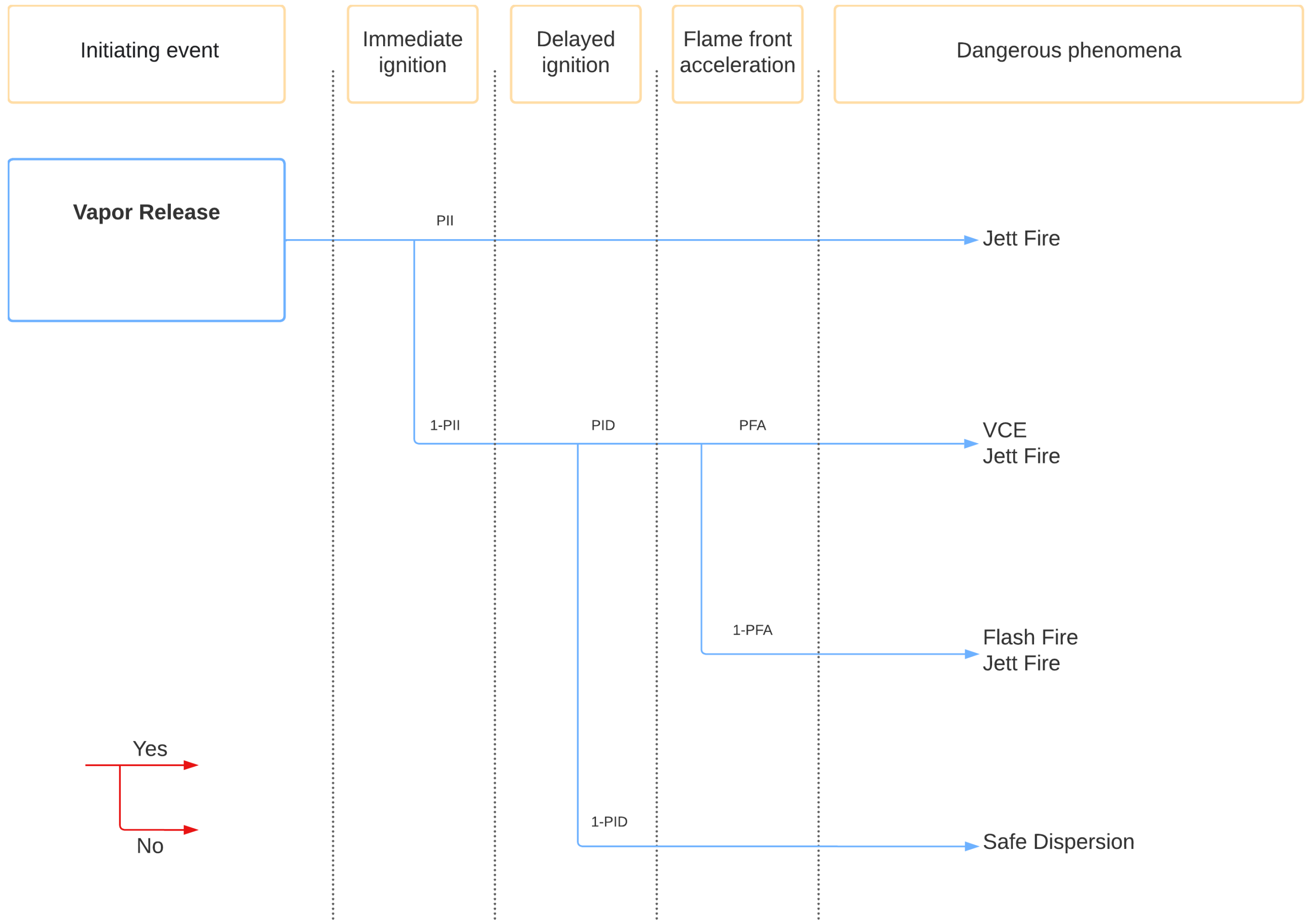

Figure 3.11: Event tree

3.5.2 Overview Of The Methodology

The event tree serves as the basis for calculating the frequency. Each branch in the tree represents a unique scenario with associated probabilities for events such as leak occurrence and ignition source presence. We will use these probabilities to calculate the overall frequency using a two-step approach: [14]

1. Analyze Components

- **Leak Frequency (F_{leak}):** Historical data, standards, or expert judgment determine likelihood of leaks.
- **Ignition Probability ($P_{ignition}$):** Flammability, ignition sources, and environment influence the chance of a leak igniting.

2. Calculate Overall Frequency

We calculate the overall frequency by multiplying the leak frequency F_{leak} and the ignition probability $P_{ignition}$ using the following formula:

$$F = F_{leak} \times P_{ignition}$$

3.5.3 Calculating the frequency based on UKOOA

Note: UKOOA is an abbreviation for United Kingdom Off-shore Operating Association.

A/ Calculating The Leak Frequency (F_{leak})

1. **Identification Of Equipment**
   For each isolated section, we identify the equipment (Process Pipe, valves, Centrifugal Pump) presented on the Data base.

2. **Calculate The Frequency For Each Equipment** For each equipment, the frequency is to be calculated using the Data Base's chart, *figure 3.12* below provides an example.

Process Equipment Leak Frequencies

Rev.:	1
Date:	26/9/2012
Source:	HCRD 10/92 – 03/10

Equipment Type: **Centrifugal Compressors**

Definition:

The scope includes the compressor itself, but excludes all attached valves, piping, flanges, instruments and fittings beyond the first flange. The first flange itself is also excluded.

Frequency Data:

Equipment Size	Category	Total	Full Pressure	Zero Pressure
0.5 in	1 - 3 mm	5.802E-03	5.583E-03	1.324E-04
	3 - 10 mm	2.462E-03	2.316E-03	1.052E-04
	10 - 50 mm	1.435E-03	1.300E-03	2.624E-04
	50 - 150 mm	0.000E+00	0.000E+00	0.000E+00
	> 150 mm	0.000E+00	0.000E+00	0.000E+00
	Total	9.699E-03	9.199E-03	5.000E-04
1 in	1 - 3 mm	5.802E-03	5.583E-03	1.324E-04
	3 - 10 mm	2.462E-03	2.316E-03	1.052E-04
	10 - 50 mm	1.435E-03	1.300E-03	2.624E-04
	50 - 150 mm	0.000E+00	0.000E+00	0.000E+00
	> 150 mm	0.000E+00	0.000E+00	0.000E+00
	Total	9.699E-03	9.199E-03	5.000E-04
2 in	1 - 3 mm	5.802E-03	5.583E-03	1.324E-04
	3 - 10 mm	2.462E-03	2.316E-03	1.052E-04
	10 - 50 mm	1.057E-03	9.686E-04	9.519E-05
	50 - 150 mm	3.772E-04	3.309E-04	1.672E-04
	> 150 mm	0.000E+00	0.000E+00	0.000E+00
	Total	9.699E-03	9.199E-03	5.000E-04

Figure 3.12: Frequency values for a Centrifugal Compressor
[16]

Equipment size refers to the dimensions of components such as vessels and flanges. For vessels (1 to 6 inches), it indicates the diameter of connections or ports on containers like storage tanks or pressure vessels. For flanges (6 to 20 inches), it specifies the nominal pipe size the flange connects to. For example, a vessel size of 3 inches means 3-inch diameter connections, and a flange size of 10 inches means it fits a 10-inch pipe. **Category** is the hole sizes categories

3. **Overall leak Frequency**F_{leak}

   After determining the probability of a leak for each piece of equipment, calculate the frequency of leaks for each isolated section by adding the probabilities of all the equipment present.

$$F_{leak} = \sum_{i=1}^{n} F_i$$

   With n representing the number of equipment and i the equipment's index

B/The probability Of Dangerous Phenomena

- **The probability of ignition**

  In real-world scenarios, the UKOOA model employs a formula to estimate the likelihood of ignition by considering factors like release rate and environmental conditions.
  A specific ignition probability is then obtained from the equation. [17]

$$P_{ign} = exp^{logP_n + \frac{(logQ - logQ_n)(logP_{n+1} - logP_n)}{logQ_{n+1} - logQ_n}}$$

  Where [17]
  P_{ign} is the Ignition probability at release rate Q
  P_n is the ignition probability at release rate Q_n
  P_{n+1} is the ignition probability at release rate Q_{n+1}
  and where the points (Q_n, P_n) and (Q_{n+1}, P_{n+1}) are adjacent points in Table 2 between which the value of Q lies.

Case No.	Case Description	Point 1 Q (kg/s)	Point 1 P_{ign}	Point 2 Q (kg/s)	Point 2 P_{ign}	Point 3 Q (kg/s)	Point 3 P_{ign}	Point 4 Q (kg/s)	Point 4 P_{ign}	Point 5 Q (kg/s)	Point 5 P_{ign}	Point 6 Q (kg/s)	Point 6 P_{ign}	Point 7 Q (kg/s)	Point 7 P_{ign}
1	Pipe Liquid Industrial	0.01	0.00100	0.03493	0.00100	0.100	0.00180	70.000	0.07000	100000	0.07000				
2	Pipe Liquid Rural	0.01	0.00100	0.03787	0.00100	0.100	0.00180	0.300	0.00350	70.000	0.00700	70.000	0.00700	100000	0.00700
3	Pipe Gas LPG Industrial	0.01	0.00100	0.08791	0.00100	0.100	0.00110	1000	1.00000	100000	1.00000				
4	Pipe Gas LPG Rural	0.01	0.00100	0.04799	0.00100	0.100	0.00110	10.000	0.00200	1000.000	0.08000	23408.547	1.00000	100000	1.00000
5	Small Plant Gas LPG	0.01	0.00100	0.07654	0.00100	0.100	0.00110	1.000	0.00250	3.000	0.01400	498.991	0.60000	100000	0.60000
6	Small Plant Liquid	0.01	0.00100	0.07548	0.00100	0.100	0.00110	1.000	0.00240	100.000	0.10000	100000	0.10000		
7	Small Plant Liquid Bund	0.01	0.00100	0.07548	0.00100	0.100	0.00110	1.000	0.00240	8.053	0.01300	100.000	0.01300	100000	0.01300
8	Large Plant Gas LPG	0.01	0.00100	0.07654	0.00100	0.100	0.00110	1.000	0.00250	100.000	0.25000	260.000	0.65000	100000	0.65000
9	Large Plant Liquid	0.01	0.00100	0.07654	0.00100	0.100	0.00110	1.000	0.00250	100.000	0.12000	109.990	0.13000	100000	0.13000
10	Large Plant Liquid Bund	0.01	0.00100	0.07548	0.00100	0.100	0.00110	1.000	0.00240	42.492	0.05000	100.000	0.05000	100000	0.05000
11	Large Plant Confined Gas LPG	0.01	0.00100	0.07654	0.00100	0.100	0.00110	1.000	0.00250	70.000	0.43000	325.028	0.70000	100000	0.70000
12	Tank Liquid 300 × 300 m Bund	0.01	0.00100	0.05250	0.00100	0.100	0.00105	1.000	0.00125	7.000	0.00270	519.617	0.12000	100000	0.12000
13	Tank Liquid 100 × 100 m Bund	0.01	0.00100	0.05250	0.00100	0.100	0.00105	1.000	0.00125	7.000	0.00270	49.035	0.01500	100000	0.01500
14	Tank Gas LPG Storage Plant	0.01	0.00104	0.00160	0.00100	0.100	0.00110	1.000	0.00116	100.000	0.96000	102.838	1.00000	100000	1.00000
15	Tank Gas LPG Storage Industrial	0.01	0.00104	0.00160	0.00100	0.100	0.00110	1.000	0.00116	100.000	0.22700	988.106	1.00000	100000	1.00000
16	Tank Gas LPG Storage Rural	0.01	0.00104	0.00160	0.00100	0.100	0.00110	1.000	0.00116	10.000	0.01540	52551.538	0.50000	100000	0.50000
17	Offshore Process Liquid	0.01	0.00100	0.07882	0.00100	0.100	0.00110	100.000	0.01750	100000	0.01750				
18	Offshore Process Liquid NUI	0.01	0.00100	0.07882	0.00100	0.100	0.00110	24.731	0.01000	100.000	0.01000	100000	0.01000		
19	Offshore Process Gas Opendeck NUI	0.01	0.00101	0.00803	0.00100	0.100	0.00110	1.000	0.00120	30.000	0.02400	31.423	0.02500	100000	0.02500
20	Offshore Process Gas Typical	0.01	0.00100	0.08833	0.00100	0.100	0.00110	3.000	0.01500	10.000	0.02400	37.008	0.04000	100000	0.04000
21	Offshore Process Gas Large Module	0.01	0.00100	0.08933	0.00100	0.100	0.00110	5.000	0.03000	30.000	0.05000	100000	0.05000		
22	Offshore Process Gas Congested_Mech Vented Module	0.01	0.00100	0.09194	0.00100	0.100	0.00110	1.000	0.01500	50.000	0.03500	92.624	0.04000	100000	0.04000
23	Offshore Riser	0.01	0.00100	0.08340	0.00100	0.100	0.00110	30.000	0.02200	38.267	0.02500	100000	0.02500		
24	Offshore FPSO Gas	0.01	0.00100	0.02688	0.00100	0.100	0.00110	1.000	0.00130	50.000	0.15000	100000	0.15000		
25	Offshore FPSO Gas Wall	0.01	0.00100	0.08393	0.00100	0.100	0.00110	0.300	0.00200	10.000	0.15000	100000	0.15000		
26	Offshore FPSO Liquid	0.01	0.00100	0.08160	0.00100	0.100	0.00110	100.000	0.02800	100000	0.02800				
27	Offshore Engulf_blowout_riser	0.01	0.00100	0.08642	0.00100	0.100	0.00110	100.000	0.10000	100000	0.10000				
28	Cox, Lees, Ang – Gas	0.01	0.00081	0.50000	0.01000	100.000	0.30000	100000	0.30000						
29	Cox, Lees, Ang – Liquid	0.01	0.00215	0.50000	0.01000	100.000	0.08000	100000	0.08000						
30	Tank Liquid – diesel, fuel oil	0.01	0.00100	0.10000	0.00100	1.000	0.00103	7.000	0.00117	25.551	0.00240	100000	0.00240		

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Figure 3.13: Lookup Correlation Data Presented in Alternative Form [17]

- **Probability of immediate and delayed ignition**
  Given that the split between "immediate" and "delayed" is primarily intended to distinguish between "fire only" and "explosion plus fire" cases, **it is considered that the use of a 30:70 split** does comply with the true implementation of the UKOOA model. [17]

3.6 Frequency Analysis Results

3.6.1 Leak Frequency

The following table presents the results of our analysis on leak frequency, specifically focusing on the different sizes of leaks encountered within the system. This detailed breakdown provides insights into the prevalence of various leak sizes, helping us identify which sizes are more likely and frequent to occur. Understanding the frequency and distribution of different leak sizes is essential for effective maintenance planning and risk mitigation strategies.

			Leak Frequency (per yr)				
Failure Case	**Isolatable section**	**Description**	**Small**	**Medium**	**Large**	**Full bore**	**Total**
WOC01-G	WOC01	Wellheads ODZC	6.43E-02	7.38E-03	9.21E-04	2.30E-03	7.49E-02
WOE01-G	WOE01	Wellheads ODZE	4.18E-02	4.83E-03	5.88E-04	1.48E-03	4.87E-02
WOW01-G	WOW01	Wellheads ODZW	7.28E-02	8.76E-03	1.01E-03	2.69E-03	8.52E-02
WLT01-G	WLT01	Wellheads LT	7.25E-02	8.44E-03	1.04E-03	2.51E-03	8.45E-02
WOZ01-G	WOZ01	Wellhead ODZ04	8.87E-03	1.06E-03	1.09E-04	2.73E-04	1.03E-02
WOZ02-G	WOZ02	Wellhead ODZ13	8.86E-03	1.06E-03	1.09E-04	2.73E-04	1.03E-02
WOZ03-G	WOZ03	Wellhead ODZ15	8.86E-03	1.06E-03	1.09E-04	2.73E-04	1.03E-02
WOZ04-G	WOZ04	Wellhead ODZ16	8.86E-03	1.06E-03	1.09E-04	2.73E-04	1.03E-02
WOZ05-G	WOZ05	Wellhead ODZ19	8.86E-03	1.06E-03	1.09E-04	2.73E-04	1.03E-02
CA01-G	CA01	Manifold1	2.17E-02	2.15E-03	3.89E-04	1.08E-03	2.53E-02
CA02-G	CA02	Manifold2&ODZ	7.73E-02	7.42E-03	1.39E-03	4.03E-03	9.01E-02
CA03-G	CA03	Manifold 1 to separator 100VA001	9.21E-03	8.04E-04	1.41E-04	5.33E-04	1.07E-02
CA04-G	CA04	Manifold 2 to separator 100VA002	1.05E-02	9.40E-04	1.67E-04	6.18E-04	1.22E-02
CA05-G	CA05	HP Separator 100VA001	1.46E-02	1.58E-03	2.79E-04	5.23E-04	1.70E-02
CA06-G	CA06	MP Separators 100VA002/003	3.11E-02	3.67E-03	8.74E-04	8.00E-04	3.64E-02
CA07-G	CA07	Outlet 100VA002/003	2.56E-02	2.90E-03	5.88E-04	7.94E-04	2.99E-02
CB01-G	CB01	Booster compressor	4.29E-02	5.12E-03	9.16E-04	1.23E-03	5.02E-02
CB02-G	CB02	Mercury & H2S removal	6.30E-02	7.50E-03	1.62E-03	1.40E-03	7.36E-02
CD01-G	CD01	H2S to CO2	5.26E-03	5.13E-04	8.94E-05	2.15E-04	6.08E-03
CD02-G	CD02	CO2 removal treatment	1.51E-01	1.79E-02	3.31E-03	3.37E-03	1.76E-01
CD03-G	CD03	CO2 removal todehydration	1.35E-02	1.29E-03	2.49E-04	5.79E-04	1.56E-02
CD05-G	CD05	CO2 from 103CB015	5.79E-03	5.49E-04	1.00E-04	2.48E-04	6.68E-03
CE01-G	CE01	Gas dehydration	5.65E-02	7.10E-03	1.70E-03	1.64E-03	6.69E-02
CF01-G	CF01	Gas Dew pointing	6.65E-02	8.20E-03	1.56E-03	1.90E-03	7.82E-02
CF03-G	CF03	Turbo expander 105KH003	1.58E-02	1.84E-03	3.21E-04	2.96E-04	1.83E-02
CF04-G	CF04	Recompressor 105KA005	1.92E-02	2.26E-03	3.75E-04	3.56E-04	2.22E-02
CF05-G	CF05	Outlet Recompressor 105KA005	4.97E-02	4.87E-03	8.57E-04	2.69E-03	5.81E-02
CG01-G	CG01	Outlet from flash drum 106VD001	2.26E-02	2.53E-03	1.27E-03	Negl.	2.64E-02
CG05-G	CG05	Compressor 106KB009/106KB025	8.32E-02	1.05E-02	2.37E-03	1.05E-03	9.71E-02
CG06-G	CG06	Outlet compressor 106KB009/025	1.42E-02	1.25E-03	7.60E-04	Negl.	1.62E-02
CO01-G	CO01	HP FG Scrubber 304VG001	2.62E-02	2.75E-03	4.60E-04	1.12E-03	3.05E-02
CO03-G	CO03	HP Fuel gas users	6.61E-03	5.54E-04	1.43E-04	2.92E-04	7.60E-03

CO05-G	CO05	LP Fuel Gas Scrubber 2	1.12E-02	1.42E-03	2.43E-04	2.34E-04	1.31E-02
CK01-G	CK01	Transfer to metering 200UJ001	8.74E-02	1.06E-02	2.01E-03	2.56E-03	1.03E-01
CK02-G	CK02	Export metering pig launcher 203VM001	1.23E-02	1.19E-03	2.15E-04	6.28E-04	1.43E-02
CS01-G	CS01	Gas export CPF andPipeline junction	1.10E-02	1.13E-03	1.76E-04	3.14E-04	1.26E-02
CS02-G	CS02	Pig receiver 203VM002	2.23E-02	2.62E-03	4.85E-04	6.62E-04	2.61E-02
CS03-G	CS03	Export End pipeline	1.85E-03	1.70E-04	2.96E-05	4.21E-05	2.09E-03
CG02-L	CG02	Condensate to 106VD016	1.03E-02	1.24E-03	5.41E-04	Negl.	1.21E-02
CG03-L	CG03	Condensate from drum 106VD016	2.25E-02	2.16E-03	8.24E-04	Negl.	2.55E-02
CG04-L	CG04	Pumped condensate 106PA017 A/B	3.05E-02	2.67E-03	1.65E-03	Negl.	3.48E-02
CL01-L	CL01	Condensate truck loading	1.07E-02	9.90E-04	1.59E-04	4.05E-04	1.22E-02
CL02-L	CL02	Condensate storage 201RA002	8.51E-03	1.33E-03	4.05E-04	6.37E-04	1.09E-02
CL03-L	CL03	Condensate storage 201RA003	8.99E-03	1.37E-03	4.12E-04	6.71E-04	1.14E-02
CL04-L	CL04	Off spec condensate storage 201RA004	9.36E-03	1.47E-03	4.06E-04	6.27E-04	1.19E-02
CL05-L	CL05	Condensate truck loading arm 201-YG-011	6.74E-04	2.60E-04	1.46E-04	5.23E-05	1.13E-03
CL06-L	CL06	Condensate truck loading arm 201-YG-021	6.74E-04	2.60E-04	1.46E-04	5.23E-05	1.13E-03
CT01-L	CT01	Diesel Storage	5.77E-03	1.16E-03	7.87E-04	Negl.	7.72E-03
CA05-D-V	CA05	HP Separator 100VA001	9.14E-04	1.17E-04	4.92E-05	Negl.	1.08E-03
CA05-D-L	CA05	HP Separator 100VA001	3.13E-03	4.01E-04	1.68E-04	Negl.	3.70E-03
CA08-D-V	CA08	Separators Filtered Liquid outlet 100VA001/002/003	1.15E-02	1.40E-03	6.66E-04	Negl.	1.36E-02
CA08-D-L	CA08	Separators Filtered Liquid outlet 100VA001/002/003	3.95E-02	4.82E-03	2.29E-03	Negl.	4.66E-02
CF01-D-V	CF01	Gas Dew pointing	8.50E-04	1.15E-04	4.11E-05	Negl.	1.01E-03
CF01-D-L	CF01	Gas Dew pointing	3.48E-03	4.70E-04	1.69E-04	Negl.	4.12E-03
CF02HP -D-V	CF02HP	HP Liquid from 105VD004 /002	1.43E-03	1.41E-04	7.81E-05	Negl.	1.65E-03
CF02HP -D-L	CF02HP	MP Liquid from 105GX001	5.88E-03	5.77E-04	3.21E-04	Negl.	6.78E-03
CF02M P-D-V	CF02MP	MP Liquid from 105GX001	4.73E-03	4.93E-04	2.00E-04	1.00E-04	5.52E-03
CF02M P-D-L	CF02MP	MP Liquid from 105GX001	5.55E-03	5.79E-04	2.35E-04	1.18E-04	6.48E-03
CG01-D-V	CG01	Outlet from flash drum 106VD001	1.56E-02	1.94E-03	8.41E-04	Negl.	1.84E-02
CG01-D-L	CG01	Outlet from flash drum 106VD001	6.15E-02	7.63E-03	3.32E-03	Negl.	7.25E-02
CI01-G	CI01	Unit 109 Header Inlet	6.64E-03	6.19E-04	1.18E-04	2.33E-04	7.60E-03
CI02-G	CI02	LP Inlet Separators	4.56E-02	5.95E-03	7.86E-04	1.07E-03	5.34E-02
CI03-G	CI03	LP Compressor 1 F	4.12E-02	5.22E-03	7.71E-04	1.04E-03	4.82E-02

CI04-G	CI04	LP Compressor 1 SecondStage	4.01E-02	5.13E-03	7.56E-04	9.65E-04	4.70E-02
CI05-G	CI05	LP Compressor 2 FirstStage	4.12E-02	5.22E-03	7.71E-04	1.04E-03	4.82E-02
CI06-G	CI06	LP Compressor 2 SecondStage	4.01E-02	5.13E-03	7.56E-04	9.65E-04	4.70E-02
CI07-G	CI07	LP Compressors OutletHeader	8.51E-03	8.44E-04	1.49E-04	3.39E-04	9.85E-03
CG01.DL -L	CG01	Condensate Unit 109 Liquid Part	4.55E-02	5.12E-03	2.44E-03	Negl.	5.30E-02
CG01.DV -G	CG01	Condensate Unit 109 Flashing Part	1.15E-02	1.30E-03	6.18E-04	Negl.	1.35E-02
TOTAL			1.82E+00	2.12E-01	4.82E-02	4.78E-02	2.12E+00
%			86%	10%	2%	2%	100%

Interpretation:

Based on the data presented in the table, we observe that the most common and frequent leak size is the small size, specifically 5 cm. This indicates that smaller leaks occur more often than larger ones within our system. Consequently, for the purposes of our further study and analysis, we will focus on this 5 cm leak size, as it is the most prevalent and representative of typical leak occurrences in our system.

3.6.2 Fire Frequency

The following table provides fire frequency data for various breach sizes, indicating the likelihood of fires occurring for each specific breach dimension. From our previous analysis, we identified that the most probable breach size is small, with a probability of 86%.

		Fire frequency (Total ignition)				Immediate fire event (Immediate ignition)				Delayed fire event (Delayed ignition)			
Failure Case	**Description**	**Small**	**Medium**	**Large**	**Full bore**	**Small**	**Medium**	**Large**	**Full bore**	**Small**	**Medium**	**Large**	**Full bore**
CA05-G	HP Separator 100VA001	2.32E-05	2.80E-05	5.82E-05	3.40E-04	6.97E-06	8.40E-06	1.75E-05	1.02E-04	1.63E-05	1.96E-05	4.07E-05	2.38E-04
CA05-D-V	HP Separator 100VA001	1.48E-06	1.74E-06	6.28E-06	0.00E+00	4.43E-07	5.21E-07	1.89E-06	0.00E+00	1.03E-06	1.22E-06	4.40E-06	0.00E+00
CA05-D-L	HP Separator 100VA001	7.86E-06	1.26E-05	2.19E-05	0.00E+00	2.36E-06	3.78E-06	6.57E-06	0.00E+00	5.50E-06	8.82E-06	1.53E-05	0.00E+00
CA06-G	MP Separators 100VA002/003	4.39E-05	4.63E-05	1.76E-04	5.20E-04	1.32E-05	1.39E-05	5.29E-05	1.56E-04	3.07E-05	3.24E-05	1.23E-04	3.64E-04
CA07-G	Outlet 100VA002/003	3.61E-05	3.65E-05	1.18E-04	5.16E-04	1.08E-05	1.10E-05	3.55E-05	1.55E-04	2.53E-05	2.56E-05	8.29E-05	3.61E-04
CA08-D-V	Separators Filtered Liquid outlet 100VA001/002/003	1.86E-05	1.11E-05	6.91E-05	0.00E+00	5.57E-06	3.32E-06	2.07E-05	0.00E+00	1.30E-05	7.74E-06	4.84E-05	0.00E+00
CA08-D-L	Separators Filtered Liquid outlet 100VA001/002/003	9.92E-05	8.92E-05	2.97E-04	0.00E+00	2.98E-05	2.68E-05	8.92E-05	0.00E+00	6.95E-05	6.24E-05	2.08E-04	0.00E+00
CB01-G	Booster compressor	6.10E-05	6.56E-05	1.88E-04	8.03E-04	1.83E-05	1.97E-05	5.63E-05	2.41E-04	4.27E-05	4.59E-05	1.31E-04	5.62E-04
CB02-G	Mercury & H2S removal	1.00E-04	1.31E-04	4.53E-04	9.09E-04	3.00E-05	3.93E-05	1.36E-04	2.73E-04	7.00E-05	9.18E-05	3.17E-04	6.36E-04
CD01-G	H2S to CO2	8.32E-06	8.87E-06	7.09E-06	1.40E-04	2.50E-06	2.66E-06	2.13E-06	4.20E-05	5.82E-06	6.21E-06	4.96E-06	9.80E-05
CD02-G	CO2 removal treatment	2.38E-04	3.06E-04	8.56E-04	2.19E-03	7.13E-05	9.18E-05	2.57E-04	6.56E-04	1.66E-04	2.14E-04	5.99E-04	1.53E-03
CD03-G	CO2 removal to dehydration	2.12E-05	2.19E-05	6.76E-05	3.76E-04	6.35E-06	6.56E-06	2.03E-05	1.13E-04	1.48E-05	1.53E-05	4.73E-05	2.63E-04
CE01-G	Gas dehydration	8.97E-05	1.24E-04	4.76E-04	1.07E-03	2.69E-05	3.72E-05	1.43E-04	4.83E-05	6.28E-05	8.69E-05	3.33E-04	1.13E-04
CF01-G	Gas Dew pointing	1.11E-04	1.67E-04	4.47E-04	1.24E-03	3.34E-05	5.01E-05	1.34E-04	3.20E-04	7.80E-05	1.17E-04	3.13E-04	7.46E-04
CF01-D-V	Gas Dew pointing	1.28E-06	1.51E-06	3.40E-06	0.00E+00	3.84E-07	4.53E-07	1.02E-06	0.00E+00	8.96E-07	1.06E-06	2.38E-06	0.00E+00
CF01-D-L	Gas Dew pointing	8.69E-06	1.56E-05	2.19E-05	0.00E+00	2.61E-06	4.67E-06	6.58E-06	0.00E+00	6.08E-06	1.09E-05	1.53E-05	0.00E+00
CF02HP-D-V	HP Liquid from 105VD004 /002	5.12E-06	3.83E-06	1.07E-05	0.00E+00	1.54E-06	1.15E-06	3.22E-06	0.00E+00	3.58E-06	2.68E-06	7.51E-06	0.00E+00
CF02HP-D-L	HP Liquid from 105VD004 /002	3.48E-06	3.11E-06	9.72E-06	0.00E+00	1.05E-06	9.34E-07	2.92E-06	0.00E+00	2.44E-06	2.18E-06	6.80E-06	0.00E+00
CF02MP-D-V	MP Liquid from 105GX001	1.43E-06	3.91E-07	2.25E-06	0.00E+00	4.30E-07	1.17E-07	6.75E-07	0.00E+00	1.00E-06	2.74E-07	1.57E-06	0.00E+00
CF02MP-D-L	MP Liquid from 105GX001	1.12E-05	1.13E-05	3.05E-05	1.53E-05	3.36E-06	3.40E-06	9.16E-06	3.92E-06	7.83E-06	7.93E-06	2.14E-05	9.14E-06
CF03-G	Turbo expander 105KH003	2.65E-05	3.74E-05	1.80E-05	1.92E-04	7.94E-06	1.12E-05	5.40E-06	2.30E-05	1.85E-05	2.62E-05	1.26E-05	5.36E-05
CF04-G	Recompressor 105KA005	2.78E-05	3.06E-05	8.11E-05	2.31E-04	8.35E-06	9.17E-06	2.43E-05	5.76E-05	1.95E-05	2.14E-05	5.68E-05	1.34E-04
CF05-G	Outlet Recompressor 105KA005	7.36E-05	7.00E-05	1.97E-04	1.75E-03	2.21E-05	2.10E-05	5.91E-05	6.94E-05	5.15E-05	4.90E-05	1.38E-04	1.62E-04
CG01-G	Outlet from flash drum 106VD001	2.26E-05	5.96E-06	2.42E-05	0.00E+00	6.77E-06	1.79E-06	7.26E-06	0.00E+00	1.58E-05	4.17E-06	1.69E-05	0.00E+00
CG01-D-V	Outlet from flash drum 106VD001	1.83E-05	1.26E-05	3.42E-05	0.00E+00	5.50E-06	3.79E-06	1.02E-05	0.00E+00	1.28E-05	8.84E-06	2.39E-05	0.00E+00
CG01-D-L	Outlet from flash drum 106VD001	1.18E-04	1.35E-04	2.73E-04	0.00E+00	3.54E-05	4.06E-05	8.20E-05	0.00E+00	8.25E-05	9.47E-05	1.91E-04	0.00E+00
CG02-L	Condensate to 106VD016	1.15E-05	4.84E-06	6.47E-06	0.00E+00	3.45E-06	1.45E-06	1.94E-06	0.00E+00	8.06E-06	3.39E-06	4.53E-06	0.00E+00
CG03-L	Condensate from drum 106VD016	3.32E-05	1.47E-05	5.59E-06	0.00E+00	9.95E-06	4.40E-06	1.68E-06	0.00E+00	2.32E-05	1.03E-05	3.91E-06	0.00E+00
CG04-L	Pumped condensate 106PA017 A/B	4.50E-05	2.22E-05	3.40E-05	0.00E+00	1.35E-05	6.67E-06	1.02E-05	0.00E+00	3.15E-05	1.56E-05	2.38E-05	0.00E+00
CG05-G	Compressor 106KB009/ 106KB025	1.29E-04	2.39E-05	5.38E-06	2.38E-06	3.87E-05	7.16E-06	1.61E-06	0.00E+00	9.04E-05	1.67E-05	3.77E-06	0.00E+00
CG06-G	Outlet compressor 106KB009/025	2.21E-05	2.84E-06	1.73E-06	0.00E+00	6.63E-06	8.53E-07	5.18E-07	0.00E+00	1.55E-05	1.99E-06	1.21E-06	0.00E+00
CL01-L	Condensate truck loading	1.23E-05	3.27E-06	2.38E-06	6.08E-06	3.70E-06	9.82E-07	7.14E-07	0.00E+00	8.64E-06	2.29E-06	1.67E-06	0.00E+00
CL05-L	Condensate truck loading arm 201-YG-011	9.83E-06	4.40E-06	3.93E-06	6.19E-06	2.95E-06	1.32E-06	1.18E-06	1.18E-06	6.88E-06	3.08E-06	2.75E-06	2.76E-06
CL06-L	Condensate truck loading arm 201-YG-021	1.04E-05	4.54E-06	4.00E-06	6.52E-06	3.12E-06	1.36E-06	1.20E-06	1.86E-06	7.27E-06	3.18E-06	2.80E-06	4.33E-06
CO01-G	HP FG Scrubber 304VG001	3.80E-05	3.72E-05	3.08E-05	1.94E-04	1.14E-05	1.11E-05	9.25E-06	3.51E-05	2.66E-05	2.60E-05	2.16E-05	8.18E-05
CO03-G	HP Fuel gas users	9.57E-06	7.49E-06	6.06E-06	2.86E-05	2.87E-06	2.25E-06	1.82E-06	1.84E-05	6.70E-06	5.24E-06	4.24E-06	4.30E-05
CO05-G	LP Fuel Gas Scrubber 2 304VG003	1.62E-05	1.92E-05	1.03E-05	2.30E-05	4.87E-06	5.76E-06	3.08E-06	3.28E-05	1.14E-05	1.34E-05	7.18E-06	7.66E-05
CK01-G	Transfert to metering 200UJ001	1.29E-04	1.53E-04	4.61E-04	1.66E-03	3.88E-05	4.58E-05	1.38E-04	5.69E-05	9.06E-05	1.07E-04	3.23E-04	1.33E-04
CK02-G	Export metering pig launcher 203VM001	1.81E-05	1.68E-05	4.86E-05	4.08E-04	5.42E-06	5.05E-06	1.46E-05	4.57E-05	1.26E-05	1.18E-05	3.40E-05	1.07E-04

3.7 Fire potential equipment

According to the API 2218 standard, specific types of equipment in industrial sites are classified as Fire Potential Equipment based on their technical specifications. This classification includes several categories of equipment, each with distinct parameters that denote their fire risk.

3.7.1 Towers, Exchangers, and Vessels

These are categorized as fire potential if they contain flammable products at temperatures exceeding 315°C. These structures are integral to processing and storage operations and often handle large volumes of hazardous materials, making them critical points of concern for fire safety.

3.7.2 Pumps

Pumps that handle flammable materials at temperatures above 230°C are considered fire risks. These devices are essential for transporting liquids within the facility, and their high operational temperatures increase the potential for ignition.

3.7.3 Control Valve Manifolds

Similar to pumps, control valve manifolds that operate with flammable materials at temperatures above 230°C are designated as fire potential equipment. These manifolds regulate the flow of hazardous substances, and their safe operation is crucial to preventing leaks and potential fires.

3.7.4 Hydrocarbon Gas Compressors

These compressors are specifically designed to handle hydrocarbon gases, which are highly flammable. Their inclusion in the fire potential category underscores the importance of stringent safety measures given the volatile nature of the gases they process.

3.7.5 Heaters

Equipment that involves the heating of flammable materials is inherently risky. Heaters used in industrial processes must be carefully monitored to prevent overheating and potential fires.

Chapter 4

Passive Fire Protection: Fireproofing

4.1 Introduction

Fireproofing is a crucial practice in the petroleum and petrochemical industries for minimizing property damage from fires, it involves applying materials or methods to slow the spread of fire and safeguard equipment or structures.

The API RP 2218 standard from the American Petroleum Institute (API) offers guidance on selecting, applying, and maintaining fireproofing systems specifically for pool fires in petroleum and petrochemical processing plants.

4.2 Objectives

Fireproofing has several overarching objectives that contribute to overall safety and damage mitigation in a fire event. Here's a breakdown of the key goals:

- **Life Safety:** Buy time for safe escape by slowing fire spread and maintaining structural integrity.
- **Property Protection:** Minimize damage by containing the fire and safeguarding equipment.

4.3 Fireproofing methodology

The API RP 2218 standard provides a proven methodology for selecting, applying, and maintaining fireproofing systems specifically for pool fires common in petroleum and petrochemical facilities. By following the API RP 2218 framework, we can create a comprehensive and reliable fireproofing plan that prioritizes safety and minimizes potential fire damage.

Each step within this methodology will have its own specific requirements based on both the API RP 2218 guidelines and the unique needs of the facility and processes.

- **Needs Analysis:** The needs analysis is the crucial first step, laying the groundwork for our fireproofing plan. Here, we leverage risk assessments (FERA/PHA) to identify areas needing fireproofing based on factors like: Flammable materials, Potential fire severity, Equipment/structure importance, unit spacing .... Details on these factors will be covered in the following titles, this analysis ensures a targeted fireproofing plan prioritizing safety throughout the facility.[12] [18]

- **Fireproofing considerations and materials:** API RP 2218 identifies critical areas within a petroleum or petrochemical facility that require fireproofing based on their potential fire risk and the importance of the equipment or structure, it also offers guidance on selecting the most appropriate fireproofing materials for specific applications. Different materials have varying fire resistance ratings and application methods. Details on these factors will be covered in the following titles.[12][18]

- **Installation and quality insurance:** API RP 2218 specifies proper installation requirements that emphasize on the qualified parties who do the installation, and the importance of verifying the quality of the fireproofing installation. This may involve inspections and testing to ensure the materials are applied correctly and meet the required thickness and fire resistance ratings.[12]

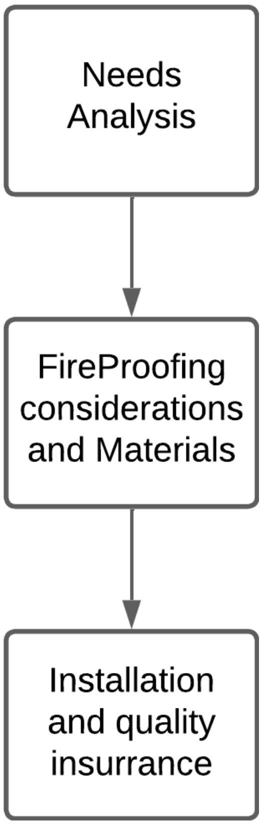

Figure 4.1: Simplified fireproofing methodology

4.4 Needs Analysis

The needs analysis stands as a pivotal step post hazard identification and scenario assessment. Its primary objective lies in categorizing each scenario and determining the requisite protection equipment and duration. Here are the questions to guide this assessment:

- What equipment requires safeguarding in each scenario?
- How much time should be allocated for providing protection in each scenario?

4.4.1 Phase 01: Potential Severity and Vulnerability

We leverage existing risk assessments (PHA/FERA) to identify fire hazards and consider process design factors, the following factors are to consider in a Needs Analysis study:

A/ Location within the thermal radiation contour

The main question to ask here is:

"what equipment or structures are potentially exposed to a leak?"[12]

- Identify all equipment and structures within the potential leak zone (near pipes, valves, flanges).
- Classify or identify the vulnerability of equipment how important or serious that equipment is.
- Evaluate the distance between the leak source and the equipment/structure of concern.

Example:

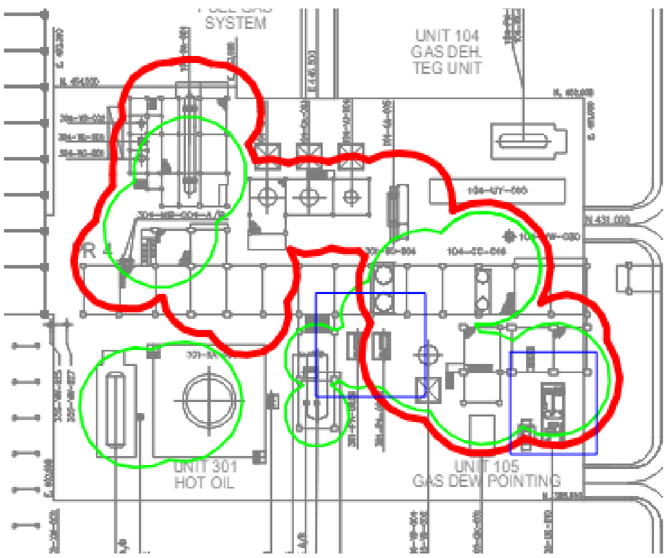

Figure 4.2: Jet Fire (red) and Pool Fire (green) contours, site of GTG.

From *Figure 4.2*, we can spot the equipment and structures located within the thermal radiation contour (given for $30Kw/m^2$ in this case, this gives us an insight about the distance evaluation and the vulnerable equipment in the zone.

B/ Severity of operating conditions

Generally speaking, equipment in oil and gas facilities contain highly flammable substances at high pressure and temperature, the following questions are to be asked:[12]

- What are the process temperature and pressure within the equipment?
- Are any process materials above their auto-ignition points?
- Does the equipment contain liquid that can absorb heat or help cool the vessel walls upon vaporizing?

An equipment that contains a highly flammable substance is the source of all hazards, and thus, needs to be properly protected, typically, equipment that carry non-flammable substances like water, are not to be fireproofed.

C/ Unit Spacing, Layout, and Fire Exposure Hazard

In central processing facilities, the facilities' layout are generally located next to each other, which can result in a domino-effect in case of an accident, to assess the situation and judge the need of fireproofing, the following questions are to be asked: [12]

- What is the spacing between units?
- How is the equipment laid out?
- Could a fire in one unit easily spread to adjacent facilities or the surrounding area?

D/ Estimation of the duration of unabated fire

Estimating the exact duration of an unabated fire within a building is a complex task. Factors like fuel load, ventilation, and fire suppression efforts can all significantly influence how long a fire burns. To simplify this process, we can consider the fire duration for the largest isolatable section within the facility. This assumption acknowledges that a larger fire will likely take longer to extinguish and provides a conservative estimate for fireproofing needs. Also, standards and references exist that specify the fire resistance time required for fireproofing various types of equipment. [12]

Assessing the potential severity and vulnerability is a major aspect of the fireproofing needs analysis, by following the steps above, we obtain an evaluation about the potential severity and the required protection, see *Figure 4.3* for a simplified chart of the potential severity and vulnerability evaluation.

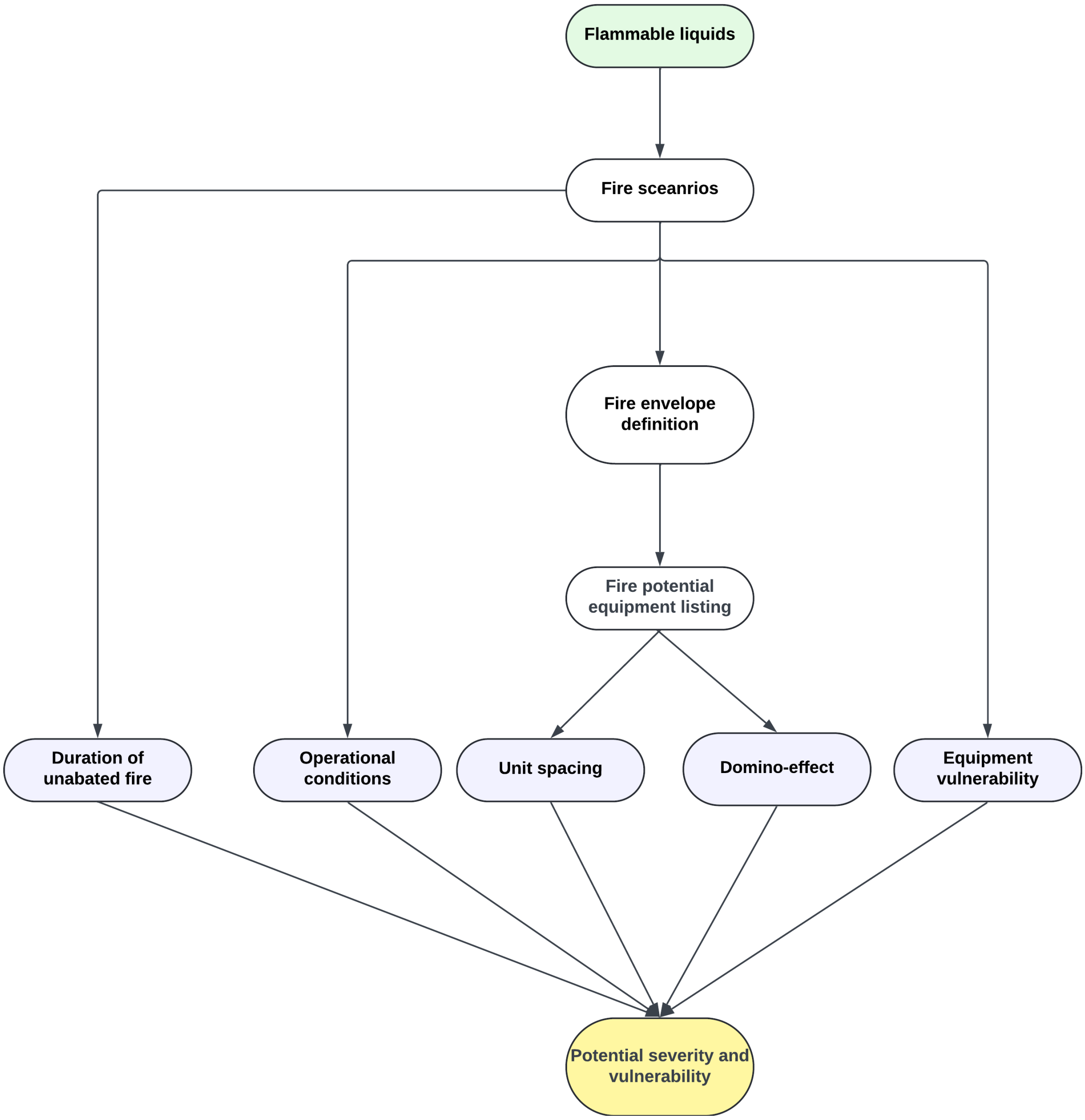

Figure 4.3: Needs Analysis: phase 01 (potential severity) simplified

4.4.2 Intervention capability

Intervention capability matters in fireproofing analysis. Strong fire suppression and fast responder access might allow for less fireproofing in some areas, while limited intervention necessitates a more robust approach. This helps find the right balance between fire resistance and cost.[12]

A/ Area Drainage System Effectiveness

- Is there is a drainage in the spillage area?
- How effective is the area drainage system at removing a hydrocarbon spill?[12]

B/ Isolation, De-inventory, or Depressurization Capability, and Shutdown Systems

- Can the systems be isolated, de-inventoried, or depressurized to prevent further release of flammable materials?
- Are there manual and/or automatic shutdown systems in place?
- How much it takes for the section to be isolated ?[12]

C/ Active Fire Protection

- Is there a fixed water spray system or fixed monitors for active fire protection?[12]

D/ Unit Spacing and Emergency Response Access

We consider the unit spacing and equipment layout again, but this time focusing on how easily emergency responders/personnel can access the area. [12]

Assessing the intervention capability is a major aspect to judge the need of further fire protection (fireproofing), in the typical oil and gas facilities there are various protection measures in site, judging the intervention capability is another criteria (along with potential severity and vulnerability) for needs analysis, the points above detail the factors to consider, see *figure 4.4* for a simplified chart.

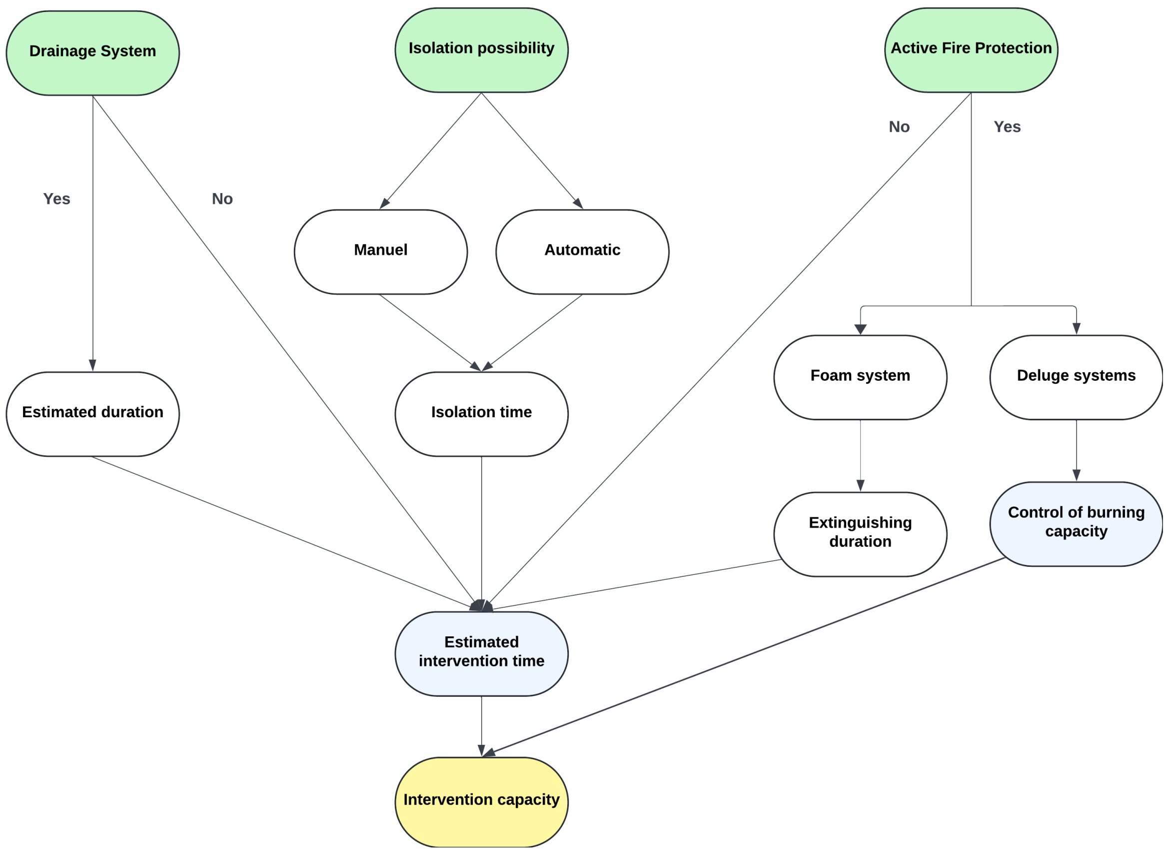

Figure 4.4: Needs Analysis phase 02 (intervention capability) simplified

4.5 Fireproofing considerations

4.5.1 Fireproofing considerations

Unlike a one-size-fits-all approach, API RP 2218 provides specific considerations for targeted application based on the unique characteristics of your structure and equipment. This means the standard doesn't dictate fireproofing everywhere, but rather guides us on prioritizing critical areas like structural supports, process equipment, and emergency shutoff valves. This case-by-case approach ensures that fireproofing efforts are strategically placed for maximum protection where it matters most, APPENDIX A provides all the fireproofing considerations from clause 5 of API RP 2218 (**see APPENDIX I-C**).

4.5.2 Fireproofing materials

API Recommended Practice 2218 (API RP 2218) transcends the mere designation of fireproofing application zones. It establishes a framework for the judicious selection of fireproofing materials. The standard furnishes a comprehensive analysis, detailing the properties, inherent advantages, and potential drawbacks associated with various fireproofing solutions.

The selection of materials is an evidence-based decision tailored to the specific project. Factors such as the requisite temperature resistance, ease of application, and long-term maintenance requirements can be objectively evaluated against the backdrop of the material's characteristics.[12] Through a nuanced understanding of the strengths and weaknesses of each fireproofing material, we can ensure the selection aligns optimally with the fire protection demands of the specific structure and its equipment, APPENDIX B provides the fireproofing materials from clause 6 of the API standard **(see APPENDIX I-D)**.

Besides providing a given extent of fire resistance, a variety of characteristics should be evaluated to ensure proper performance in the environment where it is installed. Principal characteristics governing selection of fireproofing materials are:

- The weight and volume limitations imposed by the project
- The fire-resistance rating (in hours)
- The material's adhesion strength and durability
- The corrosiveness of the atmosphere and of fireproofing materials to the substrate
- Equipment operating temperature limitations in non-fire conditions
- Ease of application
- Reinforcing requirements

4.5.3 Fire resistance rating (FRR)

The required duration a fireproofing material protects a structure against fire is called the fire resistance rating.[12][18]

Factors Determining FRR

- Fuel Isolation Time: The time needed to isolate and contain any released fuel.
- Water Supply: Availability and capacity of a reliable water supply for firefighting.
- Fixed Water Systems: Response time for activating fixed water spray systems or monitors.
- Mobile Fire Response: Response time and capabilities of fire brigades using portable or mobile equipment (including foam for suppression).
- Hydrocarbon Spill Drainage: Time required for the drainage system to remove a potential hydrocarbon spill.

Structures and Equipment	Exposure Time to Hydrocarbon Fire
Steel structures supporting equipment	2–3 hours
Main pipe rack structures inside process units	1–2 hours
Main pipe rack structures in process units that also support equipment	2–3 hours
Structural supports for process unit transfer lines	2 hours
Piping supported from hangers	2 hours
Flue gas stack supports	2 hours
Vessels containing substantial volumes of flammables or heated combustibles (refinery crude desalters, chemical facility reactors, etc.)	1–3 hours
Equipment, vessel, and column supports (skirts, legs, etc.)	1–3 hours
Main instrument runs	15 minutes
Tubing, conduit, and valve operators	15 minutes

Figure 4.5: Typical Fireproofing Rating For Structures And Equipment[18]

Equipment supports should be protected with at least a 1 hour, high-risehydrocarbon fire resistance rating, or equivalent.[18]

4.6 Installation and quality insurance

Fireproofing systems must be applied properly to be successful. A variety of factors are involved which include: the availability of the proper on-specification material, the proper equipment, and qualified personnel to complete the task in accordance with the manufacturer's specifications. For most fireproofing systems the long term success depends on attention to detail during installation.[12][18]

4.6.1 Fireproofing installation considerations

A/ Pre-installation

- **Surface Preparation:** Clean substrate surfaces from contaminants (oil, grease, dust, rust, etc.)
- **Primer Compatibility:** Ensure primer (if required) is compatible with the fireproofing material.

B/ Installation Specifications

- **Thickness/Layers:** Follow specified thickness or number of layers.
- **Attachment:** Insurance of adequate attachment of the fireproofing system.
- **Finishing:** proper caulking performance, sealing, or top-coating as required.

C/ Applicator Expertise

- **Dense Concrete:** Can be applied by facility personnel or experienced contractors.
- **Lightweight Concrete, Mastics, Magnesium Oxychloride Plasters:** Require specialized applicators with experience in these materials.

D/ Material Handling

- **Shelf Life:** Maintain material within its shelf life.
- **Storage:** Following manufacturer's recommendations (e.g., upright containers for some materials).
- **Temperature Sensitivity:** Awareness of temperature limitations during storage and shipping.

E/ Application Considerations

- **Original Containers:** Apply directly from sealed containers to avoid contamination.
- **Curing:** Follow required curing periods to prevent cracking.
- **Drying:** Allow drying period above freezing for materials with free water.
- **Thickness:** Specified thickness refers to the dry state, not wet application thickness (account for shrinkage).

4.6.2 Quality control, inspection and maintenance

A/ Quality control

- **Personnel Knowledge:** All involved personnel should understand the chosen fireproofing material, its application techniques, and relevant manufacturer specifications. Resources include data sheets, site visits, or consulting previous users.
- **Sample Application:** Applicator may need to provide a finished surface sample for approval.
- **Inspection:** Qualified personnel monitor application per specifications (mixing, density, thickness, reinforcement, finishing).
- **Thickness Control:** Crucial for proper fire resistance, especially with thin mastic coatings. Random core sampling can verify thickness and bonding. (Ref: ASTM E605 & E736)

B/ Fireproofing Inspection

- Periodic inspections with manufacturer/applicator involvement (optional).
- Survey coatings for cracks, delamination, rust, bubbles, or bulging.
- Check for weathering signs (color change, powdering, thinning).
- Remove small sections to examine substrate and reinforcement (look for corrosion). Repair inspection areas.
- Visually check for mechanical damage to fireproofing. (For specific materials) Set aside fireproofing samples for periodic fire testing.
- Ensure fireproofing hasn't been removed for maintenance and not replaced.
- Identify any potential new hazard sources or equipment needing fireproofing.

C/ Fireproofing Inspection

- **Timely and consistent:** Ensures fireproofing remains in good condition.
- **Hairline Cracks:** Clean and fill cracks with new material according to manufacturer instructions.
- **Substrate Bonding Loss:** If detected by bulges or abnormal sound, remove fireproofing, clean the substrate, and re-prime before reapplication.
- **Bond Failure:** Remove fireproofing in affected areas, clean the substrate, and re-prime before reapplication.

- **Top Coating:** Maintain top coating per manufacturer's recommendations, especially if it provides corrosion protection or water resistance. Conduct inspections before top coat renewal to avoid hiding defects.

- **Management of Change (MOC):** Inform relevant personnel about potential impacts of operational, equipment, or fireproofing material changes on fireproofing needs.

4.7 Firpeoofing plan

This section is the realization of the fireproofing plan, which will be provided in **APPENDIX III.** The plan will be presented in a clear table format, mirroring the previously outlined methodology. Each factor influencing fire risk will be assigned a scale for quantification, enabling systematic evaluation of potential vulnerabilities and the corresponding fireproofing measures. This data-driven approach ensures all aspects are considered and effectively mitigated **(see APPENDIX III).**

4.7.1 Needs Analysis

Phase 01: Potential severity and vulnerability

- **Release location:** Refers to the concerned equipment where the leak takes place.

- **Release material:** The equipment's inventory (gas, condensate, hot oil, TEG...).

- **Exposed equipment and structures:** The equipment located within the the fire contour.

- **Equipment vulnerability:** To assess equipment vulnerability, we consider both exposure to thermal radiation and the nature of the inventory stored within. Highly flammable materials in equipment directly exposed to heat will be assigned a higher vulnerability score (1-4) compared to well-protected equipment storing non-flammable items.

Vulnerability	Scale
Low	1
Moderate	2
High	3
Very High	4

Table 4.1: Equipment vulnerability rating

- **Operational conditions:** While operational conditions are considered during fireproofing planning, they hold less weight compared to other factors in oil and gas facilities. This is because most materials handled here typically exist above their flash point (the minimum temperature at which they ignite), and extreme pressures and temperatures are often standard operating conditions, but is still a factor that the API standard highlights.

- **Unit spacing:** A crucial factor in fire safety planning, considers both exposure and distance between equipment. We'll utilize the facility's mass plan to map equipment locations and assess these factors. The unit spacing is measured by the following scale:

Unit spacing	Scale
Isolated from CPF	1
Low proximity to CPF	2
High proximity to CPF	3
Crowded within CPF	4

Table 4.2: Unit spacing rating

- **Domino effect:** The possibility of an escalation of the consequences.

Phase 02: Intervention capability

- **Drainage system:** A functional drainage system allows burning liquids to be directed away from critical areas and facilitates firefighter intervention with water runoff. The absence of a drainage system influences the need of fireproofing.

- **Leak duration based on isolation and detection time:** According to the API 581 standard, automatic and manual isolation time has been defined as the following:

Isolation type	Automatic	Manual
Leak duration (max)	20 minutes	30 minutes

Table 4.3: Isolation time according to API 581 [14]

  Notes:

  - The detection class according to API 581 is A, which means that the instrumentation is designed specifically to detect material losses by changes in operating conditions (i.e. loss of pressure or flow) in the system.
  - The automatic isolation is classified as class A by the API 581 standard (doesn't need operators' intervention to activate), while the manual one (needs the operators' intervention) is class B.
  - The maximum leak duration have been taken for 1/4 inches leaks (small breaches), which is the most probable breach size according to chapter 3.

- **Active fire protection:** The fireproofing plan will indicate whether the concerned equipment is protected by active fire protection systems without delving into the details of the system evaluation. Generally speaking, all equipment within the site that carry or are exposed to hydrocarbon risks are covered by active fire protection systems. However, a detailed evaluation of these systems will be provided in Chapter 5.

4.7.2 Fireproofing considerations

Phase 03: Fireproofing

- **Considerations:** The API fireproofing considerations are given in **APPENDIX I-C**.
- **Fire resistance rating (FRR) (hours):** FRR is calssified and given by *Figure 5.13* above.
- **Fireproofing materials:** The materials used for fireproofing, detailed in **APPENDIX I-D**.

Notes:

- The chosen fireproofing materials are mainly **concrete** and **cementtitious** spray-applied materials, both are efficient fire-resistant materials (up to 4 hours of protection, not expensive).
- Concrete can be applied on vessels' saddles and legs, however, it adds extra weight which makes it difficult to apply on racks and structures, in this case, cementitious SFRM is a good substitute and easier to apply.
- Concrete can't be applied on skirts, that's why SFRM are chosen for skirt applications.

4.8 Conclusion

In conclusion, the fireproofing plan detailed in **APPENDIX III** provides a systematic approach to assess whether process equipment should be fireproofed. The standards define all the factors, criteria, and considerations for fireproofing, and the chosen materials are selected based on their efficiency and ease of application.

It is important to note that passive fire protection is not a replacement for active fire protection. *The main objective of fireproofing equipment is to buy time to prevent further escalation of the consequences*, allowing active fire protection systems and intervention efforts more time to successfully extinguish the fire.

Chapter 5

Active Fire Protection: Foam and Water systems

5.1 Introduction

Active fire protection systems are the first responders in a fire emergency. This chapter explores their types and functions. We'll evaluate them against NFPA standards, ensuring they meet industry best practices to ensure safety.

5.2 Objectives

Active fire protection systems in oil and gas facilities play a critical role in mitigating the unique fire hazards present. Their key objectives include:

- **Rapid Detection and Suppression:** Active systems like heat detectors, flame detectors, and gas monitors trigger alarms and immediately activate extinguishing measures like water sprinklers, foam deluge systems, or high-pressure water mist systems to control flames and extinguish them.
- **Containment and Control:** Fixed or mobile extinguishing systems are used to stop flames from reaching critical equipment or storage areas, and deploying fire suppression curtains to isolate specific zones.

5.3 Active fire protection evaluation steps and criteria

5.3.1 System selection

The most effective fire suppression system hinges on understanding the potential fire threats. By analyzing fire scenarios (like flammable gas release or flammable liquid spills) and the specific hazards present (type of combustibles, presence of sensitive equipment), we can select the most appropriate extinguishing agent and system design.

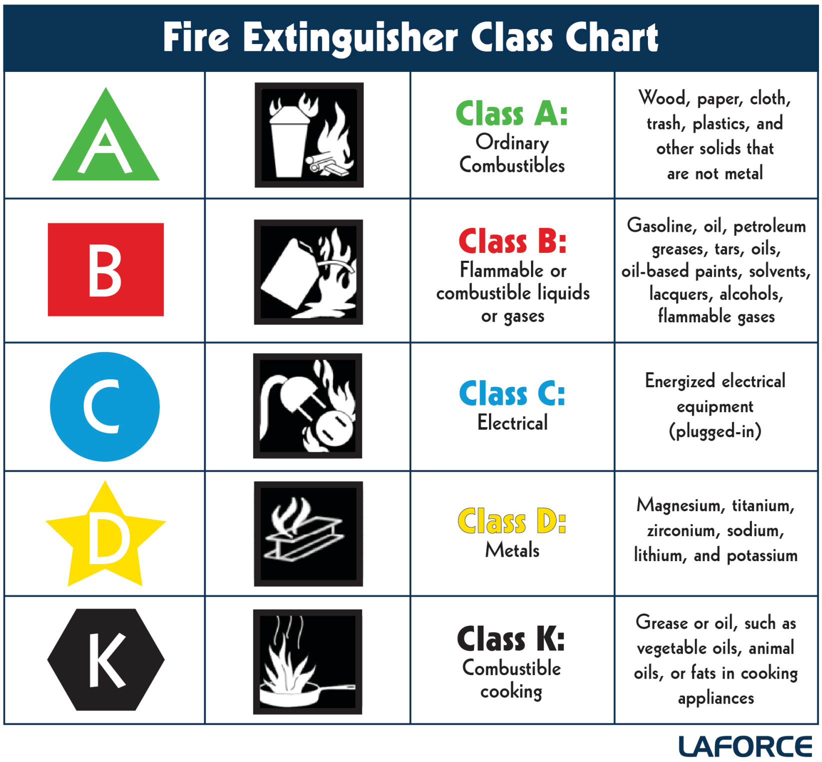

Figure 5.1: Fire classes and their extinguishment

5.3.2 Water supply evaluation

A robust water supply is essential for an effective water-based fire protection system. This evaluation includes assessing available water flow rate, pressure, and the reliability of sources like public fire hydrants and on-site water storage tanks. Ensuring a sufficient and reliable water supply optimizes fire suppression systems throughout the gas treatment site.

5.3.3 System coverage

Once the extinguishing agent is selected, defining the system's coverage is crucial. This involves designing the layout of sprinkler heads, foam discharge nozzles, or other extinguishing devices to ensure comprehensive coverage of potential ignition sources and flammable materials. Strategic placement guarantees a swift and effective fire response across the gas treatment site.

5.3.4 System Capacity Evaluation

To ensure effective active fire protection, it is crucial to evaluate the flow rate and discharge rate of the extinguishing agent. First, we verify that the agent can deliver an adequate discharge rate to control a potential fire (given by NFPA standards), considering the fire size and protected area. Second, we assess the system's hydraulics to confirm that the flow rate is sufficient to reach all sprinkler heads or foam nozzles (given by NFPA also). This ensures the system can effectively control and extinguish fires across the gas treatment site.

5.4 Water systems

5.4.1 Design objective

- **Extinguishment:** Water extinguishment is a method of fire suppression that involves using water to control and extinguish fires. The process relies on the cooling effect of water to lower the temperature of the burning material below its ignition point, and it can also help to smother the fire by cutting off the oxygen supply.[8]
- **Control of burning:** Application of water spray to equip-ment or areas where a fire can occur to control the rate of burning and thereby limit the heat release from a fire until the fuel can be eliminated or extinguishment effected.[8]
- **Exposure Protection:** Absorption of heat through application of water spray to structures or equipment exposed to a fire, to limit surface temperature to a level that will minimize damage and prevent failure.[8]

5.4.2 Equipment that must be deluged

The list of equipment that must be deluged is based on the NFPA 15 **(see APPENDIX I-B)**. In process fire zone , fixed water deluge systems will be provided on vessels and heat exchangers if the hydrocarbon liquid inventory is significant, reaching at least one of the following criteria: [8][18]

- Equipment pressure is above 7 barg.
- Equipment volume is larger than $5m^3$.
- Equipment pressure multiplied by volume is above 100 barg.

The following conditions will be considered for the fire water demand calculation:

- Vessels and heat exchanges where design pressure is higher than two times operating pressure will not be deluged.
- Equipment which does not contain hydrocarbon or combustible material will not be deluged.
- Buried equipment will not be deluged.
- Structures will not be provided with deluge systems as they will be provided with fireproofing.
- Compressors, air coolers and pipe racks will not be deluged. Pipe racks will be provided with Passive Fire Protection or will be constructed from concrete.
- Main cable trays shall not be protected by deluge as they will be located underground to provide required protection against hazardous events (external electrical cables are fire resistant).

5.4.3 Water demand calculation

In water demand calculation, we prioritize the zone with the highest fire risk and water demand. This zone's calculation sets the benchmark for the entire deluge system, ensuring sufficient water flow to tackle fires effectively throughout the protected area.

A/ Fire Water Demand (FW Demand):

The total amount of water required by the fire protection system. The FW Demand is comprised of two main components:

- **Deluge Consumption:** The amount of water used by the deluge system to extinguish a fire. This is calculated based on the specific area protected by the deluge system and the application rate (amount of water needed per square foot per minute) required to suppress the anticipated fire hazard.
- **Requirement for personnel protection during escape and evacuation/manual fire-fighting by personnel:** This accounts for the water needed for hose streams firefighters might use to extinguish the fire or for occupant use during evacuation.

B/ Deluge system water requirement calculation

After choosing the fire zone most water demanding (PFZ1 in this case), we select the equipment and structure that should be deluged **See Figure 5.2**

Deluge Valve	Equipment	Width/Diameter (m)	Length (m)	Total area (m2)	Water rate (L/min)/m2	Water consumption L/min
100-XW-1001	100-VA-001 HP Inlet Separator	2,9	9,2	97,03	10,2	989,69
	100-MB-021A/B Filter	0,2	0,937	1,30	10,2	13,29
	100-VA-002 MP Inlet Separator	3,2	10,3	119,63	10,2	1220,24
	100-MB-023 A/B Filter	0,2	0,872	1,22	10,2	12,46
	100-VA-003 MP Inlet Separator	3,2	10,3	119,63	10,2	1220,24
	100-MB-025 A/B Filter	0,2	0,872	1,22	10,2	12,46
	100-PA-013 A/B Condensate Pump	0,5	0,7	0,35	20,4	7,14
	100-VA-012	1,3	3,3	4,38	10,2	44,68
	Total water consumption for unit 100					3520,20
101-XW-1001	101-VD-002 Boooster Compressor	3	4,9	60,32	20,4	1230,50
	101-VJ-006 Boooster Compressor	1,43	6,1	30,62	20,4	624,57
	Total water consumption for unit 100					1238,66
102-XW-1001	101-KA-004 Booster Compressor	0,5	0,8	0,40	20,4	8,16
	102-VW-001 Mercury Removal Guard Bed	4	2,3	54,04	10,2	551,16
	102-VW-002 H2S Removal vessel	3,5	6,835	94,40	10,2	962,85
	102-VW-003 H2S Removal vessel	3,5	6,835	94,40	10,2	962,85
	102-MB-004A Bypass Particule Filter	0,446	3,193	4,79	10,2	48,82
	102-MB-004B Bypass Particule Filter	0,446	3,193	4,79	10,2	48,82
	Total water consumption for unit 100					2582,66
	Total water consuption for FIRE ZONE FPZ1					7341,52

Figure 5.2: fire water demand calculation for PFZ1

C/ Calculation of water consumption for each equipment:

$$\text{Water Consumption} = \text{Total area of the equipment} \times \text{water rate required for the equipment}$$

D/ Water Requirement for personnel protection during escape and evacuation

- **Determine the Number of Hose Streams per Unit:** Estimate the number of hose streams required for each unit based on the unit's size, layout, and fire hazard classification.
- **Flow Rate of Each Hose Stream:** Identify the flow rate of each hose stream to be used within the unit.

F/ Fire Hydrants and Monitors requirement

- Remote controlled monitors shall be installed where escape way could be rapidly destroyed.
- Monitors should be positioned to be accessible during a fire and located where they will provide effective water streams for the equipment to be protected.
- Each Firezone should have at least two monitors placed and available for cooling equipment affected by the fire and for clearing the evacuation roadway.
- Hydrants are generally spaced a maximum of 60 m apart in process areas.
- Hydrants and monitors should be located a minimum of 15 m from any equipment to be protected.
- Water Cannons Within 30 m of the equipment they need to protect.
- Hydrants should be located on the street or roadside of all pipelines or drainage ditches to allow access for the pumper truck.
- Monitors should be positioned to be accessible during a fire and located where they will provide effective water streams for the equipment to be protected. Typically, monitors are provided to cool equipment that, upon failure, would result in escalation of fire.

In PFZ1 there are 2 water monitors and the flow rate for each monitor is 120 m3/h. the total consumption of water per 2 monitors is: 240m3/h.

5.4.4 Water Supply

The water source must be able to deliver the calculated water demand for a sustained period of at least 4 hours. based on (**NFPA 16 3-2.3**).

Maximum demand for deluge	**440.49 m3/h**
15% margin added to ensure reliability and safety	**506.57 m3/h**
Monitor used for personal protection	**240 m3/h**
Total FireFighting demand	**746.57 m3/h**
FireFighting demand in 4h	**2 986.28 m3/4h**

Having a water capacity of $7500m^3$ and utilizing $2986.28m^3$ over a span of 4 hours suggests a robust infrastructure capable of meeting operational demands effectively.

5.4.5 Coverage

Make sure that the equipment that must be deluges are fully covered by a deluge system or fixed water system and the flow rates of each equipment matches NFPA 15 requirements **(APPENDIX I-B)**.

design discharge rates

Equipment	Application rate	Remarks
Vessels, columns, exchangers, developed surface	10.2 (l/min/m²)	Of developed surface, vertical length and ends
Pumps	20.4 (l/min/m²)	including the shaft, seals, and other critical parts.(see API 2030 section 7.3.1)
Atmospheric storage tank	15 (l/min/ m)	on all exposed surface

Figure 5.3: water discharge rates

Water Spray System Plant

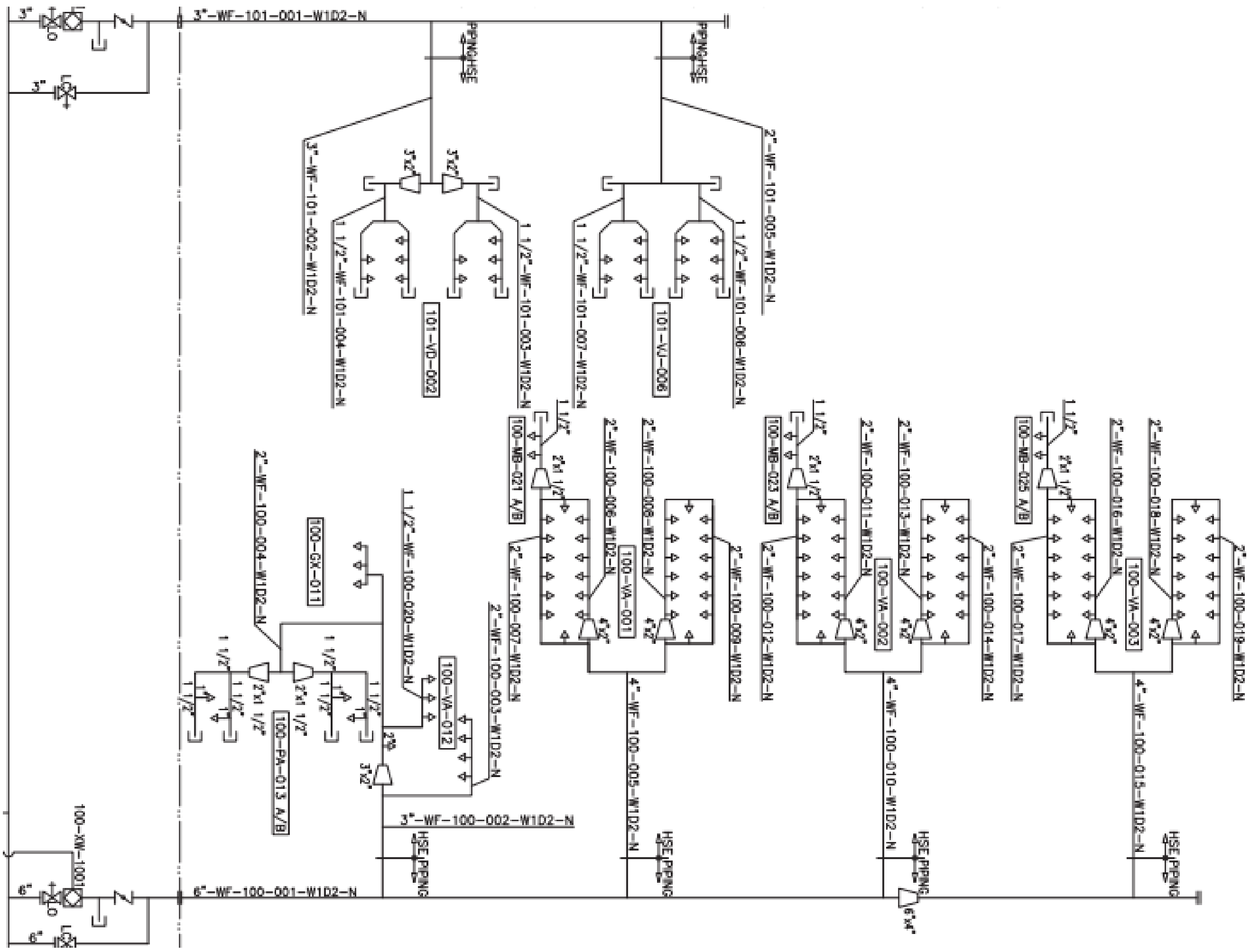

Figure 5.4: water spray system for UNIT 100 and 101

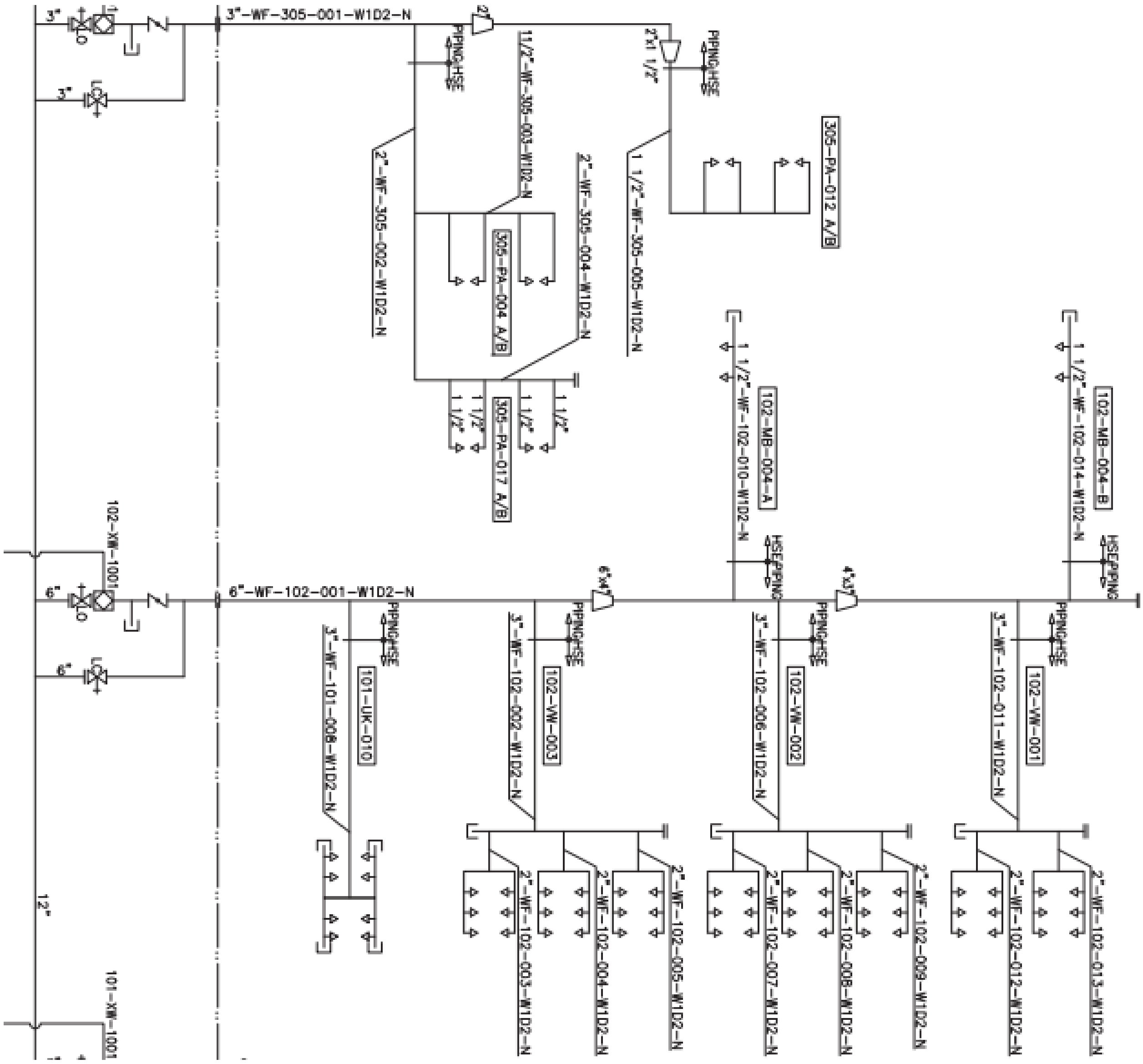

Figure 5.5: water spray system for UNIT 102 and 305

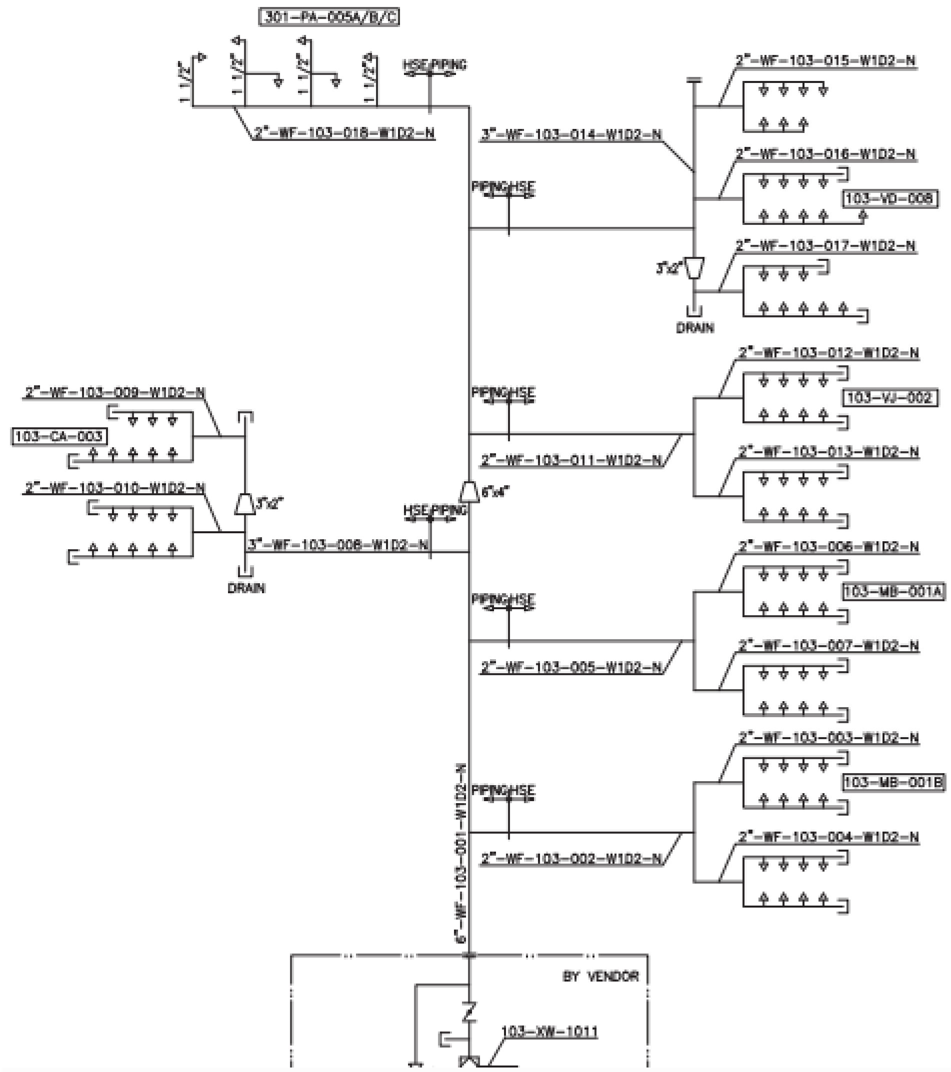

Figure 5.6: water spray system for UNIT 103

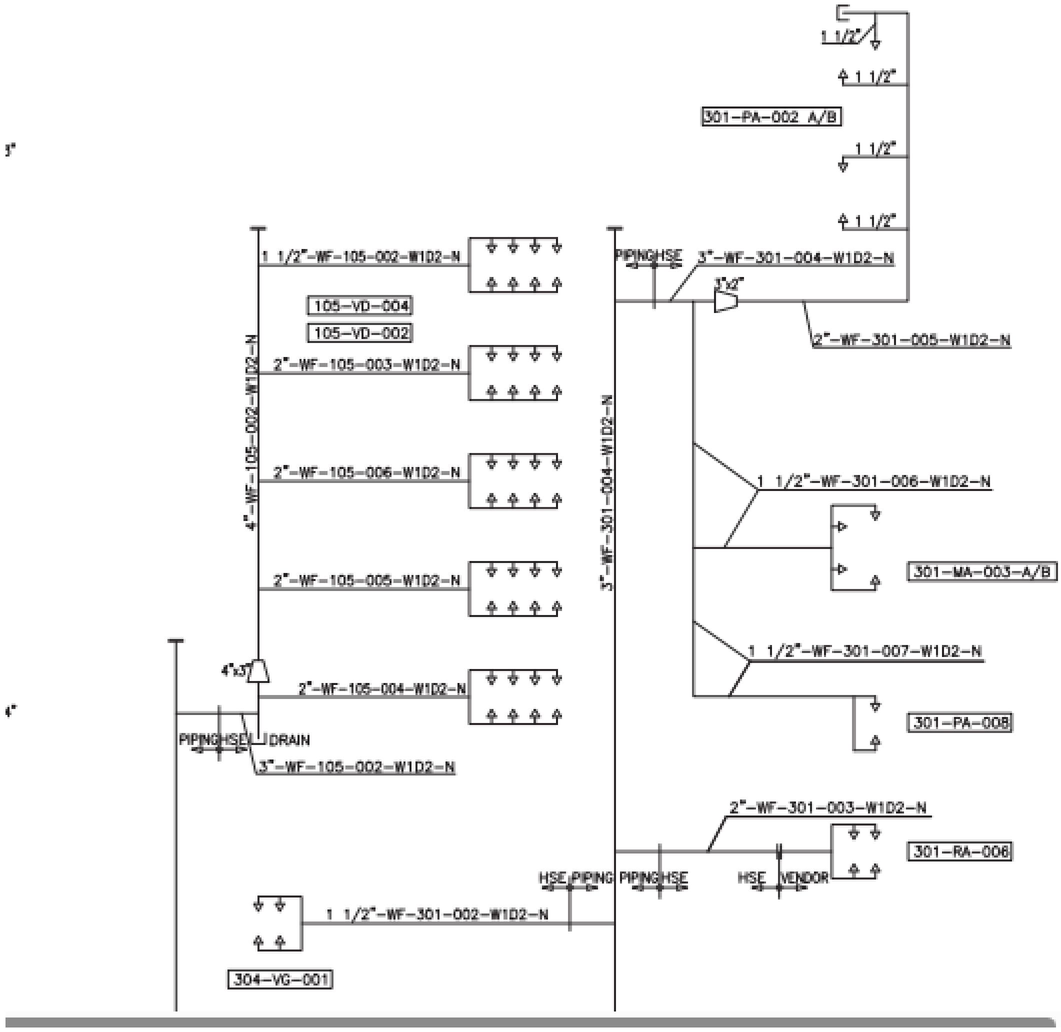

Figure 5.7: water spray system for UNIT 105 and 301

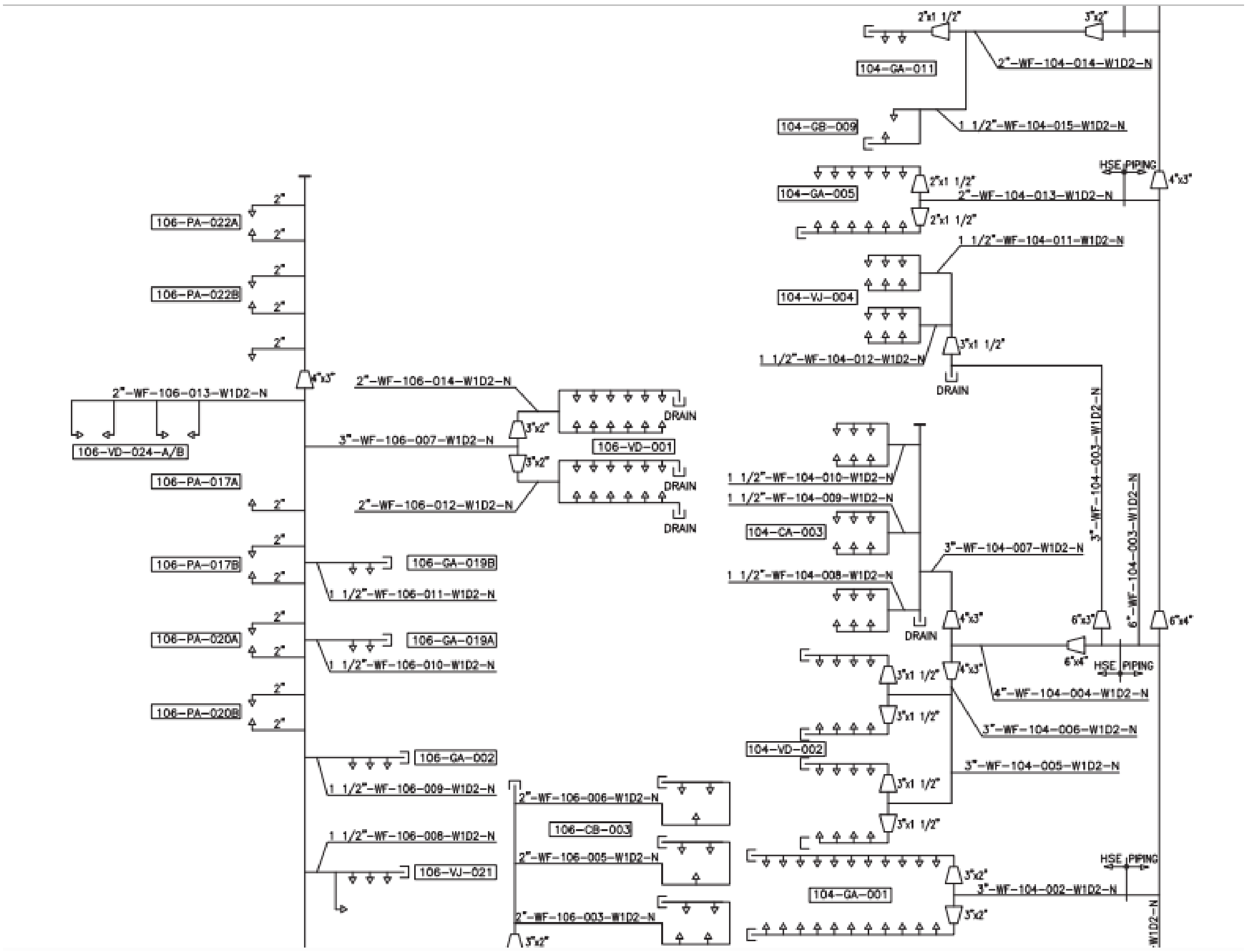

Figure 5.8: water spray system for UNIT 104 and 106

5.4.6 Water system evaluation results -conclusion-

In conclusion, the evaluation of the deluge system indicates positive performance. All equipment requiring deluge protection is fully covered by the spray patterns of the nozzles. The water supply is sufficient to meet the required flow rates. The nozzle placement is suitable to ensure complete coverage, and the flow rates comply with the standards outlined in NFPA 15. This comprehensive evaluation confirms that the deluge system is functioning effectively and is ready to suppress fires as intended.

5.5 Foam systems evaluation

5.5.1 Composition

- **Water supply systems:** the primary function of these systems is to provide water, it is composed of water storage tanks and pumps.
- **Foam concentrate systems:** these systems store and provide foam concentrate, they're found in foam stations and composed of foam concentrate storage tanks and pumps.

- **Foam proportioning:** installed on deluge skids, their primary function is to properly mix foam concentrate and water to obtain the foam solution.

- **Foam outlets:** They shall discharge at a nominal pressure 2 barg above the water pressure at the eductor.

5.5.2 Water supply

A/ Water Quantity

According to the site's fire fighting basic design specification, the calculation of the maximum fire water demand is based on the maximum fire water required $Q_{m^3/h}$, as presented below:

$$\text{Main Fire Water storage} = Q_{m^3/h} \times 12 \text{ hours}$$

For foam monitors, the flow rate is given by $Q = 120m^3/h$ by monitor, so the main fire water storage for all monitors is given by:

$$\sum \text{Main Fire Water Storage} = \text{number of monitors} \times Q_{m^3/h} \times 12 \text{ hours.}$$

The global storage takes into account the stand-by water systems, hence, the global water storage demand is given by the following formula:

$$\text{Global storage} = \ Q_{m^3/h} \times 12 \text{ hours} \times 2$$

According to NFPA 11 requirements about water quantity, the water supply shall be sufficient for both foam apparatus and other firefighting operations (see APPENDIX I-A), the site's water supply has the ability to provide water for 12 hours continuously, **water supply is then in accordance with NFPA 11 requirements.**

B/ Pressure, temperature and quality

- The water quality doesn't have adverse effects on foam formation and foam stability: absence of corrosion inhibitors, emulsion breaking chemicals and other additives.

- The storage temperature is between 18-30 °C.

- Pumps operating pressure shall provide fire water at 12 barg, which is the operating pressure at the inlate of the foam system.

5.5.3 Foam concentrate

- The concentrate used is 3% AFFF concentrate, so no mixed foam concentrates are used (in compliance with NFPA 11 - APPENDIX I-A)

- The foam system shall consist of a foam station including foam concentrate storage and pumps, and a dedicated foam concentrate network to flow foam concentrate from foam station to each deluge skid where the foam solution is produced. 2 x 100% capacity pumps shall be provided (in compliance with NFPA 11 - APPENDIX I-A).

5.5.4 Foam monitors and discharge outlets

A/ Discharge rates

Discharge rates are in compliance with NFPA 11 requirements, the figure below indicates the discharge rates per type of tanks:

Scenaries	Tank dike fire	Fixed roof Tank	Floating roof Tank	Adjacent Tanks
Reference NFPA code	NFPA 11, sec. 5.7	NFPA 11, sec. 5.2	NFPA 11, sec. 5.3	N.A.
Foam Application rate	4.1 l/min/m²	4.1 l/min/m²	12.2 l/min/m²	N.A.
Foam discharge duration	30 minutes	55 minutes	20 minutes	N.A.

Figure 5.9: Foam Discharge rates[9]

B/ System design

The system specific design is compliant with NFPA 11 requirements (see APPENDIX I-A)

- A factor of 1.5 is considered for foam application rate.
- Monitors shall be designed in such a way that the hydraulic forces, including pressure surge when opening the monitor valve, are balanced. Each monitor shall have a block valve. This block valve shall be locked open in normal service.
- Foam concentrate of alcohol resistant type (AR FFF) shall be used for methanol/glycol storage tanks.

C/ System coverage

For comprehensive fire protection, a multi-layered foam system blankets the entire facility layout. Foam discharge outlets strategically placed on storage tanks provide immediate attack capability. Fixed foam monitors, positioned throughout the facility, offer continuous coverage of critical areas. Additionally, mobile foam monitors mounted on vehicles ensure firefighters can reach any location within the facility to combat potential blazes. This combined approach ensures rapid and effective foam application for any fire scenario.
The following figures indicate fixed and mobile foam monitors throughout the CPF:

- **Fire fighting system layout units 100, 101, 102**

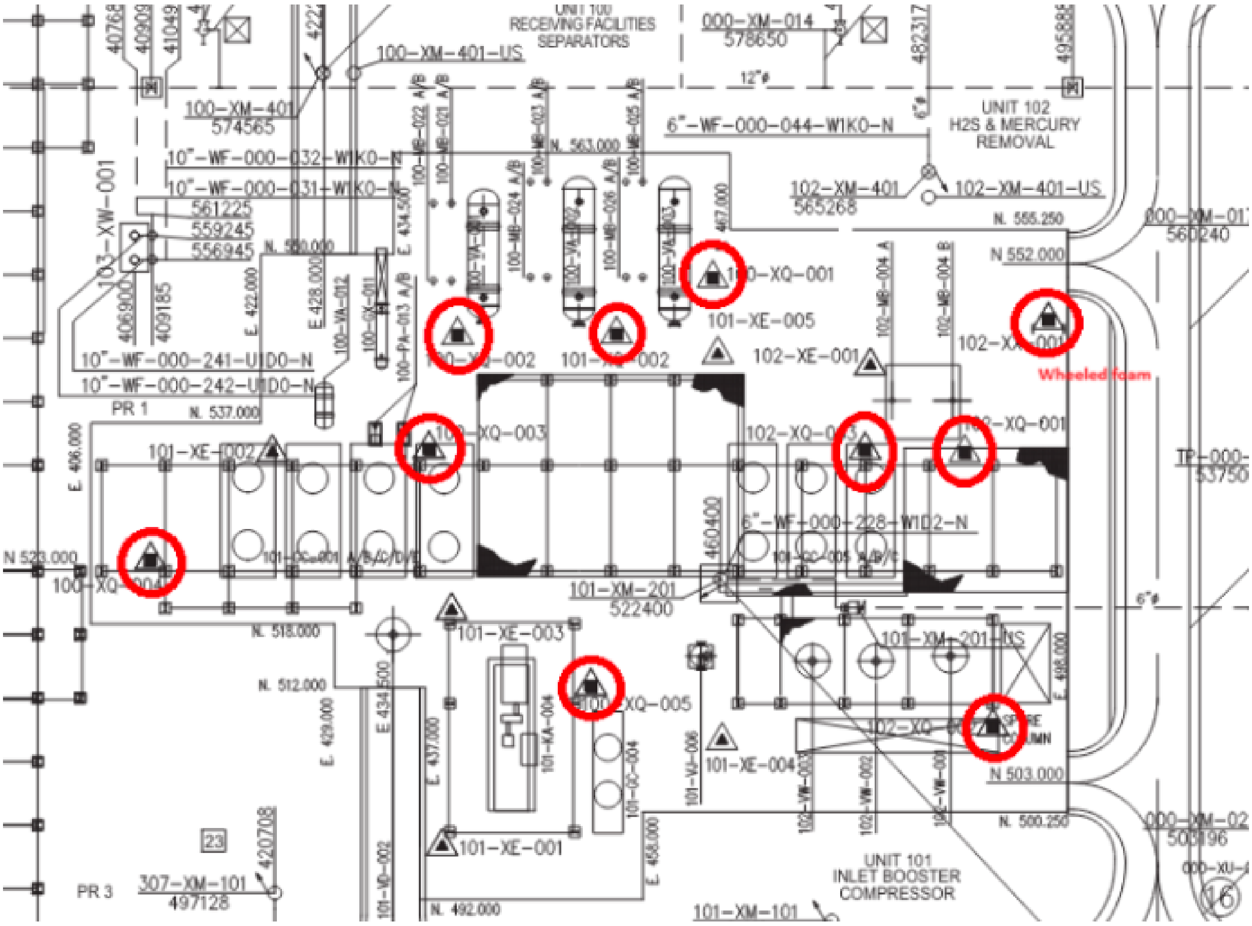

Figure 5.10: Foam monitors (unit 100, 101, 102)

- **Fire fighting system layout unit 103**

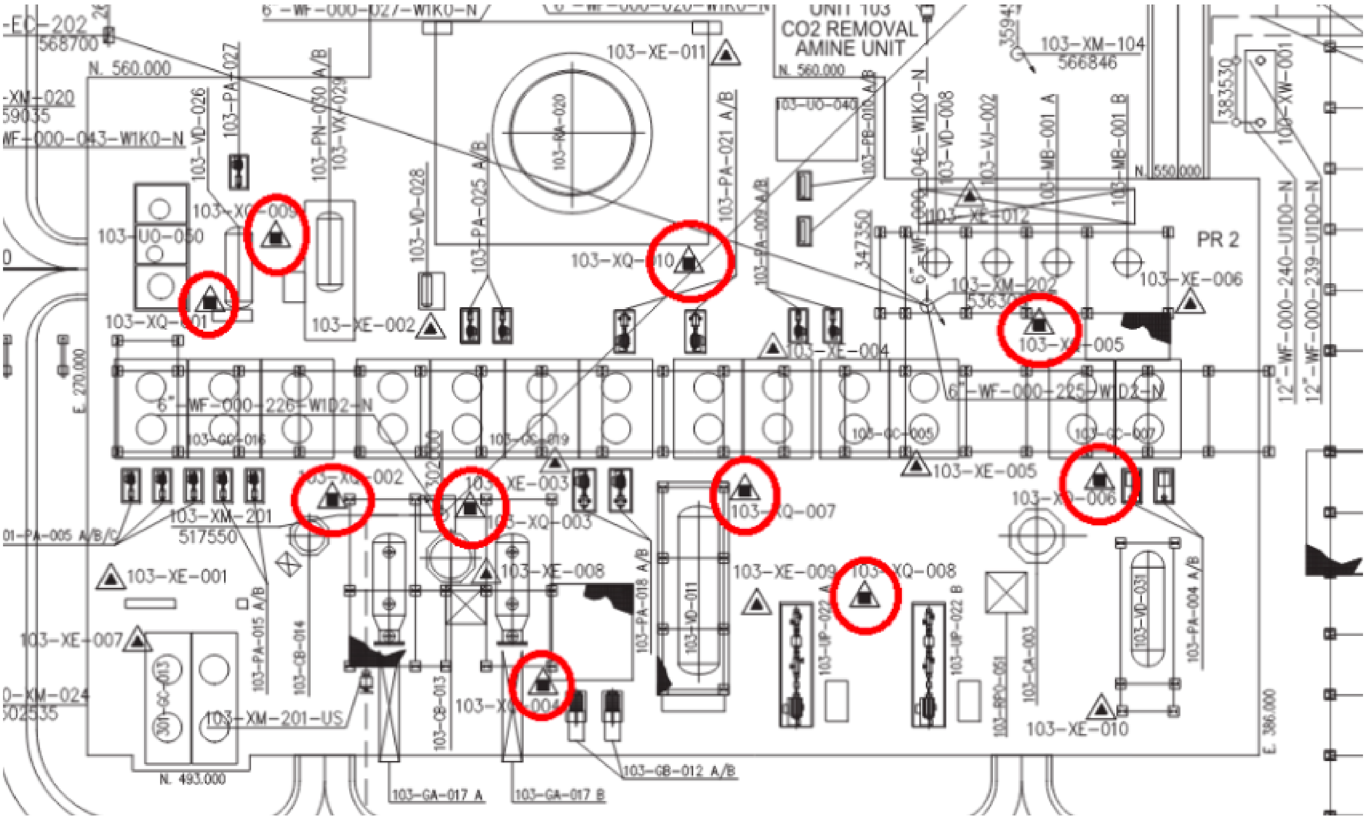

Figure 5.11: Foam monitors (unit 103)

- **Fire fighting system layout unit 105 & 301**

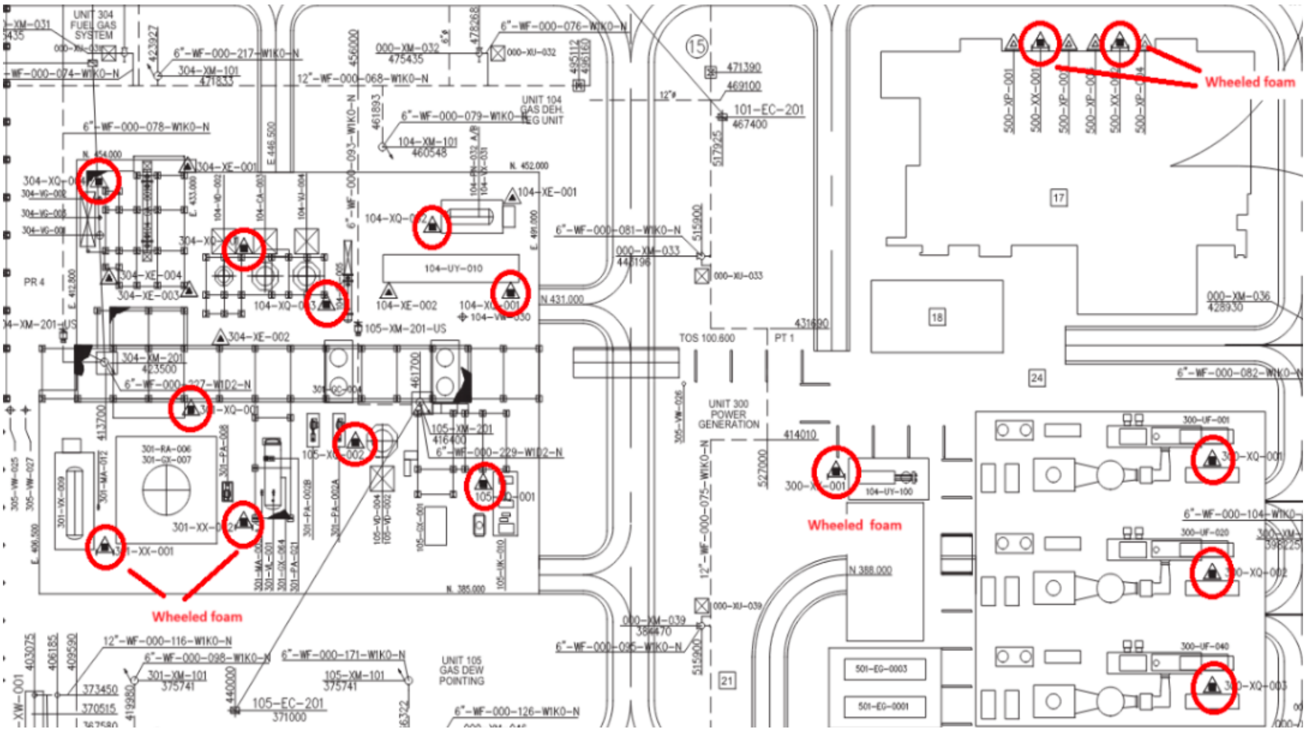

Figure 5.12: Foam monitors (unit 105 & 301)

- **Fire fighting system layout unit 106**

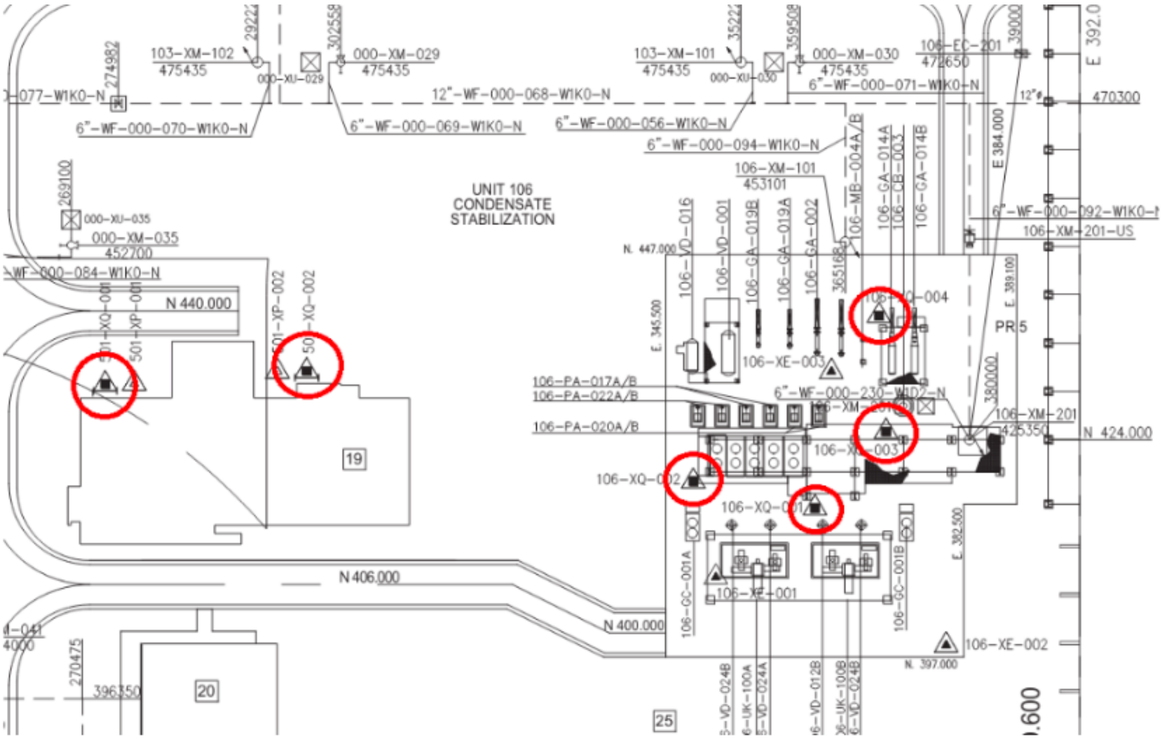

Figure 5.13: Foam monitors (unit 106

- **Fire fighting system layout unit 201**

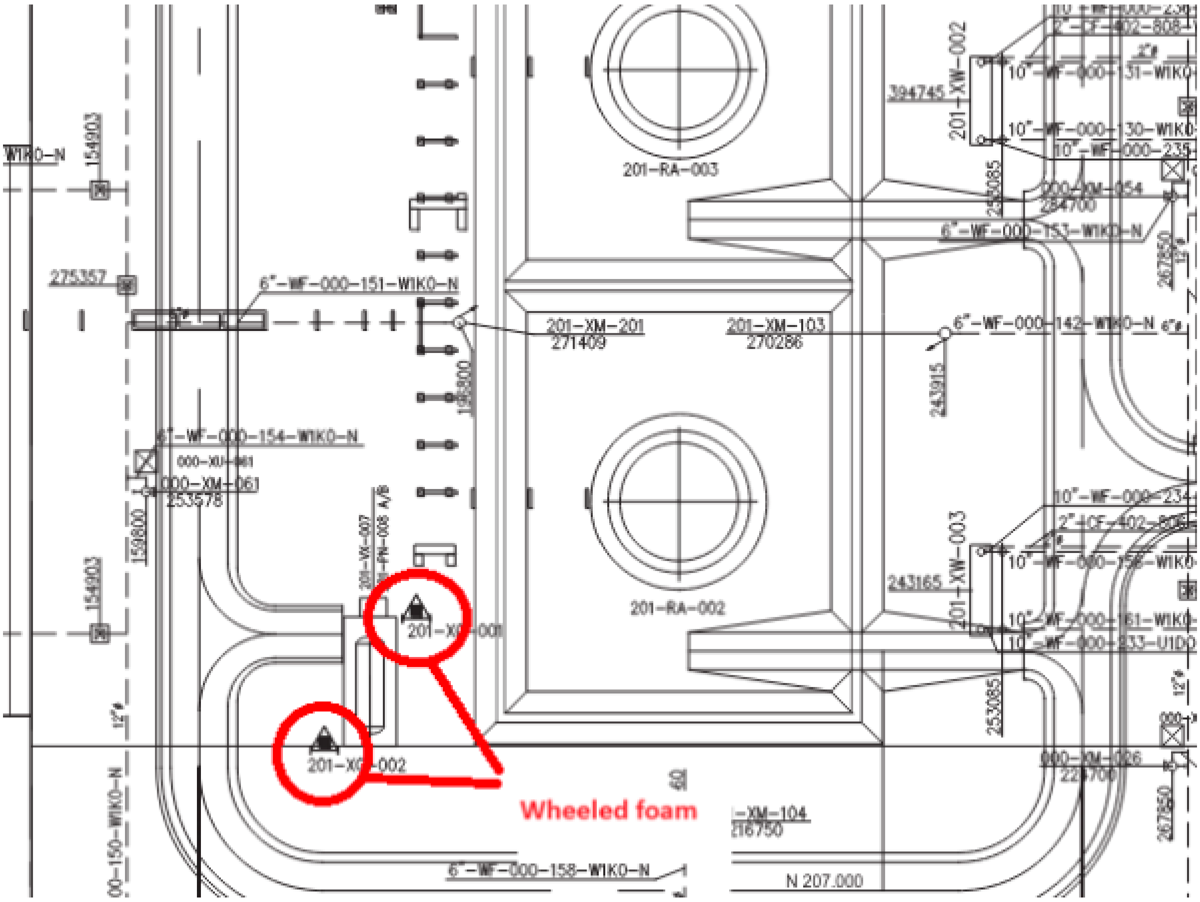

Figure 5.14: Foam monitors (unit 201)

5.5.5 Foam system evaluation results -conclusion-

In conclusion, the evaluation of the foam system indicates positive performance. All equipment requiring foam protection is fully covered by the spray patterns of the foam monitors. The foam concentrate and water supply are sufficient to meet the required flow rates. The foam monitor placement is suitable to ensure complete coverage, and the flow rates comply with the standards outlined in NFPA 11. This comprehensive evaluation confirms that the foam system is functioning effectively and is ready to suppress and extinguish fires as intended.

General Conclusion

This dissertation has addressed the critical aspect of fire protection at a gas treatment site, focusing on both passive and active measures to enhance safety, Key results from our study include:

- **Fire Hazards Analysis (FHA):**
  - Conducted FHA to identify and assess potential fire risks.
  - Used FHA results to inform the development of targeted fire protection measures.
- **Integration of Technical Documents and Data**
  - Utilized facility layouts, equipment data, and operational parameters to design the fireproofing plan.
  - Applied FHA results to address specific fire scenarios.
- **Development of a Fireproofing Plan**
  - A comprehensive fireproofing plan was developed based on the API RP 2218 standard.
  - The plan includes materials and techniques to slow down fire spread, reduce heat transfer, and protect critical equipment during fire events.
- **Evaluation of Firefighting Systems**
  - Existing fire suppression and extinguishing systems were evaluated for conformity with NFPA standards (NFPA 11, NFPA 15, NFPA 17).
  - The evaluation considered water supply systems, system capacity and discharge rates, and system coverage to ensure comprehensive protection.

These outcomes highlight the importance of a multi-layered fire protection approach combining active and passive measures. The methodologies and findings presented contribute to improving fire safety standards and practices in high-risk industrial environments, ensuring the protection of personnel and assets.

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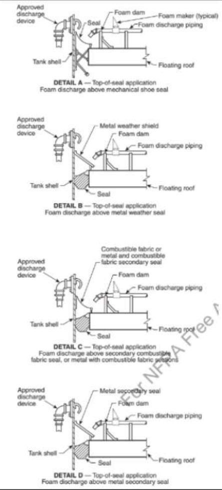
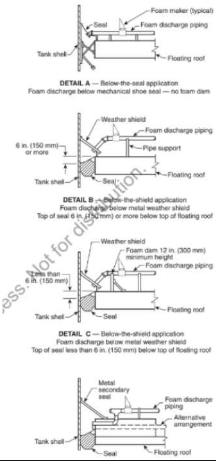
APPENDIX I: Standards' requirements

APPENDIX I-A: NFPA 11 Requirements

<table>
<tr><th>Purpose</th><th>System</th><th colspan="2">Requirements</th><th>Notes</th></tr>
<tr><td rowspan="14">Foam making</td><td rowspan="9">Water supply</td><td rowspan="2">Quality</td><td>The water doesn't have adverse effects on foam formation and foam stability</td><td></td></tr>
<tr><td>Absence of corrosion inhibitors, emulsion breaking chemicals or any other additives (except for prior consultation with foam concentrate</td><td></td></tr>
<tr><td rowspan="2">Quantity</td><td>Water supply shall be sufficient for both foam apparatus and other firefighthing operations</td><td></td></tr>
<tr><td>Pre-mixed solution type systems do not require continuous water supply</td><td></td></tr>
<tr><td>Pressure</td><td>The pressure at the inlet of the foam system under the required flow shall meet the minimum system's pressure of which it is designed for</td><td></td></tr>
<tr><td>Temperature</td><td>The temperature shall be between 4°C and 38°C</td><td></td></tr>
<tr><td rowspan="2">Design</td><td>Presence of line strainers if the water contains solids likely to clog orifices in discharge devices</td><td></td></tr>
<tr><td>Hydrants fursnishing the water supply shall be at the required number according to NFPA 24 and their location approved by AHJ</td><td></td></tr>
<tr><td>Storage</td><td>Water supplies or premixed solutions shall be protected against freezing in climates where freezing temperatures are expected</td><td></td></tr>
<tr><td rowspan="3">Foam concentrate</td><td colspan="2">Different types of foam concentrates (or different brands) shall not be mixed (unless the data provided by the provider and accepted by the authorities allows it)</td><td></td></tr>
<tr><td colspan="2">Foam concentrates shall be stored in a location that isn't exposed to the hazard they protect from (if housed, in a non-combustible structure)</td><td></td></tr>
<tr><td colspan="2">Reserve supplies or ways to obtain more foam concentrate within 24hours should be taken into account and stored seperately</td><td></td></tr>
<tr><td rowspan="2">Foam proportioning</td><td colspan="2">The proportioning system shall meet the listed minimum flow rates based on the minimum and maximum system discharge flow rate</td><td></td></tr>
<tr><td colspan="2">The method of proportioning shall conform to one of the following: self-educting nozzle, in-line inductor, pressure proportioning, around the pump proportioning, direct injection variable output foam pump system, coupled water-motor driven pump proportioner, balanced pressure pump-type proportioners.</td><td></td></tr>
<tr><td rowspan="12">Protecion</td><td rowspan="12">Outdoor fixed roof tanks</td><td rowspan="4">Foam monitors and handlines</td><td>A factor of 1.5 shall be considered for foam application rates to compensate for potential foam loses due to wind and ambient conditions</td><td></td></tr>
<tr><td>If the liquid is destructive to non-alcohol-resistant foams (such as water-soluble and certain ignitable liquids and polar solvents), then alcohol-resistant foams are to be used instead.</td><td></td></tr>
<tr><td>Foam handlines shall not be permitted to be used as the primary mean of protection for fixed-roof tanks over 9m in diameter or those above 6.1m of height</td><td></td></tr>
<tr><td>Discharge rates:</td><td>Table 5.2.4.2.2 Foam Handline and Monitor Protection for Fixed-Roof Storage Tanks Containing Hydrocarbons<table>
<tr><th rowspan="2">Hydrocarbon Type</th><th colspan="2">Minimum Application Rate</th><th rowspan="2">Minimum Discharge Time (minutes)</th></tr>
<tr><th>gpm/ft²</th><th>mm/min*</th></tr>
<tr><td>Flash point between 100°F and 140°F (38°C and 60°C)</td><td>0.16</td><td>6.5</td><td>50</td></tr>
<tr><td>Flash point below 100°F (38°C) or liquids heated above their flash points</td><td>0.16</td><td>6.5</td><td>65</td></tr>
<tr><td>Crude petroleum</td><td>0.16</td><td>6.5</td><td>65</td></tr>
</table>Notes:
* L/min·m² is equivalent to mm/min.</td></tr>
<tr><td rowspan="8">Fixed discharge outlets for surface applications</td><td>There should be at least 2 discharge outlets spaced equally around the tank periphery</td><td></td></tr>
<tr><td>Outlets shall be individually piped and separately valved for isolation outside the dike area</td><td></td></tr>
<tr><td>Each outley shall grant the minimum application rate or higher</td><td></td></tr>
<tr><td>The outlet's location and connections shall prevent the tank's contents from overflowing to the foam lines</td><td></td></tr>
<tr><td>The discharge outlets shall be placed in a way that the displacement of the roof will not damage them</td><td></td></tr>
<tr><td>Discharge outlets shall be provided with seals frangible under low pressure in order to prevent the vapor from entering the outlets and the pipelines</td><td></td></tr>
<tr><td>Discharge outlets shall be provided with inspection means to allow maintenance and replacement of vapor seals</td><td></td></tr>
<tr><td>Number of outlets:</td><td><table>
<tr><th colspan="2">Tank Diameter (or Equivalent Area)</th><th rowspan="2">Minimum Number of Discharge Outlets</th></tr>
<tr><th>ft</th><th>m</th></tr>
<tr><td>Up to 80</td><td>Up to 24</td><td>1</td></tr>
<tr><td>Over 80 to 120</td><td>Over 24 to 37</td><td>2</td></tr>
<tr><td>Over 120 to 140</td><td>Over 37 to 43</td><td>3</td></tr>
<tr><td>Over 140 to 160</td><td>Over 43 to 49</td><td>4</td></tr>
<tr><td>Over 160 to 180</td><td>Over 49 to 55</td><td>5</td></tr>
<tr><td>Over 180 to 200</td><td>Over 55 to 61</td><td>6</td></tr>
<tr><td>Over 200</td><td>Over 61</td><td>6
Plus 1 outlet for each additional 5000 ft² (465 m²)</td></tr>
</table></td></tr>
</table>

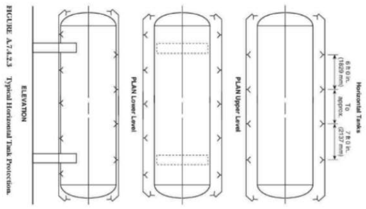
<table>
<tr><td rowspan="14"></td><td rowspan="11"></td><td rowspan="2"></td><td>The minimum discharge application rate:</td><td>
Table 5.2.5.2.2 Minimum Discharge Times and Application Rates for Type II Fixed Foam Discharge Outlets on Fixed-Roof (Cone) Storage Tanks Containing Hydrocarbons
<table>
<tr><th></th><th colspan="2">Minimum Application Rate</th><th>Minimum Discharge Time</th></tr>
<tr><th>Hydrocarbon Type</th><th>gpm/ft^2</th><th>mm/min*</th><th>(minutes)</th></tr>
<tr><td>Flash point between 100°F and 140°F (38°C and 60°C)</td><td>0.10</td><td>4.1</td><td>30</td></tr>
<tr><td>Flash point below 100°F (38°C) or liquids heated above their flash points</td><td>0.10</td><td>4.1</td><td>55</td></tr>
<tr><td>Crude petroleum</td><td>0.10</td><td>4.1</td><td>55</td></tr>
</table>
Notes:
*$L/min \cdot m^2$ is equivalent to mm/min.
</td></tr>
<tr><td>For alcohol-resistant foams, it is necessary to consult the manufacturer for listing the specific products to determine the application rate, the recommended application time is 55 minutes</td><td></td></tr>
<tr><td rowspan="9">Fixed discharge outlets for sub-surface applications</td><td>Subsurface injection shall not be used for protection of class 1A hydrocarbon liquids or for the protection of alcohol, esters, ketones, aldehydes, anhydrides or other products requiring the use of alcohol-resistant foams</td><td></td></tr>
<tr><td>The foam velocity at the point of discharge shall not exceed 3m/s for class 1B liquids or 6m/s for other classes of liquids (unless actual tests prove higher velocities satisfactory)</td><td></td></tr>
<tr><td>Minimum number of subsurface Foam discharge outlets</td><td>
Table 5.2.6.2.8 Minimum Number of Subsurface Foam Discharge Outlets for Fixed-Roof Tanks Containing Hydrocarbons
<table>
<tr><th colspan="2">Tank Diameter</th><th colspan="2">Minimum Number of Discharge Outlets</th></tr>
<tr><th>ft</th><th>m</th><th>Flash Point Below 100°F (38°C)</th><th>Flash Point 100°F (38°C) or Higher</th></tr>
<tr><td>Up to 80</td><td>Up to 24</td><td>1</td><td>1</td></tr>
<tr><td>Over 80 to 120</td><td>Over 24 to 37</td><td>2</td><td>1</td></tr>
<tr><td>Over 120 to 140</td><td>Over 37 to 43</td><td>3</td><td>2</td></tr>
<tr><td>Over 140 to 160</td><td>Over 43 to 49</td><td>4</td><td>2</td></tr>
<tr><td>Over 160 to 180</td><td>Over 49 to 55</td><td>5</td><td>2</td></tr>
<tr><td>Over 180 to 200</td><td>Over 55 to 61</td><td>6</td><td>3</td></tr>
<tr><td>Over 200</td><td>Over 61</td><td>6
Plus 1 outlet for each additional 5000 ft^2 (465 m^2)</td><td>3
Plus 1 outlet for each additional 7500 ft^2 (700 m^2)</td></tr>
</table>
</td></tr>
<tr><td>For further foam distribution, outlets can be shell connections or fed through a pipe manifold within the tank from a single shell connection</td><td></td></tr>
<tr><td>Shell connections shall be permitted to be made in manwy covers rather than installing additional tank nozzels</td><td></td></tr>
<tr><td>Outlets shall be located at least 300mm above the highest water level to prevent the destruction of the foam</td><td></td></tr>
<tr><td>The minimum discharge application rate:</td><td>
Table 5.2.6.5.1 Minimum Discharge Times and Application Rates for Subsurface Application on Fixed-Roof Storage Tanks
<table>
<tr><th></th><th colspan="2">Minimum Application Rate</th><th>Minimum Discharge Time</th></tr>
<tr><th>Hydrocarbon Type</th><th>gpm/ft^2</th><th>mm/min*</th><th>(minutes)</th></tr>
<tr><td>Flash point between 100°F and 140°F (38°C and 60°C)</td><td>0.1</td><td>4.1</td><td>30</td></tr>
<tr><td>Flash point below 100°F (38°C) or liquids heated above their flash points</td><td>0.1</td><td>4.1</td><td>55</td></tr>
<tr><td>Crude petroleum</td><td>0.1</td><td>4.1</td><td>55</td></tr>
</table>
Notes:
(1) The maximum application rate shall be 0.20 gpm/ft^2 (8.1 mm/min).
*$L/min \cdot m^2$ is equivalent to mm/min.
</td></tr>
<tr><td>If the discharge rate is higher than 4.1mm/min a reduction in time is possible provided that the time reduction doesn't exceed 70% of the times shown and the maximum velocities (3m/s for class 1B liquids or 6m/s for other classes of liquids)</td><td></td></tr>
<tr><td>All equipment used in semi-subsurface systems shall be listed or approved for this purpose</td><td></td></tr>
<tr><td rowspan="3">Outdoor open-top floating roof tanks</td><td rowspan="3">Seal protection: top of seal method with foam dam</td><td>Discharge outlets can be mounted above of the tank shell or on the periphery of the floating roof</td><td></td></tr>
<tr><td>The discharge application rates:</td><td>
Table 5.3.5.3.1 Top-of-Seal Fixed Foam Discharge Protection for Open-Top and Internal Floating Roof Tanks
<table>
<tr><th></th><th></th><th colspan="2"></th><th></th><th colspan="4">Maximum Spacing Between Discharge Outlets with</th></tr>
<tr><th></th><th>Applicable Illustration</th><th colspan="2">Minimum Application Rate</th><th>Minimum Discharge Time</th><th colspan="2">12 in. (305 mm) Foam Dam</th><th colspan="2">24 in. (600 mm) Foam Dam</th></tr>
<tr><th></th><th>Detail</th><th>gpm/ft^2</th><th>mm/min*</th><th>(minutes)</th><th>ft</th><th>m</th><th>ft</th><th>m</th></tr>
<tr><td>Mechanical shoe seal</td><td>A</td><td>0.3</td><td>12.2</td><td>20</td><td>40</td><td>12.2</td><td>80</td><td>24.4</td></tr>
<tr><td>Tube seal with metal weather shield</td><td>B</td><td>0.3</td><td>12.2</td><td>20</td><td>40</td><td>12.2</td><td>80</td><td>24.4</td></tr>
<tr><td>Fully or partly combustible secondary seal</td><td>C</td><td>0.3</td><td>12.2</td><td>20</td><td>40</td><td>12.2</td><td>80</td><td>24.4</td></tr>
<tr><td>All metal secondary seal</td><td>D</td><td>0.3</td><td>12.2</td><td>20</td><td>40</td><td>12.2</td><td>80</td><td>24.4</td></tr>
</table>
*$L/min \cdot m^2$ is equivalent to mm/min.
</td></tr>
<tr><td>If the discharge rate is higher than the values given in the table, a reduction in time is possible provided that the time reduction doesn't exceed 70% of the times shown</td><td></td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td>Top-of-Seal system design:</td><td>
</td></tr>
<tr><td></td><td></td><td rowspan="3">Weather Shield Method (below primary seal)</td><td>For this method it is necessary to install a foam dam, the foam release is above the primary seal, the top of the primary seal is less than 152mm below the top of the pontoon</td><td></td></tr>
<tr><td></td><td></td><td>Weather Shield Method System design:</td><td>
</td></tr>
<tr><td></td><td></td><td>Foam dam design specifications:</td><td>* The foam dam shall be circular and constructed of at least 3.4mm steel plate
* The foam dam shall be welded (or fastened) to the floating roof
* Dam height shall be at least 300mm measured between the steal and the roof
* The dam shall extend at least 50mm above a metal secondary seal or a combustible seal using a plastic-foam log
* Dam shall be at least 50mm higher than any burnout panels in metal secondary seals
* The foam shall be at least 300mm but not more than 600mm, from the tank shell at the highest point of the foam dam
* To allow drainage of rainwater, the foam dam bottom shall be slotted on the basis of 278mm^2 of slot area per m^2 of dammed area. restricting drain slots to a maximum 10mm in height</td></tr>
<tr><td></td><td></td><td rowspan="2">Below Seal (weather shield system)</td><td>Below-the-seal (shield) application shall not be used with combustible secondary seals</td><td></td></tr>
<tr><td></td><td></td><td>The design parameters shall be in accordance with the following table:</td><td>Table 5.3.5.3.6.1 Below-the-Seal Fixed Foam Discharge Protection for Open-Top Floating Roof Tanks
<table>
<tr><th rowspan="2">Seal Type</th><th rowspan="2">Applicable Illustration Detail</th><th colspan="2">Minimum Application Rate</th><th rowspan="2">Minimum Discharge Time (minutes)</th><th rowspan="2">Maximum Spacing Between Discharge Outlets</th></tr>
<tr><th>gpm/ft²</th><th>mm/min*</th></tr>
<tr><td>Mechanical shoe seal</td><td>A</td><td>0.5</td><td>20.4</td><td>10</td><td>130 ft (40 m) — Foam dam not required</td></tr>
<tr><td>Tube seal with more than 6 in. (150 mm) between top of tube and top of pontoon</td><td>B</td><td>0.5</td><td>20.4</td><td>10</td><td>60 ft (18 m) — Foam dam not required</td></tr>
<tr><td>Tube seal with less than 6 in. (150 mm) between top of tube and top of pontoon</td><td>C</td><td>0.5</td><td>20.4</td><td>10</td><td>60 ft (18 m) — Foam dam required</td></tr>
<tr><td>Tube seal with foam discharge below metal secondary seal†</td><td>D</td><td>0.5</td><td>20.4</td><td>10</td><td>60 ft (18 m) — Foam dam not required</td></tr>
</table>
*L/min·m² is equivalent to mm/min.
†A metal secondary seal is equivalent to a foam dam.</td></tr>
</table>

<table>
<tr><td rowspan="3">Outdoor covered (Internlal) floating roof tanks</td><td rowspan="2">Steal protection</td><td><u>The roof constructions concerned by seal protection are:</u>
Steel double check
Steel pontoon
Full liquid surface contact metallic sandwich panel (conforming to apendix H NFPA 11 requirements of API STD 650: Welded tanks for oil storage)</td><td></td></tr>
<tr><td>Full liquid surface contact metallic sandwich panel (conforming to apendix H NFPA 11 requirements of API STD 650: Welded tanks for oil storage) and the specifations in NFPA 11 5.4.2 <u>is concerned by seal</u></td><td></td></tr>
<tr><td>Full surface protection</td><td>All types of roof construction other than the ones that require seal protection shall require full surface protection.</td><td></td></tr>
<tr><td rowspan="5">Indoor hazards (tanks with surface areas of 37m^2 or higher)</td><td colspan="2">The tanks shall be equiped with type II fixed foam discharge outlets like the following:</td><td>Table 5.2.6.2.8 Minimum Number of Subsurface Foam Discharge Outlets for Fixed-Roof Tanks Containing Hydrocarbons<table>
<tr><th colspan="2">Tank Diameter</th><th colspan="2">Minimum Number of Discharge Outlets</th></tr>
<tr><th>ft</th><th>m</th><th>Flash Point Below 100°F (38°C)</th><th>Flash Point 100°F (38°C) or Higher</th></tr>
<tr><td>Up to 80</td><td>Up to 24</td><td>1</td><td>1</td></tr>
<tr><td>Over 80 to 120</td><td>Over 24 to 37</td><td>2</td><td>1</td></tr>
<tr><td>Over 120 to 140</td><td>Over 37 to 43</td><td>3</td><td>2</td></tr>
<tr><td>Over 140 to 160</td><td>Over 43 to 49</td><td>4</td><td>2</td></tr>
<tr><td>Over 160 to 180</td><td>Over 49 to 55</td><td>5</td><td>2</td></tr>
<tr><td>Over 180 to 200</td><td>Over 55 to 61</td><td>6</td><td>3</td></tr>
<tr><td>Over 200</td><td>Over 61</td><td>6
Plus 1 outlet for each additional 5000 ft^2 (465 m^2)</td><td>3
Plus 1 outlet for each additional 7500 ft^2 (700 m^2)</td></tr>
</table></td></tr>
<tr><td colspan="2">The discharge application rates:</td><td>Table 5.2.5.2.2 Minimum Discharge Times and Application Rates for Type II Fixed Foam Discharge Outlets on Fixed-Roof (Cone) Storage Tanks Containing Hydrocarbons<table>
<tr><th></th><th colspan="2">Minimum Application Rate</th><th>Minimum Discharge Time</th></tr>
<tr><th>Hydrocarbon Type</th><th>gpm/ft^2</th><th>mm/min*</th><th>(minutes)</th></tr>
<tr><td>Flash point between 100°F and 140°F (38°C and 60°C)</td><td>0.10</td><td>4.1</td><td>30</td></tr>
<tr><td>Flash point below 100°F (38°C) or liquids heated above their flash points</td><td>0.10</td><td>4.1</td><td>55</td></tr>
<tr><td>Crude petroleum</td><td>0.10</td><td>4.1</td><td>55</td></tr>
</table>Notes:
*L/min-m^2 is equivalent to mm/min.</td></tr>
<tr><td colspan="2">The minimum application rate should be 6.5 min/s of liquid surface area</td><td></td></tr>
<tr><td colspan="2">If the application rate is higher than recommended, the discharge time shall be permitted to be</td><td></td></tr>
<tr><td colspan="2">Water-soluble and certain ignitable liquids and polar solvants require alcohol-resistant foams.</td><td></td></tr>
<tr><td rowspan="7">Diked areas (outdoor)</td><td colspan="2">Diked areas shall be areas bounded bu contours of land or physical barriers that retain a fuel to a depth greater than 25mm</td><td></td></tr>
<tr><td colspan="2">Protection of these areas shall be achieved by either fixed discharge outlets, fixed or portable monitors or foam hoselines</td><td></td></tr>
<tr><td colspan="2">Minimum application rates and discharge times for fixed discharge outlets on diked areas are given by the following table</td><td>Table 5.7.3.2 Minimum Application Rates and Discharge Times for Fixed Foam Application on Diked Areas Involving Hydrocarbon Liquids<table>
<tr><th></th><th colspan="2">Minimum Application Rate</th><th colspan="2">Minimum Discharge Time (minutes)</th></tr>
<tr><th>Type of Foam Discharge Outlets</th><th>gpm/ft^2</th><th>mm/min*</th><th>Class I Hydrocarbon</th><th>Class II Hydrocarbon</th></tr>
<tr><td>Low-level foam discharge outlets</td><td>0.10</td><td>4.1</td><td>30</td><td>20</td></tr>
<tr><td>Foam monitors</td><td>0.16</td><td>6.5</td><td>30</td><td>20</td></tr>
<tr><td>Foam using compressed air foam technology</td><td>Consult manufacturer for listed minimum application rate</td><td>Consult manufacturer for listed minimum application rate</td><td>30</td><td>20</td></tr>
</table>*L/min-m^2 is equivalent to mm/min.</td></tr>
<tr><td colspan="2">Large diked areas can be subdivided to keep the total design solution within practical limits</td><td></td></tr>
<tr><td colspan="2">For low level foams discharge outlets, they shall be located so that no point in the diked area is more than 9m from a discharge outlet where the discharge per outlet is 230 L/min or less (for discharge outlets having application rates higher than 230 L/min, the maximum distance between discharge outlets shall be 18m</td><td></td></tr>
<tr><td colspan="2">For foam monitors, they should be used from outside and aimed against dike walls or tank surfaces</td><td></td></tr>
<tr><td colspan="2">For liquids requiring alcohol-resistant foams, the same methods shall be used, the minimum application rate is 30 minutes and it shall be in accordance with manufacturer's</td><td></td></tr>
</table>

<table>
<tr><td rowspan="3">Non-diked spill areas</td><td>Spill areas shall be estimated</td><td></td></tr>
<tr><td>Minimum application rates and discharge time for non-diked spill fire protection using portable foam nozzles or monitors:</td><td>
Table 5.8.1.2 Minimum Application Rates and Discharge Times for Nondiked Spill Fire Protection Using Portable Foam Nozzles or Monitors
<table>
<tr><th rowspan="2">Foam Type</th><th colspan="2">Minimum Application Rate</th><th rowspan="2">Minimum Discharge Time (minutes)</th><th rowspan="2">Anticipated Product Spill</th></tr>
<tr><th>gpm/ft²</th><th>mm/min*</th></tr>
<tr><td>Protein, fluoroprotein, and SFFF†</td><td>0.16</td><td>6.5</td><td>15</td><td>Hydrocarbon</td></tr>
<tr><td>AFFF, FFFP, and alcohol-resistant AFFF or FFFP</td><td>0.10</td><td>4.1</td><td>15</td><td>Hydrocarbon</td></tr>
<tr><td>Alcohol-resistant foams†</td><td></td><td></td><td>15</td><td>Ignitible liquids requiring alcohol-resistant foam</td></tr>
</table>
*L/min-m² is equivalent to mm/min.
†Consult manufacturer for listings on specific products.
</td></tr>
<tr><td>Non-indluded foam types shall be permitted to be used in accordance with their listing</td><td></td></tr>
<tr><td rowspan="5">Foam house stream</td><td>Approved foam hose stream equipement shall be provided in addition to tank foam installation</td><td></td></tr>
<tr><td>The minimum number of fixed/portable hose streams are given by the following table:</td><td>
Table 5.9.2.2 Supplemental Foam Hose Stream Requirements Diameter of Largest Tank
<table>
<tr><th colspan="2">Diameter of Largest Tank</th><th rowspan="2">Minimum Number of Hose Streams Required</th></tr>
<tr><th>ft</th><th>m</th></tr>
<tr><td>Up to 65</td><td>Up to 20</td><td>1</td></tr>
<tr><td>65 to 120</td><td>20 to 36</td><td>2</td></tr>
<tr><td>Over 120</td><td>Over 36</td><td>3</td></tr>
</table>
</td></tr>
<tr><td>Additional foam productiong materials shall be provided to allow the operation of hose stream equipment simultaneously with tank foam installations</td><td></td></tr>
<tr><td>Hose stream operating times (supplementing tank foam installations) are given by the following table:</td><td>
Table 5.9.2.4 Hose Stream Operating Times, Supplementing Tank Foam Installations
<table>
<tr><th colspan="2">Diameter of Largest Tank</th><th rowspan="2">Minimum Operating Time* (minutes)</th></tr>
<tr><th>ft</th><th>m</th></tr>
<tr><td>Up to 35</td><td>Up to 11</td><td>10</td></tr>
<tr><td>35 to 95</td><td>11 to 29</td><td>20</td></tr>
<tr><td>Over 95</td><td>Over 29</td><td>30</td></tr>
</table>
</td></tr>
<tr><td>The solution application rate of each foam stream shall be at least 190 L/min</td><td></td></tr>
</table>

APPENDIX I-B: NFPA 15 Requirements

<table>
<tr><th>Design objective</th><th>Purpose</th><th>Equipment/situation</th><th>Aplication rate (minimum)</th><th>Nozzle spray and placement</th><th>NOTES</th><th>Images</th></tr>
<tr><td rowspan="2">Control of Burning</td><td rowspan="2">Application of water spray to equipment or areas where a fire can occur to control the rate of burning and thereby limit the heat release from a fire until the fuel can be eliminated or extinguishment effected</td><td><u>Pumps, Compressors, and Related Equipment:</u>
Critical parts (like shafts, seals), of pumps and similar devices handling flammables need water spray protection.</td><td>20.4 (L/ min) / m2</td><td rowspan="2">Positioned to directly spray water on the source of fire and areas where spills might spread or accumulate</td><td></td><td></td></tr>
<tr><td><u>Flammable and Combustible Liquid Pool Fires.</u>
Water spray systems designed to control pool fires resulting from a flammable or com busti ble</td><td>12.2 (L/ min) / m2</td><td></td><td></td></tr>
<tr><td rowspan="6">Exposure Protection</td><td rowspan="6">Absorption of heat through application of water spray to structures or equipment exposed to a fire, to limit surface temperature to a level that will minimize damage and prevent failure.</td><td><u>1 Vessels.</u>
Water spray shall be applied to vessel surfaces (including top and bottom surfaces of vertical vessels) 2 All uninsulated vessel skirts and any uninsulated steel saddles greater than 12 in. (305 mm) high at the lowest point</td><td>10.2 (L/ min)/m2</td><td>Vertical or inclined surfaces :
Vertical vessels and towers may need to be protected only to a height of 40 ft (12.2 m) above the level at which a liquid pool fire could form
Distance between nozzles on different levels Max 12 ft (3.7 m) along the surface.
Horizontal distance :
Overlapping spray patterns on the protected surface</td><td>.Spherical or horizontal cylindrical surfaces below the vessel equator shall not be considered wettable from rundown
Obstructions (projections): Additional nozzles required to maintain water coverage.</td><td>
FIGURE A.7.4.2.3 Typical Horizontal Tank Protection.

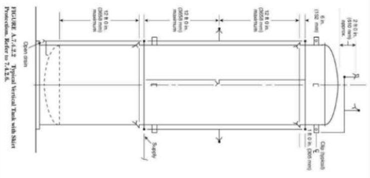
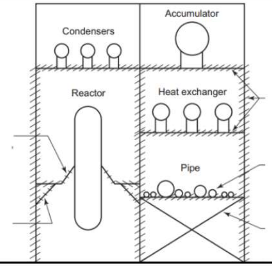
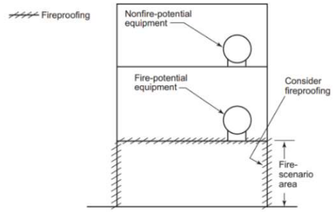
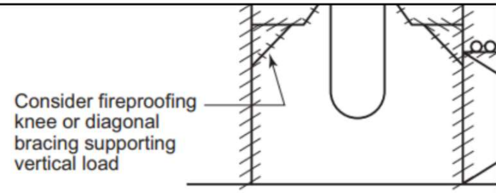
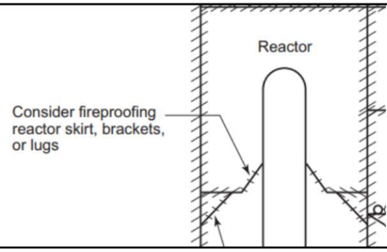



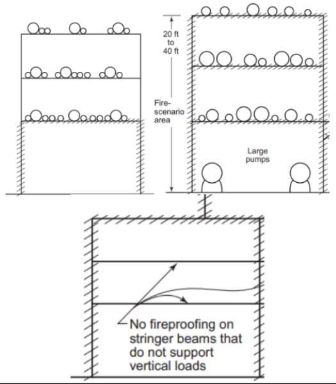
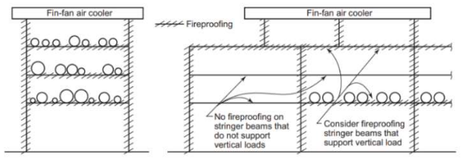
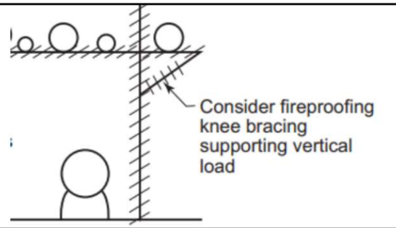
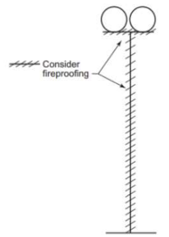
FIGURE A.7.4.2.2 Typical Vertical Tank with Skirt Protection.</td></tr>
<tr><td>horizontal Structural Steel
Vertical Structural Steel</td><td>4.1 (L/ min) / m2</td><td>Nozzle placement should be designed to ensure complete water coverage of this defined wetted surface on the horizontal and vertical structural membe</td><td>Horizontally and vertical encased steel with approved fire-resistant insulation or engineer-certified fire resistance doesn't require water spray protection</td><td>

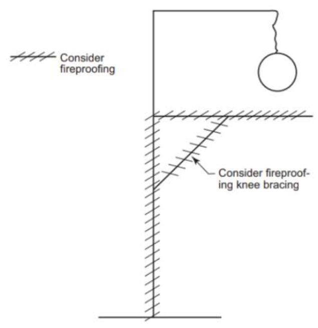
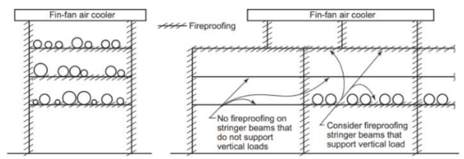
FIGURE 7.4.3.1 Wetted Surface of a Structural Member (a beam or column).</td></tr>
<tr><td>Metal Pipes, Tubing, and Conduit in Racks</td><td>Table 7.4.3.7.3 Protection of Metal Pipe, Tubing, and Conduit
<table>
<tr><th rowspan="2">Number of Rack Levels</th><th colspan="2">Plan View Density at Lowest Level</th><th colspan="2">Plan View Density at Upper Level(s)*</th><th rowspan="2">Levels Requiring Nozzles</th></tr>
<tr><th>gpm/ft²</th><th>(L/min)/m²</th><th>gpm/ft²</th><th>(L/min)/m²</th></tr>
<tr><td>1</td><td>0.25</td><td>10.2</td><td>N/A</td><td>N/A</td><td>All</td></tr>
<tr><td>2</td><td>0.20</td><td>8.2</td><td>0.15</td><td>6.1</td><td>All</td></tr>
<tr><td>3, 4, or 5</td><td>0.20</td><td>8.2</td><td>0.15</td><td>6.1</td><td>Alternate</td></tr>
<tr><td>6 or more</td><td>0.20</td><td>8.2</td><td>0.10</td><td>4.1</td><td>Alternate</td></tr>
</table>
*The table values contemplate exposure from a spill fire.</td><td>Water spray targets the underside of pipes, tubes, and conduit in racks.
place them To cover the entire width of the rack With overlapping spray patterns for complete coverage.
Max 2.5 ft below the protected level.
spaced Within rack bays if horizontal supports block the spray.</td><td>. In cases of physical limitations or space constraints, the top of pipes may be sprayed instead . Water spray shall be applied to the underside of the top level even if located immediately above a protected level.</td><td></td></tr>
<tr><td>Vertically stacked p iping</td><td>6.1 (L/ min)/ m2</td><td>water spray directed at one side (vertical plane) of the piping</td><td></td><td></td></tr>
<tr><td>Cable Trays and Cable Runs</td><td>Without flame shields: 12.2 L/min/m² With flame shields: 6.1 L/min/m²</td><td>Without flame shields: Wtater spray nozzles shall be arranged to supply water both over and under (or to the front and rear) of cable or tubing runs and to the racks and supports.
With flame shields: upper surface of the cables or rack.</td><td>. Flame shields equivalent to a 1/6 inch (1.6 mm) thick steel plate can be used to reduce water spray requirements.
. Shields must be wide enough to extend beyond the tray sides to deflect heat and flames from spills below.
. If other water spray systems exist for the fire scenario, the cable/tube spray rate can be reduced to 0.15 gpm/ft² (6.1 L/min/m²) on its upper surface, front, or back.</td><td></td></tr>
<tr><td>Trasformers</td><td>. Rectangular prism envelope (transformer and attachments): 10.2 (L/ min)/ m2 . Non-absorbent ground surface: 6.1(L/ min)/m2</td><td>. Water spray must completely cover all exposed exterior surfaces of the transformer
. if under-transformer nozzle installation is impossible, use horizontal protection or directed nozzles for the bottom surfaces.</td><td>. Water supply needs to handle both design flow and 250 gpm hose stream for 1 hour.
. Piping cannot go over top of transformer unless necessary and safe clearances are maintained.
. Components with gaps over 305 mm need individual water spray protection.</td><td></td></tr>
</table>

		Air-Fin Coolers	(10.2 L/min/m²) of horizontal surface.	. Nozzles **positioned below** the cooler, spraying **upwards** . For **forced draft** (fan below) type coolers, nozzles should be **placed inside** the **plenum, between the fan and the tubes and at the air** inlet to the fan	**Non-fireproofed steel supports:** Water spray at **10.2(L/min/m²)** on **one side**, covering up to **12 ft (3.7 m) vertically**.	
		Large Engine/Turbine Driven Compressors	10.2 (L/min/m²)	Directly **spray all exposed equipment** surfaces, **including auxiliary equipment.**		
		Large Compressors in Buildings/Canopies	12.2 (L/min/m²)	Use **180-degree spray nozzles** or **open sprinklers just below the roof**/canopy.	Consider additional coverage for sub-floor areas/basements at 12.2 (L/min/m²)	
		Motor	10.2 (L/min/m²)	Cover all exposed external surfaces of the motor.		
		non-fireproofed critical Fired Heater supports	10.2 (L/min/m²)	Cover all the surfaces area		
		combustible cooling tower	6.1 to 20.4 (L/min/m2)	Cover all the surfaces area		
		Atmospheric Storage Tank	4.1 (L/min/m²)	**Upper 12-24 ft (3.7-7.4 m) of the shell,** allowing 12 ft (3.7 m) of runoff. **Below wind girders at the top**	Water spray is not typically recommended for atmospheric storage tanks due to limited effectiveness. Hose streams and monitor nozzles: Potentially more efficient but access may be limited.	

APPENDIX I-C: API RP 2218 Requirements (Fire Proofing Considerations)

Areas	Sturctures	Description	Fireproofing	Illustration	Note
Fireproofing Inside Processing Areas	Multi-level Equipment Structures (Excluding Pipe Racks)	.Holds significant fuel (flammable liquids, gases) .Could worsen fire (explosions, fuel release)	fireproof the **vertical and horizontal steel support** members from **grade up to the highest level** at which the equipment is supported		
		Unprotected structures holding equipment could collapse in a fire, damaging nearby equipment with fire risk.	should be considered for **the vertical and horizontal steel** members from **grade level up to and** including the **level that is nearest to a 30-ft (9.1-m)** elevation above grade	 **Figure 3C—Structure Supporting Non-fire Potential Equipment in a Fire Scenario Area**	
		Knee and diagonal bracing that supports vertical loads column stability within the fire zone	Aply fireproofing on the **knees and diagonal bracing**		In many cases where knee and diagonal bracing are **used only for wind, earthquake**, or surge loading they need **not be** fireproofed
		Reactors, towers, or similar vessels are installed on protected steel or reinforced concrete structures	fireproofing should be considered for equivalent protection of supporting **steel brackets, lugs, or skirts**		Beware that the insulating effect of the fireproofing material may result in overheating the supports for vessels that operate at high temperatures. **To avoid thermal stresses and cracking** of the fireproofing, often the fireproofing is terminated **1 ft to 2 ft below the skirt/vesse**l weld and the bare area is covered in fireproof insulation.
		fireproofing is required for horizontal beams supporting piping	fireproofing the uper and the lower surface of the beam		**the upper surface** of the beam need **not be** fireproofed **if the smooth** surface is needed for **pipe movement** reasons.

Supports for Pipe Racks within a Fire Scenario Envelope	pipe rack is within a fire scenario envelope	1. fireproofing should be considered for **vertical and horizontal** supports **up** to and including **the first level**(especially if the supported piping contains **flammable materials,** combustible liquids or toxic materials) 2. If a pipe rack carries piping that has a **diameter greater than 6 in. (150 mm)** at levels **above the first horizontal beam**, or l**arge hydrocarbon pumps** are installed **beneath the rack**, fireproofing should be considered **up** to and including the level that is **nearest to a 30-ft (9-m)** elevation		**Wind or earthquake bracing and non-load-bearing** stringer beams that run parallel to piping need **not be** fireproof you can **extend the jacket an extra 18 inches (450mm)** further away from the beam, providing a **larger "cooling zone"** around it.
	air fin fan coolers are installed on top of a pipe rack within a fire scenario envelope	fireproofing should be considered for all **vertical and horizontal** support members on **all levels of the pipe rack** including **support members for the air fin-fan** coolers, **regardless of their elevation** above grade	 **Figure 4C—Pipe Rack Supporting Fin-Fan Air Coolers in a Fire Scenario Area**	
	knee and diagonal bracing that contributes to the support of vertical loads	Fireproofing should be considered for **knee and diagonal bracing**		Knee or diagonal bracing used **only for wind or earthquake** loading need **not be** fireproofed.
	In industry, pipe racks need **extra support** like lateral racks or stanchions are needed outside the main rack **for large or critical pipes**, for **pipes over 6 inches in diameter** for safety	fireproofing should be considered for **the extra suports**	 **Figure 4E—Transfer Line Support in a Fire Scenario Area**	

	pipes carrying flammable, combustible, or toxic materials are hung using rod or spring connections from a support structure called a pipe rack.a **safety measure called a "catch beam" is recommended**	The **"catch beam" and its support members** should be fireproofed	 **Figure 4D—Transfer Line with Hanger Support in a Fire Scenario Area**	if the pipe which is hung by rod or spring type connections **is the only line** on the pipe rack which contains **flammable or toxic material** then **Fireproof** the parts of the **pipe rack support that hold the "catch beam."**
Air Coolers within a Fire Scenario Envelope	air fin-fan coolers in liquid hydrocarbon service are **located at grade level**	fireproofing should be considered for their supports.		
	all air cooled exchangers **handling flammable or combustible** liquids at an inlet temperature **above their auto-ignition** temperature or **above 600 °F (315 °C)**, whichever is lower.	Fireproofing should be considered **for the structural supports** of all air cooled exchangers		
	When air cooled exchangers are **located above vessels** or equipment that **contain flammable materials**	**Structural supports** within a **horizontal radius** of 20 to **40 feet** (6 to 12 meters) **from vessels or equipment, regardless of their height**, should be fireproofed	 **Figure 4C—Pipe Rack Supporting Fin-Fan Air Coolers in a Fire Scenario Area**	
	air coolers are handling **gas only** and are **not exposed to a fire** from other equipment at grade	**no firefroofing**		
Tower and Vessel Skirts within a Fire Scenario Envelope	**1. exterior surfaces** of skirts **2. interior surfaces** of skirts	fireproofing the **exterior** and the **interior surfaces IF flanges or valves** are **inside** the skirt. If there are **unsealed openings** exceeding 24 in. **(600 mm) in diameter** in the skirt.		"**skirt**" refers to a **structural component** that provides **support to the base** or lower part of the equipment(twers, vessels).
	brackets or lugs that are used to **attach vertical reboilers** or **heat exchangers** to towers or **tower skirts**	Fireproofing should be considered for **brackets or lugs**		
Leg Supports for Towers and Vessels within a Fire Scenario Envelope	towers or vessels are **elevated** on **exposed steel legs**	fireproofing the **leg supports** to their **full load bearing height** should be considered		leg is a vertical support, while a skirt is a structural extension at the base of a vessel or tower. Both contribute to the stability and support of industrial equipment but serve different functions in terms of design and placement.

	Supports for Horizontal Exchangers, Coolers, Condensers, Drums, Receivers, and Accumulators within a Fire Scenario Envelope	**steel saddles** that support horizontal heat exchangers, coolers, condensers, drums, receivers, and accumulators that have a **diameter greater than 30 in. (750 mm)** However, this is subject to the requirement that the smallest **vertical gap** between **the concrete pier** and the **outer shell** of the equipment should be more than **12 inches (300 mm).**	Fireproofing should be considered for steel saddles		
	Fired Heaters within a Fire-Scenario Envelope	**Structural members supporting** fired heaters handling **flammable or combustible** liquids Structural steel members supporting **fired heaters in other services**	Fireproofing the structural members supporting fired heaters		
		structural support is provided by **horizontal steel beams beneath the firebox** of an elevated heater	fireproofing should be considered **for the beams** unless at least one flange face is in continuous contact with the elevated firebox.		
		common chimneys or stacks handle flue gas from several heaters	fireproofing should be considered for the structural supports for ducts or breeching between heaters and stacks		"**stacks**" often refer to tall vertical structures, such as **chimney stacks or exhaust stacks**. These are used to **vent gases or smoke** into the atmosphere. "**Ducts**" generally refer to **channels** or **passages used** for the conveyance of **air, gases, or liquids.**
	Power and Control Lines within a Fire Scenario Envelope	1. Electrical, **instrument and control** systems **used to activate emergency systems** needed **to control a fire** (e.g., emergency shut-down) 2. **Control wiring** used to **activate emergency systems** during a **fire** 3. **Pneumatic and Hydraulic** instrument Lines	fire proofing should be considered for bouth Systems **activating emergency** and **Control wiring** 1) The use of cable rated **for high temperatures** (minimum **15 to 30 minutes** in UL 1709 or functional equivalent fire conditions) such as **stainless steel jacketed** (MI/SI) mineral insulated cable, protected by intumescent material fireproofing. 2) **The use of foil-backed** endothermic wrap insulating systems properly sealed to exclude moisture in accordance with the manufacturer's recommendations. 3) The **use of cable tray** systems **designed to protect** the **cables from fire**		.Electrical, instrument and control systems used to activate emergency systems needed to control a fire they dont need protection if they are designed to fail safe during a fire **.The primary methods** of **avoiding early cable failure** in a fire situation include the following before doing fireproofing a) Burying cable below grade. b) Routing cable around areas that have a high fire potential. **.Two relevant tests** are now available. **ASTM E1725-95** and **UL 2196**
	Emergency Valves within a Fire Scenario Envelope				
	Special Hazard Fireproofing	Process units which **use radioactive sources** (as frequently used in level indicators) or have **toxic gas analyzers** (such as for sulfur dioxide)	aply fireproofing for this		Enclosures made of **fireproof materials** can be used **for this purpose**.
Fireproofing Outside Processing Units	Pipe Racks within a Fire Scenario Envelope	**pipe rack supports** outside processing units are located within a fire-scenario envelope	fireproofing is considered		**not to fireproof** bracing for **earthquakes, wind,** or surge protection and **stringer beams** that run **parallel to piping** Some **recommendations** recommend **extending fireproofing** from the primary members to a distance 18 in. **(450 mm) from the primary member.**
		important pipe racks **run within 20 ft to 40 ft (6 m to 12 m)** of open drainage ditches or **channels** that may **contain oil waste** or receive accidental spills	fireproofing should be **considered** for the **pipe rack supports** or **the ditch** should be covered.		
		carrying hydrocarbons uses bellows-style expansion joints.	fireproofing should be **considered** for the **pipe rack supports** or **the ditch** should be covered.		
	LPG Storage Spheres within a Fire Scenario Envelope				

	Horizontal Pressurized LPG Storage Tanks within a Fire-Scenario Envelope					
	Flare Lines within a Fire-Scenario Envelope					

*

APPENDIX I-D: API RP 2218 Requirements (Fire Proofing Materials)

	description	Properties	Advantages	Disadvantages	notes
Dense Concretes	Concretes made with Portland cement Dense concretes can be formed in place or pneumatically sprayed	**specific weight:**(2200 kg/m3 to 2400 kg/m3) **High thermal conductivity**	a) durability; can withstand **thermal shock** and **direct hose streams**; b) can withstand **direct flame impingement up to 2000 °F (1100 °C);** c) ability for **most contractors to satisfactorily** apply (no specialty contractors required); d) extensive proven performance; **can provide 4 or more hours of protection.**	a) relatively high weight; b) relatively high thermal conductivity; c) need for steel reinforcement d) installation cost and time involved in forming in place, especially when applied to existing facilities.	
Lightweight Concretes	Lightweight concretes use very light aggregates such as vermiculite or perlite (instead of gravel) with cements that are resistant to high temperatures	**specific weight:**(400 kg/m3 to1300 kg/m3)	a) They can withstand thermal shock and moderate pressure hose. b) Lightweight concrete fireproofing can be used at thinner coating thickness for equivalent fire exposure time ratings. c) They are capable of withstanding direct flame impingement up to 2000 °F (1100 °C). d) They can be satisfactorily applied by most contractors.	a) Porosity which can allow penetration by water (with potential for corrosion (and eventual hydrocarbon leakage). b) Moisture absorption can lead to cracking and spalling in freezing climates. c) Maintaining a top coating is often overlooked. d) Shielding and/or caulking are necessary to prevent moisture or hydrocarbons from penetrating. e) Lightweight concretes are more susceptible to mechanical damage than dense concrete materials (but can be shielded if mechanical damage is a threat).	Pneumatically applied material is about 20 % heavier than poured-in-place lightweight concrete

Organic SFRM	its a Spray-applied Fire Resistive Materials (SFRM)	**a) Subliming mastics absorb** large a **mounts of heat** as they **change** directly **from a solid to a gaseous** state. **b) Intumescent mastics expand to several times** their volume **when exposed to heat** and form a protective insulating char. This char then serves as a thermal barrier to insulate the steel. **c) Ablative mastics: absorb heat as they lose mass** through oxidative erosion	a) They can be speedily applied. b) They are lighter than cement based products per unit area making them candidates for use on existing equipment supports that may not handle additional weight c) Excellent damage resistance. d) Properly applied, some have excellent bonding, durability and corrosion protection. e) Product is available which is flexible and tolerates vibration. f) Certain materials have demonstrated exceptional durability in severe jet-fire tests and hose stream tests. g) Because they are based on an organic system special characteristics can be designed into the coating	a) Coat Thickness and Bonding:Rigorously follow manufacturer-specified application techniques for proper bonding and coat thickness.b) Experienced Appliers:Prefer experienced applicators for mastics to ensure effective and reliable application. c) Vendor-Approved Equipment: Some materials require vendor-approved application equipment and trained, material-experienced appliers. d) Shrinkage Consideration:Specify wet thickness to achieve required dry thickness, especially for mastics prone to shrinkage. e) Skilled Application for Thin Coats:Skillful application is crucial for materials with thin coat requirements; frequent checks by a qualified person are advised. f) Environmental Controls:Some mastics demand stringent environmental controls (temperature, humidity) during application. g) Quality Assurance During Application:Implement substantial Quality Assurance during application to monitor quality and prevent costly rework. h) Post-Fire Repair Consideration:Some materials may require repair or replacement after a brief fire; consultation with the supplier is advisable. i) Hose Stream Impact:Use of hose streams during a fire can reduce the overall effectiveness by knocking off protective char or material. j) Char Erosion Possibility: Some products may experience char erosion during a fire when exposed to fire hose streams. k) Expertise and Special Equipment:Expertise and quality control are crucial; some mastics may require multiple coats or special dual-component application. l) Certified Application Personnel:Some manufacturers necessitate certified approved application personnel. m) Unsuitable for Permanently Staffed Areas:Not suitable for permanently staffed areas due to smoke generation during a fire. n) Flammable Solvent Precautions:Some mastics use flammable solvents, requiring precautions during application to avoid ignition sources. o) Durability Concerns:Mastics may be less durable than traditional concrete materials when subjected to mechanical impact and abrasion.	Self-Healing Property: Some intumescent mastics can self-heal small scratches or chips during a fire. Volume and Density Changes: intumescent materials undergo volume and density changes in heat. Cracking Risk: Swelling and shrinking may lead to cracking, especially in edges or intricate shapes. Exposure Vulnerability: Cracks expose the assembly to fire, posing a risk in affected areas.

Inorganic SFRM	A sprayed (or troweled) coating formulated from Portland cement and vermiculite or perlite provides excellent fireproofing insulation.	Lightweight Cementitious Fireproofing **specific weight:**700 kg/m3 to 800 kg/m3	a) Up to 4 hours in UL 1709 or (functional equivalent tests) with durability in exterior applications. b) The properties of the vermiculite can allow it to dent rather than crack or shatter on moderate impact. c) The material is relatively light weight at 45 lbs/ft 3 to 50 lbs/ft3 (700 kg/m3 to 800 kg/m3) with respect to other forms of concrete fire protection. d) Low material costs. e) Can use relatively unskilled labor and equipment for application. f) Can be troweled to give a plastered appearance.	a) Does not protect (nor accelerate) steel from corrosion. b) The primer is compromised by the application of the pins required for the mesh. c) Typically two coats of finish are required to ensure adequate corrosion protection. d) Requires continuing maintenance of the top-coat to ensure fire performance and minimize corrosion. e) Difficult to determine extent of corrosion without destructive testing. f) Slow drying, mechanical properties and large crew sizes not favorable to offsite application.	
Preformed Inorganic Panels or Epoxy PFP Molds/Panels	Preformed fire-resistant inorganic panels can be cast or compressed from lightweight aggregate and a cement binder or from compressed inorganic insulating material such as calcium silicate or from epoxy PFP materials		a) they can be applied cleanly; b) they have no curing time; c) they have low conductivity; d) improved control of thickness	a) labor-intensive application when unit instruments and appurtenances are attached to columns; b) preformed materials are more susceptible than concretes to damage from impact after installation.	When panels are used outdoors, an external weatherproofing system to prevent moisture penetration is typically required
Masonry Blocks and Bricks					
Endothermic Wrap Fireproofing	Endothermic materials absorb heat both chemically and physically. The inorganic sheet, with a bonded aluminum foil outer layer, is flexible, tough, and versatile, suitable for wrapping around various exposed equipment. It's particularly effective in protecting electrical cable trays.	**Heat Absorption:**Chemical and physical absorption mechanisms. **Composition:**Inorganic sheet with aluminum foil. High-endothermic filler, minimal binder, and fiber. **Versatility:** Wraps around exposed equipment. Focus on electrical cable tray protection	a) Fire rated wrap systems are easily reentered and repaired, allowing retrofitting over steel without dissembling wiring and other attached items. b) The wrap material does not catalyze corrosion (nor protect against corrosion). c) Endothermic wrap systems can be applied directly over existing cement or block where additional protection is required. d) These systems can be applied directly over other fireproofing, although a reduction in rated system requirements may not be allowed for the existing materials. e) Flexible endothermic wrap systems are explosion rated	a) When used outdoors where weather proofing is required for the wrapped assembly, the fire protection system must be protected; recommended protection is stainless steel jacketing or wrapping with the manufacturer's specified environmental protection tape. b) Long term susceptibility to water or moisture ingress.	

APPENDIX II: Fire Hazard Analysis

APPENDIX II-A: Potential Hazard Identification

No.	Phase	Equipment	ERC	Causes	Consequences	Comments
1	Separation (Unit 101)	100-VA-001 HP inlet separator	Gas leak	Valve repair, pipe orifice, pipe crack, corrosion, human intervention	UVCE / Jet Fire	UVCE comes from delayed Ignition (a leak far from the energy source) Jet Fire comes from immediate Ignition at the time of the leak
2		100-VA-002 HP inlet separator				
3		100-VA-003 HP inlet separator				
4		100-VA-001 HP inlet separator	Condensate spill	Valve repair, pipe orifice, human intervention	UVCE / Groundwater fire	UVCE comes from a delayed Ignition (a leak far from the energy source) The Pool Fire comes from an immediate Ignition at the time of the leak
5		100-VA-002 HP inlet separator				
6		100-VA-003 HP inlet separator				
7		100-MB-021 A/B condensate sand filter	Loss of containment	Valve repair, pipe orifice, human intervention	Pool fire / UVCE	Filters only contain condensate, so the energy source and location determines whether the spilled condensate will cause a pool fire or UVCE
8		100-MB-025 A/B condensate sand filter				
9		100-MB-023 A/B sand filter	Loss of containment	Valve repair, pipe orifice, human intervention	Tablecloth fire / UVCE / Jet fire	The filters are three-phase, a gas leak can cause a jet fire or UVCE and a condensate spill will cause a pool fire or UVCE
10		100-MB-022 A/B condensate sand filter				
11		100-PA-013 A/B condensate pump	Condensate leak	Holes and weak spots (from corrosion), worn seals or packings, cracked pump body	Pool fire / UVCE	UVCE comes from delayed Ignition (a leak far from the energy source) Jet Fire comes from immediate Ignition at the time of the leak
12	Intake pre-compression (Unit 102)	101-GC-001 Air cooler	Gas leak	Pipe orifice, pipe crack, corrosion joint failure	Jet Fire / UVCE	
13		101-GC-005 Air cooler				

14		101-VD-002 Boooster Compressor intel Separator	Loss of containment	Mechanical ruptures resulting from overpressure (orifices, broken welds) and failures of safety valves	Jet Fire / UVCE / Explosion	
15		101-VJ-006 Boooster Compressor Discharge Coalescer (Separator)				
16		101-KA-004 Booster Compressor	Gas leak	Compressor seal failure, crack or rupture (pressure increase, vibration)	Jet Fire / UVCE	
17		102-MB-004A/B Bypass Particle Filter	Gas leak	Valve repair, pipe orifice, human intervention	Jet Fire/UVCE	
18			Obstruction	Particle accumulation	Blast	
19		102-VW-001 Mercury Removal Guarl Bed	Gas leak	Valve repair, pipe orifice, human intervention	Jet Fire/UVCE	
20		102-VW-002 H2S Removal vessel	Gas leak	Valve repair, pipe orifice, human intervention	Jet Fire/UVCE	
21		102-VW-003 H2S Removal vessel				
22	CO2 Removal (Unit 103)	103-MB-001A/B Feed Gas Particle Filter	Gas leak	Mechanical ruptures resulting from overpressure (orifices, broken welds) and failures of safety valves	Jet Fire / UVCE	
			Obstruction	Particle accumulation	Blast	
23		103-GC-005 Pump Around Air Cooler	Gas leak	Compressor seal failure, crack or rupture (pressure increase, vibration)	Jet Fire / UVCE	
24		103-GC-005 Treated Gas Air Cooler	Gas leak	Pipe orifice, pipe crack, corrosion joint failure	Jet Fire / UVCE	
25		103-VJ-002 Feed Gas Filter Coalescer	Loss of containment	Mechanical ruptures resulting from overpressure (orifices, broken welds) and failures of safety valves	Jet Fire / UVCE	
26		103-VD-028 Hydrocarbon Skimming Drum	Loss of containment, variously hydrocarbons	Rupture (corrosion, Shock)	Pool fire	

27		103-VJ-002 Feed Gas Filter Coalescer	Gas leak	Mechanical ruptures resulting from overpressure (orifices, broken welds) and failures of safety valves	Jet Fire / UVCE	
28	Dehydration (unit 104)	104-VJ-004 Dehydration Outlet Gas Filter Coalescer	Loss of containment	Mechanical ruptures resulting from overpressure (orifices, broken welds) and failures of safety valves	Jet Fire / UVCE	
29		104-GA-001 Gas/Gas Heat Exchanger	Gas leak and air ingress	Internal breakdowns (Cracks, defects, or loose connections)	Jet Fire / UVCE	
30		104-CA-003 Glycol Contactor	Leaks at contactor level	Failures in the contactor tank, piping or valves	Jet Fire / UVCE	
31	Gas Dew Point Adjustment (Unit 105)	105-KH-003 Expander	Gas leak	Rupture (corrosion, shock, weld failure)	Jet Fire/UVCE	
32		105-KA-005 Recompressor	Gas leak	Rupture (corrosion, increase in pressure, vibration, weld failure)	Jet Fire/ UVCE/ EXPLOSION	
33		105-VD-004 Cold Separator	Loss of containment	Rupture (corrosion, shock, weld failure, pressure increase)	Jet Fire/UVCE	
34		105-VD-002 ExpanderKO Drum	Loss of containment	Rupture (corrosion, shock, weld failure, pressure increase)	Jet Fire/UVCE	
35		105-GX-001 Heat exchanger	Gas leak	Internal breakdowns (Cracks, defects, or loose connections)	Jet Fire/UVCE	
36	Condensate Stabilization (Unit 106)	106-PA-017 A/B Stabilized Condensate Pumps	Leak, condensate spill	Rupture (Corrosion, Vibration)	pool fire / UVCE	
37		106-PA-022 A/B Condensate Recycle Pump				
38		106-PA-020 A/B Condensate Pumps				
39		106-GA-019 A/B Condensate Pre-Heater	Leak, condensate spill	Pipe breakage (corrosion, vibration, weld failure)	pool fire / UVCE	

40		106-GA-002 Feed/Effluent Exchanger				
41		106-GA-014 A/B Stabilize Reboiler				
42		106-VJ-021 Condensate Filter Coalescer	Leak, condensate spill	Rupture (corrosion, weld failure)	pool fire / UVCE	
43		106-MB-004 A/B Particles Filter				
44		106-CB-003 Condensate Stabilize	Condensate spill	Rupture (corrosion, weld failure, increase in pressure)	pool fire / UVCE	
45		106-VD-001 Condensate Flash drum	Leak, condensate spill	Rupture (corrosion, weld failure, increase in pressure, shock)	pool fire / UVCE	
46		106-VD-016 Condensate Degassing drum				
47		106-VD-024B 2nd Stage inlet KO drum				
48		106-GC-015 Stabilized Condensate Air Cooler	Leak, condensate spill	Pipe orifice, pipe crack, corrosion joint failure	pool fire / UVCE	
49		106-GC-011B 2nd Stage Off Gas Compressor Inlet Air Cooler				
50		106-GC-010B 1st Stage Off Gas Compressor Inlet Air Cooler				
51		106-KB-025 A 2nd Stage Off Gas Compressor	Leak, condensate spill	Rupture (corrosion, weld failure, increase in pressure, shock, vibration)	Pool fire / UVCE	
52		106-KB-025 B 2nd Stage Off Gas Compressor				

53		106-KB-009B 1st Stage Off Gas Compressor				
54	Demercurization shipping	24-GC-0001 Filter Coalescer Mercury Removal	Gas leak	Internal ruptures (seals, filter elements, fittings, wear, corrosion)	Jet Fire, UVCE	
55		24-FA-0021 Guard Bed Filter Mercury Removal				
56		24-XG-0001 Guard Bed Filter Mercury Removal				
57		24-GC-0021 Filter Coalescer Mercury Removal				
58		24-GC-0002 MRU Vessel				
59	Counting (unit 200)	200-UJ-001 Export Fiscal Metering	Spark generation	Internal breakage or poor electrical connection	Inflammation	
			Internal leaks/piping	Internal ruptures, corrosion	Jet Fire, UVCE	
60	Condensate export (Unit 201)	201-UJ-010/020/030 Condensate Melering	Leak, Condensate spill	Coupling system failure, Damaged charging hoses, Valve failure	Pool fire, UVCE	
61		201-UJ-011/021/031 Condensate Loading Arm				
62		201-PA-005 A/B Condensate Truck Loading Pumps		Leaks at the connections, overpressure in the piping, failure of the seals, wear		
63		201-PA-005 A/B Condensate Truck Loading Pumps				
64		201-VX-007 Condensate Drain Drum		Level too high, corrosion of the tank, obstruction of the vent therefore increasing the pressure		
65		201- Off Spec Condensate Storage Tank		Level too high, corrosion of the tank, obstruction of the vent		

66		201-RA-002 Condensate Storage Tank		therefore increasing the pressure		
67		201-RA-003 Condensate Storage Tank				
68	export line (Unit 203)	203-VM-001 Permanent Pig Launcher for 28" Gas Export Pipeline	Gas leak	Breakage (corrosion, shock, etc.)	Jet Fire/UVCE	
69	electricity production and heat recovery (Unit 300)	300-UF-001 Waste Heat Recovery And Power Generation Package 1	Loss of containment (Oil/Gas)	Turbine: Dirty fuel injectors, burner overheating. Heat exchanger: Corroded tubes, blocked tubes.	Turbine: Flash fire, UVCE, Jet fire Heat exchanger: Pool Fire	
70		300-UF-040 Waste Heat Recovery And Power Generation Package 3				
71		300-UF-020 Waste Heat Recovery And Power Generation Package 2				
72	Fuel Gas System (Unit 304)	304-VG-003 LP Fuel Gas Scrubber 2	Loss of containment	Human intervention, mechanical failures	Jet Fire, UVCE	
73		304-VG-001 HP Fuel Gas Scrubber				
74	Flare Systems (Unit 305)	305-PA-004 A HP Flare KO Drum Pumps	Gas leak	Weld failure Vibration Joint failure	Jet Fire, UVCE	
75		305-PA-012 A/B LP Flare KO Drum Pumps				
76		305-PA-017 A/B HP Flare KO Drum Pumps				
77		305-GX-009 HP KO Drum Electric Heater	Uncontrolled release of gas	Cracks, faulty connections, faulty valves,	Jet Fire, UVCE	
78		305-GX-016 LP KO Drum Electric Heater				
79		305-VW-024 LLP Flare Boot	Gas leak	Gas leaks in pipes, valves or joints. Failure of safety systems, such as gas detectors or fire suppression systems.	Jet Fire, UVCE, Explosion	
80		305-VW-025 LLP Flare Boot 2				

81		305-VW-026 LP Flare Boot		Corrosion or wear of torch system components		
82		305-VW-027 LP Flare Boot 2				
83		305-VD-008 HP Flare KO Drum				
84		305-VD-011 LP Flare KO Drum				
85		305-UF-010 LP Flare Package				
86		305-UF-020 LLP Flare Package				
87		305-UF-001(2ND Part) HP Flare Package (HP2)				
88		305-UF-001(1ST Part) HP Flare Package (HP1)				
89	Venting systems (Unit 306)	306-UY-005 VOC treatment package	Inflammation	Internal ignition sources (sparks, hot surfaces, etc.)	Jet Fire, UVCE	
90	Drainage Systems (Unit 307)	307-VX-003 Closed Drain Drun	gas leak / condensate advance	Rupture, corrosion, manipulation, seal failure	Jet Fire, UVCE / Pool Fire	
91		307-PN-004 A/B Closed Drain Pump	gas leak / condensate advance	Rupture (corrosion, mishandling, seal failure, vibration)	Jet Fire, UVCE / Pool Fire	
92		307-GX-018 Closed Drain Electrical Heater	gas leak / condensate advance	Rupture, overheating of pipes, thermal fatigue	Jet Fire, UVCE / Pool Fire	
93	Diesel storage (Unit 308)	308-RB-001 Diesel Storage Tank	diesel spill	Rupture, corrosion, manipulation, seal failure	pool fire, UVCE	
94		308-PA-002 A/B Diesel Transfer Pumps	diesel spill	Rupture (corrosion, mishandling, seal failure, vibration)	pool fire, UVCE	
95		308-GX-005 Diesel Storage Electrical Heater	diesel spill	Rupture, overheating of pipes, thermal fatigue	pool fire, UVCE	
96		308-UO-004 Diesel filter Coalescer Package	diesel spill	Rupture, corrosion, manipulation, seal failure	pool fire, UVCE	

APPENDIX II-B: Operational Parameters

Unit	Equipment	Phase	Modeling substance	Consequences	Presseur (bar)	Temperature (°C)	Mass Flow (Kg/h)	Density (kg/m3)		Section Volume (m3)	Mass (Kg)		Isolation		Notes
								Liquid	Vapor		Liquid	Vapor	From	To	
Separation (unit 100)	100-VA-001 HP Inlet Separator	Gas	Methane	Jet fire, Flash Fire, VCE	94	52	82317	-	93	45	-	4165	SDV 0103 SDV 0104	SDV 0502 SDV 0504 SDV 0505	
		Liquid	n-pentane	Pool Fire, VCE	94	52	4811	641	93	37	23743.6	-	SDV 0103 SDV 0104	SDV 0101	Flashing liquid diphasiucs considered
	100-VA-002 MP inlet separator	Gas	Methane	Jet fire, Flash Fire, VCE	71	70.5	415084	-	54	162	-	8701	SDV 0303	SDV 0203 SDV 0204	
		Liquid	n-pentane	Pool Fire, VCE	71	70.5	4811	641	92	1	658.5	-	SDV 0303	SDV 0201 SDV 0202	Flashing liquid diphasiucs considered
	100-VA-003 MP inlet separator	Gas	Methane	Jet fire, Flash Fire, VCE	71	70.5	415084	-	54	162	-	8701	SDV 0303	SDV 0203 SDV 0204	
		Liquid	n-pentane	Pool Fire, VCE	94	52	4811	641	92	1	658.5	-	SDV 0303	SDV 0301 SDV 0302	Flashing liquid diphasiucs considered
	100-MB-021 A/B condensate sand filter	Liquid	n-pentane	Pool Fire, VCE	94	52	4811	641	92	1	658.5	-	SDV 0101	ESDV 1101	Flashing liquid diphasiucs considered
	100-MB-022 A/B sand filter	Liquid	n-pentane	Pool Fire, VCE	94	52	4811	641	92	1	658.5	-	SDV 0102	SDV 1201 SDV 1202	Flashing liquid diphasiucs considered
	100-MB-023 A/B sand filter	Liquid	n-pentane	Pool Fire, VCE	94	52	4811	641	92	1	658.5	-	SDV 0201	ESDV 1101	Flashing liquid diphasiucs considered
	100-MB-025 A/B sand filter	Liquid	n-pentane	Pool Fire, VCE	94	52	4811	641	92	1	658.5	-	SDV 0301	ESDV 1101	Flashing liquid diphasiucs considered
	100-PA-013 A/B Condensate Pump	Liquid	n-pentane	Pool Fire, VCE	94	52	4811	641	92	1	658.5	-	SDV 1201	ESV 1101	Flashing liquid diphasiucs considered
In-let booster & compression (unit 101)	101-GC-001 Air cooler	Gas	Methane	Jet fire, Flash Fire, VCE	71	70.9	417828	-	54	24	-	1283	SDV 0203 SDV 0204 SDV 2501A SDV 2501B ESDV 2501	SDV 0101 SDV 0103	
	101-VD-002 Boooster Compressor intel Separator	Gas	Methane	Jet fire, Flash Fire, VCE	70	57	416843	-	56	78	-	4402	SDV 0101 SDV 0103	PSV0201A/B BDV 0201 PSV 0501A/B/C SDV 0501 SDV 0503	
	101-KA-004 Booster Compressor	Gas	Methane	Jet fire, Flash Fire, VCE	70	57	416843	-	56	78	-	4402	SDV 0101 SDV 0103	PSV 0501A/B/C SDV 0501 SDV 0503	
	101-GC-005 Air cooler	Gas	Methane	Jet fire, Flash Fire, VCE	70	57	416843	-	56	78	-	4402	SDV 0101 SDV 0103	SDV 0501 SDV 0503	
	101-VJ-006 Boooster Compressor Discharge Coalescer (Separator)	Gas	Methane	Jet fire, Flash Fire, VCE	94	57.1	499160	986	-	15	-	1233	SDV 0501 SDV 0502 SDV 0503 SDV 0504 SDV 0505	BDV 0106 ESDV 0101	
H2S & Hg removal (unit 102)	102-VW-001 Mercury Removal Guarl Bed	Gas	Methane	Jet fire, Flash Fire, VCE	94	57.1	499160	986	-	15	-	1233	SDV 0501 SDV 0502 SDV 0503 SDV 0504 SDV 0505	BDV 0106 ESDV 0101 BDV 0102 PSV 0101 A/B	
	102-VW-002 H2S Removal Guarl Bed	Gas	Methane	Jet fire, Flash Fire, VCE	94	57.1	499160	986	-	15	-	1233	SDV 0501 SDV 0502 SDV 0503 SDV 0504 SDV 0505	BDV 0201	
	102-VW-003 H2S Removal Guarl Bed	Gas	Methane	Jet fire, Flash Fire, VCE	94	57.1	499160	986	-	15	-	1233		BDV 0301	

CO2 removal (Unit 103)	103-MB-001A/B Feed Gas Particle Filter	Gas	Methane	Jet fire, Flash Fire, VCE	92	56,6	108067	-	78	319	-	24884	ESDV 0101 SDV 0103 SDV 0104	BDV 0101A/B PSV 0101A/B PSV 0301A/B BDV 0301 BDV 0801 ESDV 9004 SDV 0803 SDV 0804 PSV 0801A/B ESDV 9003	
		Liquide	Methane	Jet fire, Flash Fire, VCE	92	56,6	108067	-	78	319	-	24884	ESDV 0101 SDV 0103 SDV 0104	SDV 0101A/B SDV 0102A/B ESDV 9002	
	103-VJ-002 Feed Gas Coalescer	Gas	Methane	Jet fire, Flash Fire, VCE	92	56,6	108067	-	78	319	-	24884	ESDV 0101 SDV 0103 SDV 0104	PSV 0201A/B PSV 0301A/B BDV 0301 BDV 0801 ESDV 9004 SDV 0803 SDV 0804 PSV 0801A/B ESDV 9003	
		Liquide	Methane	Jet fire, Flash Fire, VCE	92	56,6	108067	-	78	319	-	24884	ESDV 0101 SDV 0103 SDV 0104	SDV 0201 ESDV 9002	
	103-CA-003 Amine Absorber	Gas	Methane	Jet fire, Flash Fire, VCE	92	56,6	108067	-	78	319	-	24884	ESDV 0101 SDV 0103 SDV 0104	PSV 0301A/B BDV 0301 ESDV 9004 SDV 0803 SDV 0804 BDV 0801 PSV 0801A/B ESDV 9003	
		Liquide	Methane	Jet fire, Flash Fire, VCE	92	56,6	108067	-	78	319	-	24884	SDV 0201	SDV 0301	
	103-VD-008 Treated Gas KO Drum	Gas	Methane	Jet fire, Flash Fire, VCE	92	56,6	108067	-	78	319	-	24884	ESDV 0101 SDV 0103 SDV 0104	SDV 0803 SDV 0804 ESDV 9004 BDV 0801 PSV 0801A/B ESDV 9003	
		Liquide	Methane	Jet fire, Flash Fire, VCE	92	56,6	108067	-	78	319	-	24884	ESDV 0101 SDV 0103 SDV 0104		
Gas dehydration (Unit 104)	Heat exchanger 104-GA-001	Gas	Metane	Jet fire, Flash Fire, VCE									ESDV 9003	BDV 0102 PSV 0102 A/B SDV 0201	
	104-VD-002	Gas	Metane	Jet fire, Flash Fire, VCE									ESDV 9003	SDV 0201	
	104-CA-003	Gas	Metane	Jet fire, Flash Fire, VCE									ESDV 9003	SDV 0302 BDV 0302	
	104-VJ-004	Gas	Metane	Jet fire, Flash Fire, VCE									ESDV 9003	BDV 0301	
Condensate stabilization (Unit106)	Condensate flash drum 106-VD-001, 106-PA020 A/B, 106-MB-001 A/B, 106-VJ021, 106-GC-015, 106-GA-002, 106-CB-003	Liquid	n-Heptane	Pool fire, flash fire, VCE	18	95	8707	654	-	9	9798,1	-	ESDV1101 ESDV0201 ESDV0601 ESDV0101	SDV0102 SDV1201A SDV1201B SDV2401B SDV2401A SDV0101 PSV0101A/B BDV0101 BDV0301 SDV0301	
	Gas outlet from Condensate flash drum 106- VD-001, 106-GA-019 A/B, 106-CB-003	Gas	Ethane	Jet fire, Flash Fire, VCE	9	59,2	2898	703	10	19	-	213	ESDV1101 ESDV0201 ESDV0601 ESDV0101	SDV0102 SDV1201A SDV1201B SDV2401B SDV2401A SDV0101 PSV0101A/B BDV0101 BDV0301 SDV0301	

	Liquid outlet from Condensate flash drum 106-VD-001, 106-PA020 A/B, 106-MB-001 A/B, 106-VJ021, 106-GC-015, 106-GA-002, 106-CB-003	Liquid	n-Heptane	Pool fire, flash fire, VCE	18	95	8707	654	-	9	9798,1	-	ESDV1101 ESDV0201 ESDV0601 ESDV0101	SDV0102 SDV1201A SDV1201B SDV2401B SDV2401A SDV0101 PSV0101A/B BDV0101 BDV0301 SDV0301	
	Condensate from Condensate degassing drum 106-VD-016, Pump 106-PA-017A/B	Liquid	n-Octane	Pool fire, flash fire, VCE	2	57,4	7868	719	-	0	207,7	-	SDV1601	ESDV1701	
	Condensate Pumps 106- PA-017 A/B & Condensate rundown header	Liquid	n-Octane	Pool fire, flash fire, VCE	2	57,4	7868	719	-	1	972,8		ESDV1701	SDV0202 SDV0302 XV0002	
	Off Gas compressor 106-KB-009, 106-GC-010 A, 106-VD-012 A, 106-GC-011 A, 106- VD-024 A, 106-KB025 A	Gas	Ethane	Jet fire, flash fire, VCE	71	132,3	2760	-	68	2	-	109	SDV0103A	SDV1201A PSV1201AA/A B PSV0901AA/A B PSV2401AA/A B PSV 2501 AA/AB BDV2501A XV2301 SDV2401A SDV2501A	
	Outlet Off Gas compressor 106-KB009 / 106-KB-025 A/B	Gas	Ethane	Jet fire, flash fire, VCE	71	132,3	2760	-	68	2	-	109	SDV2501A SDV2501B	ESDV2501	

APPENDIX II-C: Consequence modeling results

Name	Description	Fire zone	Operating pressure (barg)	Jet Fire 30 kW/m2 Radiation Distance [m] 5D	Jet Fire 30 kW/m2 Radiation Distance [m] 2F	Pool Fire 30 kW/m2 Radiation Distance [m] 5D	Pool Fire 30 kW/m2 Radiation Distance [m] 2F
CA05-G-S-IS	HP Separator 100VA001	PFZ1	94	8	7	No Hazard	No Hazard
CA05-G-S-IF	HP Separator 100VA001	PFZ1	94	8	7	No Hazard	No Hazard
CA05-D-V-S-IS	HP Separator 100VA001	PFZ1	94	11	7	No Hazard	No Hazard
CA05-D-L-S-IS	HP Separator 100VA001	PFZ1	94	No Hazard	No Hazard	9	8
CA05-D-V-S-IF	HP Separator 100VA001	PFZ1	94	11	7	No Hazard	No Hazard
CA05-D-L-S-IF	HP Separator 100VA001	PFZ1	94	No Hazard	No Hazard	9	8
CA06-G-S-IS	MP Separators 100VA002/003	PFZ1	71	6	6	No Hazard	No Hazard
CA06-G-S-IF	MP Separators 100VA002/003	PFZ1	71	6	6	No Hazard	No Hazard
CA07-G-S-IS	Outlet 100VA002/003	PFZ1	71	6	6	No Hazard	No Hazard
CA07-G-S-IF	Outlet 100VA002/003	PFZ1	71	6	6	No Hazard	No Hazard
CA08-D-V-S-IS	Separators Filtered Liquid outlet 100VA001/002/003	PFZ1	94	11	7	No Hazard	No Hazard
CA08-D-L-S-IS	Separators Filtered Liquid outlet 100VA001/002/003	PFZ1	94	No Hazard	No Hazard	9	8
CA08-D-V-S-IF	Separators Filtered Liquid outlet 100VA001/002/003	PFZ1	94	11	7	No Hazard	No Hazard
CA08-D-L-S-IF	Separators Filtered Liquid outlet 100VA001/002/003	PFZ1	94	No Hazard	No Hazard	9	8
CB01-G-S-IS	Booster compressor	PFZ1	70	6	6	No Hazard	No Hazard
CB01-G-S-IF	Booster compressor	PFZ1	70	6	6	No Hazard	No Hazard
CB02-G-S-IS	Mercury & H2S removal	PFZ1	94	8	7	No Hazard	No Hazard
CB02-G-S-IF	Mercury & H2S removal	PFZ1	94	8	7	No Hazard	No Hazard
CD01-G-S-IS	H2S to CO2	PFZ2	93	8	7	No Hazard	No Hazard
CD01-G-S-IF	H2S to CO2	PFZ2	93	8	7	No Hazard	No Hazard
CD02-G-S-IS	CO2 removal treatment	PFZ2	92	7	7	No Hazard	No Hazard
CD02-G-S-IF	CO2 removal treatment	PFZ2	92	7	7	No Hazard	No Hazard
CD03-G-S-IS	CO2 removal to dehydration	PFZ2	91	7	7	No Hazard	No Hazard
CD03-G-S-IF	CO2 removal to dehydration	PFZ2	91	7	7	No Hazard	No Hazard
CE01-G-S-IS	Gas dehydration	PFZ3	91	8	7	No Hazard	No Hazard
CE01-G-S-IF	Gas dehydration	PFZ3	91	8	7	No Hazard	No Hazard
CF01-G-S-IS	Gas Dew pointing	PFZ3	89	9	4	No Hazard	No Hazard
CF01-G-S-IF	Gas Dew pointing	PFZ3	89	9	4	No Hazard	No Hazard
CF01-D-V-S-IS	Gas Dew pointing	PFZ3	89	11	5	No Hazard	No Hazard
CF01-D-L-IS	Gas Dew pointing	PFZ3	89	No Hazard	No Hazard	9	8
CF01-D-V-S-IF	Gas Dew pointing	PFZ3	89	11	7	No Hazard	No Hazard
CF01-D-L-S-IF	Gas Dew pointing	PFZ3	89	No Hazard	No Hazard	9	8
CF02HP-D-V-S-IS	HP Liquid from 105VD004 /002	PFZ3	89	11	6	No Hazard	No Hazard
CF02HP-D-L-S-IS	HP Liquid from 105VD004 /002	PFZ3	89	No Hazard	No Hazard	9	8
CF02HP-D-V-S-IF	HP Liquid from 105VD004 /002	PFZ3	89	11	6	No Hazard	No Hazard
CF02HP-D-L-S-IF	HP Liquid from 105VD004 /002	PFZ3	89	No Hazard	No Hazard	9	8
CF03-G-S-IS	Turbo expander 105KH003	PFZ3	89	9	4	No Hazard	No Hazard
CF03-G-S-IF	Turbo expander 105KH003	PFZ3	89	9	4	No Hazard	No Hazard
CF04-G-S-IS	Recompressor 105KA005	PFZ3	72	7	6	No Hazard	No Hazard
CF04-G-S-IF	Recompressor 105KA005	PFZ3	72	7	6	No Hazard	No Hazard

CF05-G-S-IS	Outlet Recompressor 105KA005	PFZ3	78	7	6	No Hazard	No Hazard
CF05-G-S-IF	Outlet Recompressor 105KA005	PFZ3	78	7	6	No Hazard	No Hazard
CG01-G-S-IS	Outlet from flash drum 106VD001	PFZ4	9	Not reached	Not reached	No Hazard	No Hazard
CG01-G-S-IF	Outlet from flash drum 106VD001	PFZ4	9	Not reached	Not reached	No Hazard	No Hazard
CG01-D-V-S-IS	Outlet from flash drum 106VD001	PFZ4	18	Not reached	5	No Hazard	No Hazard
CG01-D-L-S-IS	Outlet from flash drum 106VD001	PFZ4	18	No Hazard	No Hazard	8	7
CG01-D-V-S-IF	Outlet from flash drum 106VD001	PFZ4	18	Not reached	5	No Hazard	No Hazard
CG01-D-L-S-IF	Outlet from flash drum 106VD001	PFZ4	18	No Hazard	No Hazard	8	7
CG02-L-S-IS	Condensate to 106VD016	PFZ4	1	No Hazard	No Hazard	5	4
CG02-L-S-IF	Condensate to 106VD016	PFZ4	1	No Hazard	No Hazard	5	4
CG03-L-S-IS	Condensate from drum 106VD016	PFZ4	2	No Hazard	No Hazard	7	5
CG03-L-S-IF	Condensate from drum 106VD016	PFZ4	2	No Hazard	No Hazard	7	5
CG04-L-S-IS	Pumped condensate 106PA017 A/B	PFZ4	2	No Hazard	No Hazard	7	5
CG04-L-S-IF	Pumped condensate 106PA017 A/B	PFZ4	2	No Hazard	No Hazard	7	5
CG05-G-S-IS	Compressor 106KB009/ 106KB025	PFZ4	71	5	7	No Hazard	No Hazard
CG05-G-S-IF	Compressor 106KB009/ 106KB025	PFZ4	71	5	7	No Hazard	No Hazard
CG06-G-S-IS	Outlet compressor 106KB009/025	PFZ4	71	5	7	No Hazard	No Hazard
CG06-G-S-IF	Outlet compressor 106KB009/025	PFZ4	71	5	7	No Hazard	No Hazard
CK01-G-S-IS	Transfert to metering 200UJ001	PFZ5	78	7	6	No Hazard	No Hazard
CK01-G-S-IF	Transfert to metering 200UJ001	PFZ5	78	7	6	No Hazard	No Hazard
CK02-G-S-IS	Export metering pig launcher 203VM001	PFZ5	77	7	6	No Hazard	No Hazard
CK02-G-S-IF	Export metering pig launcher 203VM001	PFZ5	77	7	6	No Hazard	No Hazard
CL01-L-S-IS	Condensate truck loading	SFZ10	6	No Hazard	No Hazard	7	6
CL01-L-S-IF	Condensate truck loading	SFZ10	6	No Hazard	No Hazard	7	6
CL05-L-S-IS	Loading arm 201-YG-011	MFZ14	6	No Hazard	No Hazard	7	6
CL05-L-S-IF	Loading arm 201-YG-011	MFZ14	6	No Hazard	No Hazard	7	6
CL06-L-S-IS	Loading arm 201-YG-021	MFZ14	6	No Hazard	No Hazard	7	6
CL06-L-S-IF	Loading arm 201-YG-021	MFZ14	6	No Hazard	No Hazard	7	6
CO01-G-S-IS	HP FG Scrubber 304VG001	PFZ3	72	7	6	No Hazard	No Hazard
CO01-G-S-IF	HP FG Scrubber 304VG001	PFZ3	72	7	6	No Hazard	No Hazard
CO03-G-S-IS	HP Fuel gas users	UFZ9	72	7	6	No Hazard	No Hazard
CO03-G-S-IF	HP Fuel gas users	UFZ9	72	7	6	No Hazard	No Hazard
CO05-G-S-IS	LP Fuel Gas Scrubber 2 304VG003	PFZ3	72	7	6	No Hazard	No Hazard
CO05-G-S-IF	LP Fuel Gas Scrubber 2 304VG003	PFZ3	72	7	6	No Hazard	No Hazard
CF02MP-D-V-S-IS	MP Liquid from 105GX001	PFZ3	14	2	2	No Hazard	No Hazard
CF02MP-D-L-S-IS	MP Liquid from 105GX001	PFZ3	14	No Hazard	No Hazard	8	7
CF02MP-D-V-S-IF	MP Liquid from 105GX001	PFZ3	14	2	2	No Hazard	No Hazard
CF02MP-D-L-S-IF	MP Liquid from 105GX001	PFZ3	14	No Hazard	No Hazard	8	6,757
CL02-L	Condensate storage 201RA002	SFZ10	ATM	-	-	Not reached	Not reached
CL03-L	Condensate storage 201RA003	SFZ10	ATM	-	-	Not reached	Not reached
CL04-L	Off spec condensate storage 201RA004	SFZ10	ATM	-	-	Not reached	Not reached
CT01-L	Diesel Storage	UFZ11	ATM	-	-	9	9
CU01-L	Methanol Storage 309-VN-001	UFZ11	1	Not reached	Not reached	Not reached	Not reached
CU02-L	Methanol Transfer Pumps 309-PF-002 A/B	UFZ11	112	Not reached	Not reached	7	7
CN01-L	Hot oil storage tank 301RA006	PFZ3	ATM	-	-	10	10
CN02-L	Hot oil distribution loop	PFZ3	9	-	-	5	5

APPENDIX III: Fireproofing

APPENDIX III-A: Fireproofing plan

PHASE 01										PHASE 02				PHASE 03					
Unit	Release Location	Type of equipment	Release material	Exposed equipment and strcutures	Equipment vulnerability	Pressure (bar)	Temperature (°C)	Unit spacing	Domino effect potential	Presence of drainage system	Time to isolate automatically	Time to isolate manually	Presence of active fire protection	Need of fireproofing	Fireproofing consideration	Note	Fire resistance rating	Fireproofing material	Note
100	HP-100VA001	Separator	Condensate	Separator MP-100VA002 , Separator MP-100VA003	4	94	70,5	4	YES	YES	20min	30min	YES	YES	Fireproofing should be considered for steel saddles	Fire proofing can be omitted because the vertical distance of the saddle is slightly below 300 mm	1 - 3 hours	Concrete	Concretes provide up to 4 hours protection, they're the perfect match to be installed on legs and long saddles
	100-VA-012	Pressurised vessel	Water	-	1	3	37,5	4	NO	NO	20min	30min	YES	NO	No fireproofing consideration	Liquid Inventory is water, no fireproofing is needed	1 - 3 hours	-	-
	MP-100VA002\3	Pressurised vessel	Condensate	Separator HP-100VA001, Separator MP100VA002\3	4	94	52	4	YES	YES	20min	30min	YES	YES	Fireproofing should be considered for steel saddles	-	1 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
	100-VA-105	Pressurised vessel	Water	-	1	3	37,5	4	NO	NO	20min	30min	YES	NO	No fireproofing consideration	Liquid Inventory is water, no fireproofing is needed	1 - 3 hours	-	-
101	PR1	Pipe racks	-	100-PA-013 A/B 100-VA-012	4	-	-	4	YES	NO	20min	30min	YES	YES	Fireproofing should be considered for the vertical and horizantal supports		1 - 2 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
	101-GC-001 A/B/C/D	Air cooler	Gas	101-GC-001 A/B/C/D	2	70	107	4	YES	NO	20min	30min	YES	NO	Fireproofing is not considered for the AIR coolers suports	because the material handled is Off-Gas (not liquid)	1 - 3 hours	-	-
	101-GC-005 A/B/C	Air cooler	Gas	101-GC-005 A/B/C	2	70	107	4	YES	NO	20min	30min	YES	NO	Fireproofing is not considered for the AIR coolers suports	because the material handled is Off-Gas (not liquid)	1 - 3 hours	-	-
	101-VJ-006	Pressurised vessel	as (condensate > 1 m	STR-MET-102-A/B, 102-VW-003	4	94,2	57	4	YES	NO	20min	30min	YES	YES	Skirt of the column should be fireproofed	-	1 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
	101-VD-002	Pressurised vessel	as (condensate > 1 m	101-GC-001 A/B/C/D	4	94,2	57	4	YES	NO	20min	30min	YES	YES	The support leg of the column should be fireproofed	The support feeding line shall be fireproofed to avoid escalation	1 - 3 hours	Concrete	Concretes provide up to 4 hours protection, they're the perfect match to be installed on legs and long saddles
102	STR-MET-102-A/B	Steel structure	-	-	2	-	-	3	NO	-	20min	30min	YES	NO	No fireproofing consideration	Process equipment below the structure are deluged and fireproofed on skirts and not supported on that structure	2 - 3 hours	-	-
	102-VW-001	Pressurised vessel	as (condensate > 1 m	102-VW-002, 102-VW-003, STR-MET-102-B	4	80	58	3	YES	NO	20min	30min	YES	YES	Skirt of the column should be fireproofed	If there is Flangs or valves in the inside area of skirt or unsealed openings exceeding (600 mm) in diameter in the skirt. the interior surface should be also fireproofed	1 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
	102-VW-002	Pressurised vessel	as (condensate > 1 m	102-VW-001, 102-VW-003, STR-MET-102-B	4	80	58	3	YES	NO	20min	30min	YES	YES	Skirt of the column should be fireproofed	If there is Flangs or valves in the inside area of skirt or unsealed openings exceeding (600 mm) in diameter in the skirt. the interior surface should be also fireproofed	1 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
	102-VW-003	Pressurised vessel	as (condensate > 1 m	102-VW-002, 102-VW-001, STR-MET-102-B	4	80	58	3	YES	NO	20min	30min	YES	YES	Skirt of the column should be fireproofed	If there is Flangs or valves in the inside area of skirt or unsealed openings exceeding (600 mm) in diameter in the skirt. the interior surface should be also fireproofed	1 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction

	103-VD-031	Pressurised vessel	Condensate	103-PA-004 A/B, 103-CA-003	4	91,7	80	4	YES	YES	20min	30min	YES	YES	Fireproofing should be considered for steel saddle	Fire proofing can be omitted because the vertical distance of the saddle is slightly below 300 mm	1 - 3 hours	Concrete	Concretes provide up to 4 hours protection, they're the perfect match to be installed on legs and long saddles
	103-CA-003	Column	as (condensate > 1 m	103-VD-031, 103-PA-004 A/B	3	91,7	70	4	YES	NO	20min	30min	YES	YES	Skirt of the column should be Fire Proofed	If there is Flangs or valves in the inside area of skirt or unsealed openings exceeding (600 mm) in diameter in the skirt. the interior surface should be also fireproofed	1 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
	103-VD-008	Pressurised vessel	as (condensate > 1 m	103-VJ-002, 103-PA-009 A/B, 103-PB-010 A/B	3	91,7	80	4	YES	NO	20min	30min	YES	YES	Skirt of the column should be Fire Proofed	If there is Flangs or valves in the inside area of skirt or unsealed openings exceeding (600 mm) in diameter in the skirt. the interior surface should be also fireproofed	1 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
	103-VJ-002	Pressurised vessel	as (condensate > 1 m	103-MB-001 A/B, 103-VD-008	3	91,7	70	4	YES	NO	20min	30min	YES	YES	Skirt of the column should be Fire Proofed	If there is Flangs or valves in the inside area of skirt or unsealed openings exceeding (600 mm) in diameter in the skirt. the interior surface should be also fireproofed	1 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
103	103-MB-001 A/B	Filter	as (condensate > 1 m	103-VJ-002, 103-MB-001 A/B	3	92	57	4	YES	NO	20min	30min	YES	YES	Skirt of the column should be Fire Proofed	If there is Flangs or valves in the inside area of skirt or unsealed openings exceeding (600 mm) in diameter in the skirt. the interior surface should be also fireproofed	1 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
	Pipe Racks 2	Pipe racks	-	-	1	-	-	3	NO	-	20min	30min	YES	NO	No fireproofing consideration	Fire Proofing protection of the Pipe rack PR2, near to the column 103-CA-003 is not considered required, because the distance from the nozzle to the column exceeds the Fire envelope (EXCEPT SOUTH WEST SIDE)	-	-	
	Support structure of 103-GC-007	Steel structure	-	-	3	-	-	3	NO	-	20min	30min	YES	NO	No fireproofing consideration	no Fire Proofing shall be considered for the support structure of the air coolers 103-GC-007 because the material handled is Off-Gas (not liquid), hence there is no possibility of pool fires	-	-	
	STR-MET-103-CA	Steel structure	-	-	3	-	-	4	NO	NO	20min	30min	YES	YES	Fireproofing should be considered for the horisontal and vertical steel suport from grade up to the highest level at wich the equipment is suported	-	2 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
	103-GC-016 A/B	Air cooler	Gas	NONE	2	3	87	4	NO	NO	20min	30min	YES	NO	No fireproofing consideration	No Fire Proofing shall be considered for the air coolers 103-GC-016 A/B because the material handled is Anti Foam, considered as non flammable.	-	-	-
	104-GA-001	Heat exchanger	Gas	NONE	2	91	56,9	1	NO	NO	20min	30min	YES	NO	No fireproofing consideration	Fluid inventory is gas, no fireproofing needed	-	-	-
	104-VX-031	Pressurised vessel	TEG	NONE	2	0,4	204	1	NO	YES	20min	30min	YES	NO	No fireproofing consideration	Drum is burried, no fireproofing needed	-	-	-
104	STR-MET-104-A	Steel structure	-	-	3	-	-	3	YES	-	20min	30min	YES	YES	should be Fire Proofed	No Fire proofing shall be required for the structure STR-MET-104-A on those sections that do not support the major equipment	2 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction

	STR-MET-104-B	Steel structure	-	-	2	-	-	3	YES	-	20min	30min	YES	NO	No fireproofing consideration	No Fire proofing shall be required for the structure STR-MET-104-B, since the process equipment 104-VD-002, 104-CA-003 and 104-VJ-004 are deluged equipment, supported on skirts, and not supported on that structure.	-	-	-
105	Expander Drum 105-VD-002	Pressurised vessel	as (condensate > 1 m	301-PA-002A	3	89	-5,4	3	YES	NO	20min	30min	YES	YES	Provide fireproofing on the skirt	Fire proofing can be omitted because the vertical distance of the saddle is slightly below 300 mm	1 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
	Cold separator 105-VD-004	Pressurised vessel	as (condensate > 1 m	301-PA-002A	3	73,8	-16	3	YES	NO	20min	30min	YES	YES	Provide fireproofing on the skirt	Fireproofing could be avoided since the equipment is provided with thermal insulation, however, water deluge should be provided in this case	1 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
301	STR-MET-301-C	Steel structure	-	-	3	-	-	4		-	20min	30min	YES	YES	Fireproofing should be considered for the horisontal and vertical steel suport from grade up to the highest level at wich the equipment is suported	-	2 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
	301-VL-001	Pressurised vessel	Hot oil	301-MA-003-A/B	4	0,5	150	4	YES	YES	20min	30min	YES	YES	The Vessel's structure should be fireproofed	The aim of fireproofing the structures is to prevent fire escalation since the vessel is located on a multi-level structure	1 - 3 hours	Concrete	Concretes provide up to 4 hours protection, they're the perfect match to be installed on legs and long saddles
	301-GC-004	Air cooler	Gas	PR4, 104-GC-016	2	4	251	4	YES	NO	20min	30min	YES	YES	The equipment's structure should be fireproofed	Fire Proofing should be considered for the supporting structure of the air cooler due to the material handled is Hot Oil below the AIT, but above its Flash Point.	1 - 3 hours	Concrete	Concretes provide up to 4 hours protection, they're the perfect match to be installed on legs and long saddles
	Pipe Racks 4	Pipe racks	-	-	3	-	-	4	YES	-	20min	30min	YES	YES	Fireproofing should be considered for the vertical and horizantal suports	Pipe rack PR4 is impinged by several Fire envelopes, and should be fire proofed on its entire length to prevent fire escalation leading to a Major accident.	1 - 2 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
106	106-CB-003	Column	Condensate	106-GA-014 A/B Pipe Racks PR5	4	9	195	4	YES	YES	20min	30min	YES	YES	Skirt of the column should be Fire Proofed	If there is Flangs or valves in the inside area of skirt or unsealed openings exceeding (600 mm) in diameter in the skirt. the interior surface should be also fireproofed	1 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction
	106-VD-001	Pressurised vessel	Condensate	106-VD-016	4	13,5	50	4	YES	YES	20min	30min	YES	YES	Fireproofing should be considered for steel saddles	Fire proofing can be omitted because the vertical distance of the saddle is slightly below 300 mm	1 - 3 hours	Concrete	Concretes provide up to 4 hours protection, they're the perfect match to be installed on legs and long saddles
	106-VD-016	Pressurised vessel	Condensate	106-VD-001	4	3	57,3	4	YES	YES	20min	30min	YES	YES	Fireproofing should be considered for steel saddles	Fire proofing can be omitted because the vertical distance of the saddle is slightly below 300 mm	1 - 3 hours	Concrete	Concretes provide up to 4 hours protection, they're the perfect match to be installed on legs and long saddles
	STR-MET-106-B	Steel structure	-	-	3	-	-	4	YES	-	20min	30min	YES	YES	Fireproofing should be considered for the horisontal and vertical steel suport from grade up to the highest level at wich the equipment is suported	-	2 - 3 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction

106	106-GC-015	Air cooler	Gas	106-GA-014 A/B, Pipe Racks PR5	2	8,4	109	4	YES	NO	20min	30min	YES	YES	Fireproofing should be considered for steel saddles	Fire proofing can be omitted because the vertical distance of the saddle is slightly below 300 mm	1 - 3 hours	Concrete	Concretes provide up to 4 hours protection, they're the perfect match to be installed on legs and long saddles
	106-GC-004	Air cooler	Gas	NONE	2	3	51	4	NO	NO	20min	30min	YES	NO	No fireproofing consideration	Fluid inventory is gas, no fireproofing needed	1 - 3 hours	-	-
	106-GA-014 A/B	Heat exchanger	Condensate	106-GC-015, Pipe Racks PR5	3	9	158	4	YES	NO	20min	30min	YES	YES	Fireproofing should be considered for steel saddles	Fire proofing can be omitted because the vertical distance of the saddle is slightly below 300 mm	1 - 3 hours	Concrete	Concretes provide up to 4 hours protection, they're the perfect match to be installed on legs and long saddles
	106-GC-010 A/B	Air cooler	Gas	NONE	2	8,5	62	1	NO	NO	20min	30min	YES	NO	Fireproofing is not considered for the AIR coolers suports	because the material handled is Off-Gas (not liquid)	1 - 3 hours	-	-
	106-GC-011 A/B	Air cooler	Gas	NONE	2	26	130	1	NO	NO	20min	30min	YES	NO	Fireproofing is not considered for the AIR coolers suports	because the material handled is Off-Gas (not liquid)	1 - 3 hours	-	-
	Pipe Racks 5	Pipe racks	-	-	3	70	-	4	YES	-	20min	30min	YES	YES	should be fire proofed on its entire length	-	1 - 2 hours	SFRM	SFRM provide up to 4 hours protection, they can be applied on structures, skirts and racks due to their lightweight and ease of applicaction