MARMARA UNIVERSITY

INSTITUTE FOR GRADUATE STUDIES IN PURE AND APPLIED SCIENCES

SIS APPLICATION AT A PETROLEUM CRUDE OIL PIPELINE PUMP STATION AFTER HAZOP STUDY

MEHMET ORHAN KILINÇ

MASTER THESIS

Department of Chemical Engineering

Thesis Supervisor

Doc. Dr. Gökçen Alev ÇİFTÇİOĞLU

Thesis CO- Supervisor

Prof. Dr. M. Neşet KADIRGAN

ISTANBUL, 2020

MARMARA UNIVERSITY

INSTITUTE FOR GRADUATE STUDIES IN PURE AND APPLIED SCIENCES

SIS APPLICATION AT A PETROLEUM CRUDE OIL PIPELINE PUMP STATION AFTER HAZOP STUDY

MEHMET ORHAN KILINÇ

524511004

MASTER THESIS

Department of Chemical Engineering

Thesis Supervisor

Doc. Dr. Gökçen Alev ÇİFTÇİOĞLU

Thesis CO- Supervisor

Prof. Dr. M. Neşet KADIRGAN

ISTANBUL, 2020

MARMARA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ

Marmara Üniversitesi Fen Bilimleri Enstitüsü Yüksek Lisans Öğrencisi Mehmet Orhan KILINÇ'nın "**SIS Application at A Petroleum Crude Oil Pipeline Pump Station after HAZOP Study**" başlıklı tez çalışması, 07 Ocak 2020 tarihinde savunulmuş ve jüri üyeleri tarafından başarılı bulunmuştur.

Jüri Üyeleri

Doç. Dr. Gökçen Alev ÇİFTÇİOĞLU (Danışman)
Marmara Üniversitesi ....(İMZA)..............

Prof. Dr. Emin ARCA (Üye)
Marmara Üniversitesi ....(İMZA)..............

Doç. Dr. Emel AKYOL (Üye)
Yıldız Teknik Üniversitesi ....(İMZA)..............

ONAY

Marmara Üniversitesi Fen Bilimleri Enstitüsü Yönetim Kurulu'nun 22.01.2020 tarih ve 2020/02 sayılı kararı ile Mehmet Orhan KILINÇ'ın Kimya Mühendisliği Anabilim Dalı Kimya Mühendisliği Programında Yüksek Lisans derecesi alması onanmıştır.

Fen Bilimleri Enstitüsü Müdürü Prof. Dr. Adı SOYADI

Prof. Dr. Bülent EKİCİ
Enstitü Müdürü

PREFACE

In this study, the current situation in an oil pumping station was investigated. While the inspection is carried out, all the equipment found in the station has been installed and in operation. The study was conducted within the framework of HAZOP criteria and reported.

ACKNOWLEDGMENT

I would like to thanks my thesis supervisor Doç. Dr. Gökçen Alev CIFTCIOGLU for her support and faith in me during this thesis. I would also like to express my gratitude to the assistant thesis supervisor Prof. Dr. M. Neşet KADIRGAN, for his support as a team.

In addition to that, I would also like to thank all my friends who supported me in the field, my wife Hale KILINÇ, who supported me in overcoming my thesis and my children Miray Gökçe and Mehmet Mert whom I stole from their times.

TABLE OF CONTENTS

ABSTRACT

SIS APPLICATION AT A PETROLEUM CRUDE OIL PIPELINE PUMP STATION AFTER HAZOP STUDY

With the continuous increase of the world population and technological needs, energy consumption dramatically increases in the world. The most used energy source, even though new investments are made to renewable energy sources, is still the petroleum crude oil. Because of the continuous increase in demand, safe and reliable transportation of crude oil becomes a priority.

The easiest, safest, and cheapest method of petroleum transportation is transportation by pipelines. Although the initial cost of installation is high. In addition, no matter how safe a pipeline is built, we can never reduce the risk of accidents to zero.

When we look at the results of our study, 248 risks were identified for only one pump station, although it is built safely. Of course, considering the number of stations on the oil pipeline and the length of the pipe, it is evident that the number of risks is quite high when we retake a look at the numerical data in our study. For the Crude Oil Pump Station, 134 deviations identified, 319 causes of these deviation and 892 results of the causes and the deviations were determined. In order to control these negative situations, 983 barriers were detected in the station, and 84 recommendations were given for the cases where these barriers were insufficient.

Although it was planned to perform SIS application after HAZOP analysis, it was determined that an SIS was performed for the pump station, which was taken as a sample, during the design and construction phase. As a result of this SIS, it was determined that the pumping station was built with all necessary safety instrumentation. Therefore no additional SIS could be performed.

ÖZET

HAZOP ÇALIŞMASINDAN SONRA HAM PETROL BORU HATTI POMPA İSTASYONUNDA SIS UYGULAMASI

Dünya nüfusunun sürekli olarak artışa devam etmesi ve ilerleyen teknolojinin enerji ihtiyacından ötürü, dünya enerji tüketimi her geçen yıl artmaktadır. Her ne kadar yenilenebilir enerji kaynaklarına yatırım yapılsa da en çok kullanılan enerji kaynağı halen ham petroldür. Artan bu sürekli ihtiyaç neticesinde ham petrolün güvenilir ve güvenli şekilde taşınması da önemli hale gelmiştir.

Her ne kadar ilk kurulum maliyeti yüksek olsa da ham petrolü en güvenli, güvenilir ve hızlı taşımanın yolu boru hatları ile yapılmaktadır. Fakat ne kadar en güvenli desek de kaza riski hiçbir zaman sıfır değildir.

Çalışmamız sonucunda, güvenli bir şekilde inşa edilmiş sadece bir pompa istasyonu için 248 adet risk tespit edilmiştir. Bir ham petrol boru hattının uzunluğu ve dolayısı ile üzerinde bulunacak pompa istasyonlarının sayısı düşünüldüğünde, bir boru hattının tamamında mevcut olan riskin yüksek olduğu görülecektir. Çalışmamızın sayısal verilerine göre, ham petrol pompa istasyonunda 134 sapma tanımlanmış, bu sapmalara neden olan 319 sebep ve 892 adet de sapmaların sonucu olarak tanımlanmıştır. Bu negatife tespitlerin kontrolü için pompa istasyonunda mevcut bulunan 983 adet bariyer belirlenmiş ve bariyerlerin yetersiz olduğu düşünülen durumlar için toplam 84 adet tavsiye verilmiştir.

Her ne kadar HAZOP çalışması sonrasında SIS uygulaması planlanmışsa da örnek alınan petrol pompa istasyonunun tasarım ve inşa aşamasında kapsamlı bir SIS değerlendirmesi yapıldığı belirlenmiştir. Yapılan bu SIS neticesinde pompa istasyonu gerekli tüm güvenlik enstrümanları ile donatılmış durumda olduğu tespit edilmiştir. Bu nedenle ilave bir SIS uygulaması yapılamamıştır.

SYMBOLS

% : Percentage

ABBREVIATIONS

AFPM : American Fuel and Petrochemical Manufacturers

AIChE : American Institute of Chemical Engineers

API : American Petroleum Institute

ATEX : Atmosphères Explosives

BP : British Petroleum

CAT : Category

CCPS : Center for Chemical Process Safety

CCTV : Closed Circuit Television

CIA : Association of Chemical Industries

CMA : Chemical Manufacturers Association

ER : Emergency Response

ERTAO : Response Team is available onsite

ESD : Emergency Shutdown

ESDV : Emergency Shutdown Valve

FCV : Flow Control Valve

FMEA : Failure mode and effects analysis

FR-PPE : Flame Retardant Personal Protected Equipment

FTA : Fault tree analysis

FS : Flow switch

HAZOP : Hazard and operability study

HSE : Health Safety and Environment

HV : Hand Valve

HVAC : Heating, Ventilation And Air Conditioning

ICC : International Chamber of Commerce

ICSS : Integrated Control and Safety System

IECEx : International Electrotechnical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres

ILO : International Labor Organization

ILI : In Line Inspection

ISO : International Organization for Standardization

ISSOW : Integrated Safety System of Work

L : Likelihood

LAH : Level Alarm High

LC : Locked Closed

LCR : Local Control Room

LI : Level Indicator

LO : Locked Open

LS : Level Switch

MAOP : Maximum Allowable Operating Pressure

MOV : Motor Operated Valve

MOL : Main Oil Line

NEP : National Emphasis Program

NSCI : No Significant Consequences Identified

NPRA : National Petroleum Refinery Association

OECD : Organization for Economic Co-operation and Development

OHS : Occupational Health and Safety

ORC : Operational Resource Consultants

OSHA : Occupational Safety and Health Administration

PCV : Pressure Control Valve

PIG : Pipeline Inspection Gauge

PPE : Personnel Protective Equipment (PPE)

PSM : Process Safety Management

PSV : Pressure Safety Valve

PTW : Permit to Work

PSPs : Process Safety Performance Indicators

P&ID : Piping and Instrumentation Diagram

RBPS : Risk Based Process Safety

RR : Risk Ranking

S : Severity

SCADA : Supervisory Control and Data Acquisition

SIL : Safety Integrated Level

Simops : Simultaneous Operations

SIS : Safety Instrumented System

SMS : safety management system Process Safety Performance Indicators (PSPIs

SV : Surge Valve

UK : United Kingdom

LIST OF FIGURES

LIST OF TABLES

1. Introduction

Petroleum is a complex mixture of a liquid, gaseous, or solid form of hydrocarbons. Often petroleum term restricted to the liquid form, but it also includes natural gas and the viscous or solid form known as bitumen. [1] Mainly, the liquid form of petroleum called crude oil.

With the continuous increase of the world population and technological needs, energy consumption dramatically increases in the world. The most used energy source, even though new investments are made to renewable energy sources, is still the petroleum crude oil. Because of the continuous increase in demand, safe and reliable transportation of crude oil becomes a priority.

Since the use of pure crude oil is not suitable for anyone, it must be refined to produce energy. In that process, the operation creates gasoline, diesel fuel, kerosene, and other products. The crude oil products produced by this operation are then used in all processes and equipment required in factories and gas stations all over the world.

The oil industry is one of the most powerful and influential factors in the world economy. Today, crude oil is one of the most important energy sources in daily life. According to 2016 data, the world produces more than four billion metric tons of oil annually (Table 1.1). Saudi Arabia, the United States, and Russia are the world's leading oil producers, each producing about 13 percent of total global production, accounting for 38 percent of total production (Figure 1.1). The Middle East region produces about one-third of the amount of oil production. [3]

Petroleum provides mechanical power to operate machinery and industries. It also provides the political power that comes from shutting down the machinery and industries of people who depend on you in oil supply. Therefore, in today's industrialized society petroleum means power [4].

Table 1.1: Statistical data on world oil production and consumption (BP)

Year	Production(Million Tones)	Consumption(Million Tones)
2000	3,620	3,581
2001	3,620	3,609
2002	3,603	3,640
2003	3,734	3,719
2004	3,906	3,865
2005	3,963	3,950
2006	3,963	3,950
2007	3,950	4,010
2008	3,992	3,995
2009	3,891	3,922
2010	3,978	4,038
2011	4,019	4,081
2012	4,119	4,131
2013	4,133	4,185
2014	4,221	4,211
2015	4,355	4,343
2016	4,368	4,422
2017	4,380	4,477
2018	4,474	4,529

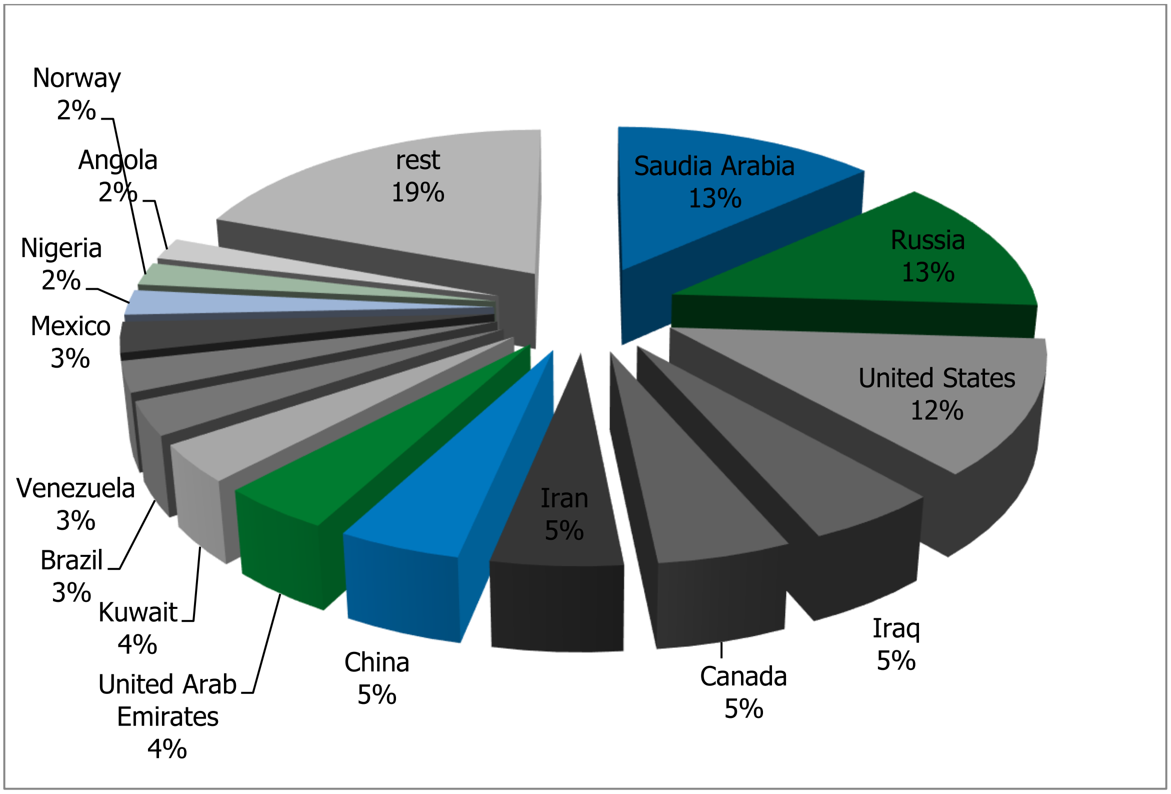

Figure 1.1: Global crude oil production of oil-producing countries (2016)

While world petroleum is continuously being demanded, transportation and production of petroleum also continually increase, becoming essential and dangerous. Thus the risk of a possible fire, explosion, and release of hazardous substances increases where it can cause serious losses in processes, long-term harmful effects on living things, occupational safety, and the environment [5]. Therefore both the environment and a lot of people can negatively be affected by petroleum production and accident than can be occurred in the petroleum industry. However, in the literature, some studies indicate that accidents in the process industry can be prevented by an effective safety management system and risk analysis [6].

When we consider accidents occurred in the petroleum industry and also continuously increasing demand for petroleum, process safety becomes very paramount. Process safety management is the management of rules and systems for identifying, understanding, and controlling process hazards that can lead to process accidents and injuries [8]. Process safety management has been created to prevent catastrophic accidents and reduce the probability and severity of accidents and the likelihood of accidents if it is applied correctly [9].

Petroleum industries consist of a large number of dangerous, flammable, and explosive materials and also complex and highly specialized processes at the same time. Therefore the consequences of an accident may also be serious. Effective risk management and process security management programs of companies are very important for managing such risks. The first and foremost step in process security management is to identify hazards as in every risk management plan. The severity or probability of accident risks cannot be reduced unless hazards are identified [10].

Approximately 30% of major accidents with high operational risk occur at oil refineries, the oil and gas industry is the second sector where the major accidents occurred [11-13]. The oil and gas industry has many risks due to its complex and dynamic structure. The risk of accidents in oil plants is very high, as large quantities of hazardous chemicals are stored in the plant, processed under very high pressure during the process and also flammable, explosive, and toxic properties of the oil. Apart from these visible hazards, it contains many invisible hazards that may affect the majority of the society like material fatigue over time, wear and corrosion on process equipment, seasonal changes, the limited emergency response time of the operator, etc.

In order to prevent and minimize losses, hazards, and possible accident risks must be identified. This study was designed to show how to determine accident risks, which is an important step in ensuring process security in the pumping station in the oil pipeline, through the application of Hazard and operability study (HAZOP) analysis.

In this study, the process safety of the pump station is described in the general framework, and the importance of the process safety in preventing accidents is emphasized. Due to the versatility of process safety and process security management systems, this study is primarily addressed in terms of determining the dangers and risks, which is an essential step in the process safety, one of the basic principles of the elements of process safety management. HAZOP analysis was preferred because of the fact that it is the most commonly used method in the complex processes and chemical industry during the determination of the accident risks [14].

1.1. Purpose of the Thesis

The short-term aim is to be an example of how to analyze possible hazards by using HAZOP at the design, installation, or operation stages of oil, gas, and petrochemical companies by identifying potential accident risks in the oil pumping station.

The aim in the medium term contributes to the establishment of process safety concepts in Turkey.

1.2. Method of Thesis

The studies in the literature related to the oil pump station were examined, and the method of determining the risks of process accidents was selected. The application was carried out in two stages in the pumping station, which is located within an oil pipeline. In the first stage, possible accident risks that could affect the process safety were identified, and in the second stage, these accident risks were graded and prioritized.

1.3. General Information

1.3.1. Proses Safety

Petroleum and petroleum-related products usage were increased in the world. Petroleum products make our lives easier, but also have direct effects on the environment and life. Due to this increasing amount of usage and its direct effects on life, it has become a necessity to carry out a preventive study in this area and to develop a number of legal regulations [15]. However, recent studies have shown that, despite all prevention studies, there has been no significant reduction in accident rates in the petroleum process industry. Current risks have increased gradually, and more and more complex risks have appeared. Due to inexperience in identifying hazards and difficulties in controlling accident risks, major industrial accidents continued [16].

Despite the worst scenarios in practice in large industries, the estimates of accidents were insufficient to reflect the facts. In spite of the developments in technology, it was stated that because of the inability to identify hazards, protection was insufficient, and improvements were made mainly after accidents [17].

There are many definitions of process safety in the literature. Process Safety is the control of incidents that causes an unplanned release of hazardous substances due to failures in processes used to convert raw materials to the finished products, according to the United States Chemical Manufacturers Association (CMA) [18].

According to the American Petroleum Institute (API), process safety is the design principle for managing the integrity of processes with dangerous operating systems, including the implementation of engineering, operation, and maintenance practices [19].

Process safety, not only during operation; it is a complete system that includes everything about the company such as; design, selection of devices, operation, maintenance, location selection of the working places, the use of the selected place in terms of safety, training of the personnel, etc. Process safety covers all the work on or in the plant and all employees from the lowest to the highest level [20].

Process safety or loss prevention studies around the world began in 1968, and in the 1970s a great deal has been achieved in this field [21]. Process safety systems aim to reduce the possibility and severity of the accident using risk assessment methods. To reach this abovementioned aim, first hazards are needed to be identified, then hazardous events, and last the risks. Once the risks are known, to reduce the risks, proper risk assessment is applied. In addtion, fire safety assessment, Procedures, management of change, and also including many process safety management elements such as cooperation with the state, employees, and the public is being conducted.

1.3.2. Process Safety Management

The consequence effects of increases in accident amount and probability made safety more important in industries. After the Flixborough disaster in 1974, where twenty-eight people died, fifty-six people were injured, and kilometers of areas were damaged, the concept of process safety management became an essential topic for industries. It is the most imported issue, especially for industries where combustible, flammable, or explosive materials are often used. Especially the oil and gas industry is one of the sectors affected by such catastrophic accidents. The term process safety management has been widely used after the Process Safety Management of Hazardous Chemicals in standard adopted in 1992, OSHA 29 CFR 1910.119 [22].

The petroleum sector can be defined as the locomotive sector because petroleum-derived products are used as raw materials in many sectors. Thus, it can be concluded that many sectors are dependent on oil. For this reason, still, at the moment, we have to continue the production of petroleum and petroleum-derived products despite the harmful effect of petroleum hazards. The complex structure of the process of petroleum production and transportation, the continuity of production, the limitation of the time required responding to the accidents and working with high pressure and temperature necessitate effective process security.

The main objective of process safety management in the oil sector is to identify hazards by a proactive approach and to prevent the spread of toxic, reactive, flammable, or explosive chemicals that may occur in the process [23].

Series of deaths, injuries, immediate and cumulative long-term harmful effects on the environment, the material loses, money loses and occurrence of prestige losses caused by petroleum and chemical industry accidents, has accelerated the process safety principles, developing safe working procedures and implementing these procedures for both the state and social partners worldwide. A number of legislative, codes of practice, procedures for eliminating or mitigating incidents have been established. Process safety management programs are often aimed to provide performance-based operation, living things, and environmental security. Mainly Center for Chemical Process Safety (CCPS), API, and CMA to provide guidance to member companies within many organizations prepared guidelines, standards, projects, and programs that include process security management [24]. Report of the Operational Resource Consultants (ORC) "Process Hazards Management of Hazards with Catastrophic Potential", International Labor Organization (ILO) "Code of Practice for

Preventing Damage of Major Accidents", National Petroleum Refinery Association (NPRA), "The Best", "International Chamber of Commerce (ICC)," Conditions for Sustainable Development" works are just some of them. Some process safety management guidelines listed in Table 1.2.

Table 1.2: Process safety management guidelines

Name	Code	Published By	Scope
Management of Process Hazards	RP 750	American Petroleum Institute (API)	Refineries, petrochemicals and main processing facilities.
Management of Hazards Associated with Location of Process Plant Permanent Buildings	RP 752	American Petroleum Institute (API)	on-site personnel located in new and existing buildings to manage risks from explosions, fires and toxic substance emissions
Management Practices, Self-Assessment Process, and Resource Materials	RP 9000		A guide to the principles and activities of individual companies aiming at improving environmental, health and safety performance.

1.3.3. Components of Process Safety Management System

The number of elements that are used for the management systems for chemical plants varies depending on the criteria used in the system. The process safety management system elements are generally designed to meet the basic needs as in other management systems [26].

In process safety management systems, a holistic risk management approach should be considered, which is evaluated in environmental factors in order to reduce the risks that tend to increase and mitigate their impacts. Process safety management is an integral part of the occupational health and safety program applied in chemical plants.

Effective process safety management provided by participating in managers, auditors, employees, subcontractors, subcontractor employees, and senior managers. But the most important point is top management should support and lead the process of safety works. Therefore at the latest version of ISO45001 Occupational Health and Safety Standard requires the leadership of management for the safety culture of the company [25].

In a process security management system, the continuity of operation, systems and organization depends on management of information (keeping and storing records well), control of process quality, possible deviations, exceptions and alternative methods, accessibility of management and audit, communication, objectives and aims, compliance audits and performance measurement [27].

Every organization developed new regulations to carry out a proper process security management system in which Occupational Health and Safety (OHS), environment, quality, and business development are considered together. The objectives of the safe management policy document should be realistic and measurable. However, in order to check the realization and availability of these targets, performance results should be regularly communicated to the top management. The fact that top management fully understand how they control a safety system contributes to the success and sustainability of the management system

Processes that identify gaps in existing systems and eliminate deficiencies are very important for determining operational risks. It is necessary to observe what is going on in the sector and in the facility, control of risks that will arise from outside the facility, to take into account the external factors and dissemination of good practices [28]. Submission of Health Safety and Environment (HSE) and process safety studies should not be from bottom to top; it has to be from top to bottom for efficient and reliable systems [29]. However, due to the fact that the safety management system (SMS) in the process industry is a dynamic structure, continuous improvement activities should be carried out through control cycles, and the system should be monitored periodically through performance indicators. Planning, organization, checking the results of the audit, and arranging and taking corrective actions constitute the elements of this control cycle. Technology, staff, energy, operation procedures, maintenance, design changes, and management of changes increases the effectiveness of safety [30].

The guidelines established by States, companies, and associations specify different components, but the most essential 14 components for a process safety management that can be used in the whole chemical industry are specified [31]. These components are sorted and summarized respectively like that.

Employee participation; this article requires employees to be involved in each Process Safety Management (PSM) program in relation to their own work area. This requires employees to be represented at each meeting where PSM-related issues will be discussed. Employee participation should be monitored in writing, and employers should formulate an official plan and share it with their employees [32-33].

Process safety information; all employees before beginning any job involving hazard risk, must be able to access and understand the technical data relating to the risks they face in work [32-33].

Process hazard analysis; this includes the need for maintenance leaders and engineers to analyze the consequences of safety failures. These analyses must be carried out in teams involving people with “knowledge of the specific process hazard methodology used.” [32-33].

Operating procedures; numerous potential chemical hazards arise after emergency shutdowns and turnarounds. Companies should have plans to keep everyone safe from the hazards that arise when restarting their systems [32-33].

Training; workers who work in facilities with hazardous chemicals must be well trained before starting work. The training should be carried out by a qualified company employee or a subcontractor [32-33].

Contractors; regular employees and contractors should be well informed about the hazards that they may or may encounter in the same way as workers. Accordıng to PSM, “The Employer shall inform contracted employers about the hazards associated with their work and process such as potential fire, explosion, and toxic release.” [32-33].

Pre-startup safety review; employers have to do this before commissioning both new and modified facilities. It must be done even if it affects only one component or process [32-33].

Mechanical integrity; periodic and documented inspections are required for various systems such as pressure vessels, storage tanks, piping systems, and ventilation systems. According to OSHA, employers or contractors carrying out these audits are not only officially trained but also test procedures needed to be included and recognized. This kind of approach is generally accepted as a good engineering practice [32-33].

Hot work permits; each employer must give special permission to workers and contractors who do or do work for jobs at high temperatures near the processes covered by it. Employers need to train their staff to follow and file these permits [32-33].

Change Management; Companies should establish standard procedures to manage the exchange and development of the chemicals, technologies, equipment, and procedures they use. Because these changes also require [32-33]:

• Technically why change is needed.

• The impact of the change on worker safety and health.

• Required changes to operating procedures.

• The time interval for change.

• Authorization requirements for the change to be made.

Incident Investigation; investigations into all incidents that may arise or may result in an extremely dangerous chemical release must be carried out. Companies should consider every possible scenario and keep in mind the countermeasures [32].

Emergency planning and response; this element obliges employers to create contingency plans for dealing with small releases. Even small chemical oscillations can cause large events.

Compliance audits; According to PSM-NEP (Process Safety Management, in particular, the National Emphasis Program), “Employers are adequately monitored and follow-up of procedures and practices developed under the standard. This element also requires employers to keep at least two latest audit reports.

Trade Secrets; until recently, some companies tried to protect private information by protecting transaction details of the process from their employees. In order to prevent this scenario and increase worker safety, “trade secrets” gives employees the right to know the processes that may affect their health and safety.

Managing all these components is very important for improving process safety. Different elements can be identified for the process safety management according to the management approach.

As a good example, CCPS, Risk-Based Process Safety (RBPS) Management approach can be used. The main structure of the RBPS approach was defined by consisting of four pillars and twenty elements [34]. This method is shown in Figure 1.2.

1.3.4. Process Safety Management Performance Indicators

Process safety studies also include performance measurement of process safety. The current situation and future situation performance have to be measured to develop and improve process safety as with all other management systems. Indicators are very important for the effectiveness and functionality of safety management systems to give accurate results [35].

Indicators such as occupational accidents, occupational diseases, near misses, injury statistics only for occupational health and safety practices are not sufficient measurement criteria for measuring process safety performance. Because the process safety principle not only protects the employees but also protects the environment, public health near the process, living things, and product loss in the process activities. For this reason, the performance indicators used in the sector also consist of safety events, safety systems, working discipline, and management of difficulties that are used to measure the performance of process safety [36].

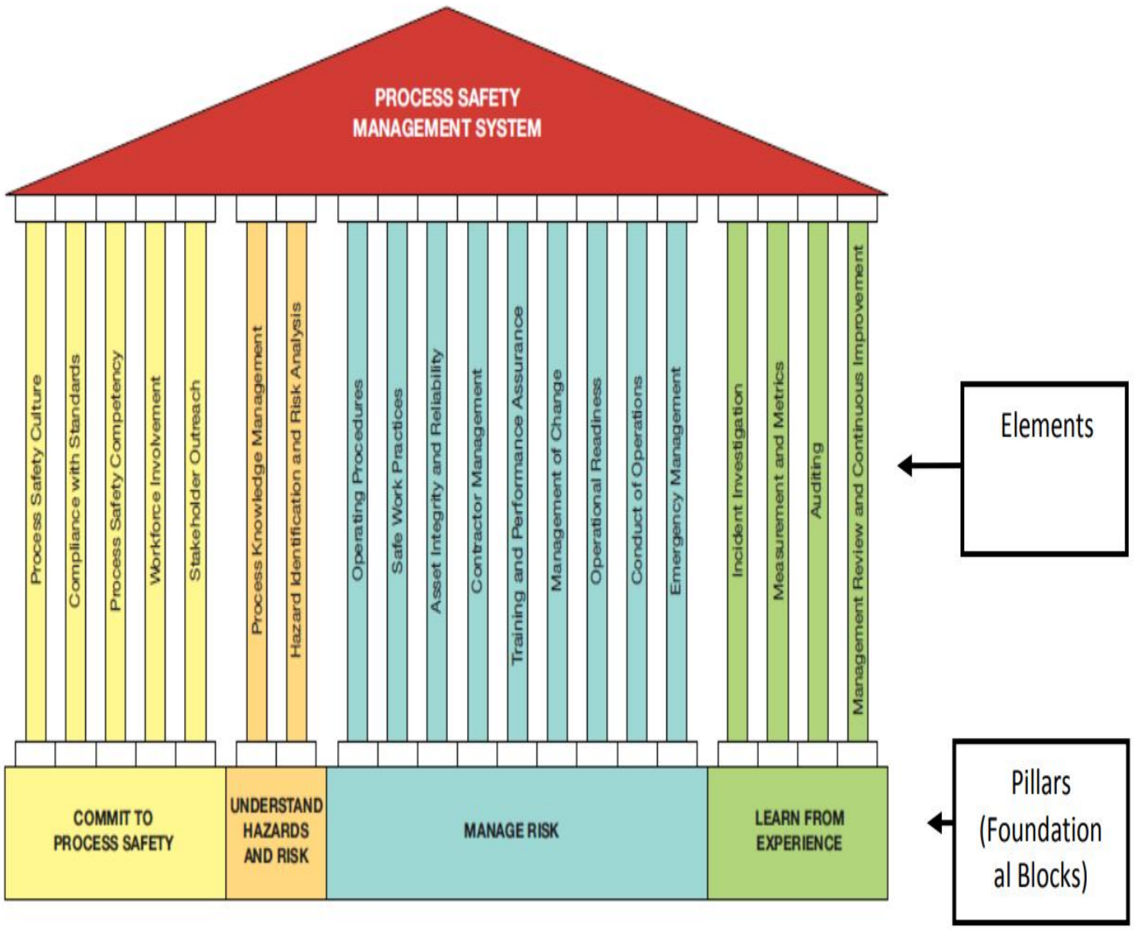

Figure 1.2: Pillars (Foundational Blocks) and related items that make up a robust RBPS Management System [10]

Safety measures such as injury frequency, accident frequency, and occupational health and safety performance indicators are not sufficient indicators for process safety performance. Process safety incidents, dangerous substances release, fire, explosion, such as causing serious consequences, living inside and outside the plant, and the environment have immediate or long-term harmful effects [37].

The reduction in mortality rates provided that the safety, personal and personal safety hazards, such as falls, electric shock, sulfur poisoning, etc. have been carried out to ensure that the health and safety activities affecting the individuals are carried out well [26]. Process safety and occupational health and safety studies should be carried out together for a safe working environment. There are many accepted and applied standards in this field in the world.

Process safety management system performance indicators are grouped under two headings as leading and lagging. The lagging indicators indicate how much deviation from the desired outputs indicates the number of events, such as the number of unexpected stops in the system. Leading indicators that show flaws and system weaknesses are measures such as maintenance activities, control elements, inspections by administrators, which cause damage and which are critical for safety [38].

Leading indicators define faults and gaps in the risk control system during routine checks. Subsequent measurements reveal faults in protective barriers after an incident or accident. The incident does not have to result in injury or environmental damage; it might be indicators of near-miss or an uncontrolled event [38].

A series of explosions occurred in the BP Texas City Refinery when reinstatement was taking place after the maintenance of the isomerization unit in 2005. According to the findings of the team investigating the incident, the use of occupational accident and injury data to measure the process safety performance of the refinery has significantly hampered the perception of process risks. After this statement was included in the report, new measures and indicators were developed for the process safety management performance with the participation of many government institutions and professional organizations as a result of the same deficiency in many enterprises [37].

The first published HSG 254 manual (Developing process safety indicators) was developed by the UK HSE and the Association of Chemical Industries (CIA), which includes the application of leading and lagging process indicators for the development of organizations for process security. The application process is listed in six steps, including team building, scope development, defining risk controls, defining controls for critical elements, collecting data, and evaluating results. Leading indicators develop according to vulnerable events such as barriers error during inspections while lagging are developed according to holes in the system after accidents or near misses [39].

In the guidelines developed by the Organization for Economic Co-operation and Development (OECD) has set an application that consists of seven steps including; team building, identifying key topics, identifying leading indicators, identifying lagging indicators, identifying risk controls, identifying controls of critical elements, collecting data and reporting results, performing activities related to findings, reviewing performance indicators. Unlike the guide of the previously published by HSE (HSG 254 manual), this guide provides guidance on performance indicator development, ranking, and prioritization [40].

Several years after the publication of these guidelines, American Institute of Chemical Engineers (AIChE) and CCPS developed three guidelines Risk Based Process Safety, Process Safety Leading and Lagging Metrics, and Guidelines for Process Safety. These guidelines are based on the classification of indicators according to the "Swiss Cheese Model" and the "Accident Pyramid". They have emphasized the importance of reporting and recording in the guidelines which are taken into consideration for the development of indicators and emphasizing that more indicators will be developed with more reporting.

The Swiss Cheese model developed by Reason in 1997 is implemented for the detection and control of major industrial accidents and the detection of hidden causes. According to Reason, major accidents are caused by several faults and holes in the system, and it is not possible to ensure safety only with safety equipment. Safety systems should be monitored and improved according to performance measurements. The holes in the model define security openings (Figure 1.3) [41].

The Process Safety Performance Indicators standard, RP 754, developed by the API, has been developed for the refinery and petrochemical industries, and the process safety performance measurement is examined in four layers. Other occupational health and safety indicators are not included in the application recommendations of this manual [42].

Some risk factors can be detected in the short term, such as failure of a pump in the plant and splitting in the pipeline; some can be detected in the medium term such as control disruptions that may vary from week to week or weather conditions, postponement of maintenance, and some of them can be detected in long terms such as change in-process material and rusting, material fatigue and failure to management of change. While risk factors in the short term can be measured by alarms and detectors, it is difficult to observe the risks in the medium and long term. However, process risk trends can be estimated with the right selected lagging indicators. Therefore, performance indicators are also effective scales in risk analysis. Since the information obtained from the indicators in the management of risks is very important, it is necessary to carefully monitor whether the indicators are selected correctly and whether loss of integrity is prevented [43].

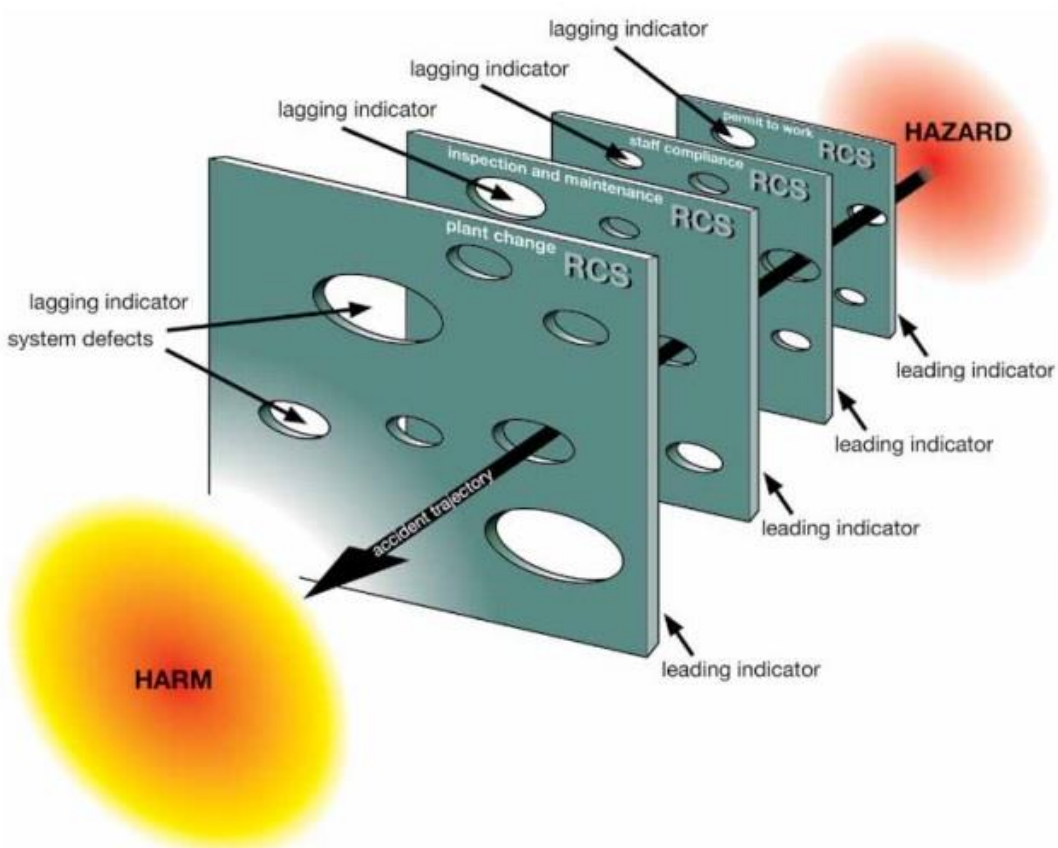

Figure 1.3: Swiss Cheese Model [41]

The Process Safety Performance Indicators standard, RP 754, developed by the API, has been developed for the refinery and petrochemical industries, and the process safety performance measurement is examined in four layers. Other occupational health and safety indicators are not included in the application recommendations of this manual [42].

Some risk factors can be detected in the short term, such as failure of a pump in the plant and splitting in the pipeline; some can be detected in the medium term such as control disruptions that may vary from week to week or weather conditions, postponement of maintenance, and some of them can be detected in long terms such as change in the process material and rusting, material fatigue and failure to management of change. While risk factors in the short term can be measured by alarms and detectors, it is difficult to observe the risks in the medium and long term. However, process risk trends can be estimated with the right selected lagging indicators. Therefore, performance indicators are also effective scales in risk analysis. Since the information obtained from the indicators in the management of risks is very important, it is necessary to carefully monitor whether the indicators are selected correctly and whether loss of integrity is prevented [43].

The development of indicators according to the organizational structure and characteristics of each facility will contribute to the development of process security. Also, the preparation of performance indicators specific to sectors is an essential step in ensuring process safety, and enterprises developing their own performance indicators will contribute to the prevention of accidents. The development and implementation of process safety performance indicators is a challenging process, as it is a new area for many businesses, but it is crucial for safety. Therefore, the studies to be developed for the development of process safety indicators should be encouraged and supported by the management. Today, many industries have developed specific performance indicators [37].

The effect of indicators is evaluated in terms of management of loss of integrity in the process industry. When the effects of the indicators on the process security are examined hierarchically, the element indicators are listed as activity, key, and special indicators at the top of the pyramid [41].

Some problems may arise during the determination of the indicators. The effect of performance indicators on the process cannot be observed day by day. Initially, most indicators require improvement of the system, and therefore, time-varying performance indicators should be observed. However, when there is no event in the enterprise, the lagging indicators tend to be zero, and the leading indicators tend to be zero when all the process safety management steps are followed. Furthermore, as the systems become more complex, the complexity of the indicators creates difficulties for data collection. To measure the performance in a facility that is running, when the results of several indicators are compared and evaluated within a certain time interval, the indicator variables will not show the actual situation and will behave in a random manner, depending on the possibility of making various mistakes and missing. All these problems can be solved at different levels and each level by conducting a separate assessment (region, facility division, mid-level management, senior management) [44].

1.3.5. Process Safety Management Improvement

In order for a process to be safe, attention must be paid to every point from the project stage to device selection, installation, operation, and maintenance. By identifying hazards and identifying accident scenarios, the most critical safety aspects can be identified. The creation of scenarios for the identification of the factors causing the error in the system also helps to evaluate the adequacy of the indicators. Risk control systems to be established for the control of the identified risks should be developed to prevent major accidents. In this way, the required safety outputs can be obtained by evaluating the effect of each control measure on the accident scenarios by ranking among the identified risks. After determining the outputs, the performance of the system is measured by leading indicators. In addition, system faults are detected by deviations from desired and expected results. For each of the critical controls, leading indicators should be selected to provide information about whether the system is being carried out as expected. However, the positioning of the premises and the location of the built-up buildings are very important for process safety. The downstream operation should be evaluated and continuously monitored using the management of change process [39].

In order to reduce the reasons that are effective in the occurrence of accidents, lessons from past disasters and the memory of the facility should be improved. The number of accidents resulting from failure to comply with them and justification should be written on each of the prepared instructions, the application code and the standard. In systems where computer-based systems are located, it is necessary to develop systems where every employee can reach information, causes and consequences related to past accidents. In addition to these, it should be given attention to the examination of the accidents that occurred in the past in the training of the employees and defining the hazard and precautions. To prevent the occurrence of accidents due to the reasons that can be repeated after years, managers need to develop the memory of the company [21].

For an effective Safety Management System, a variety of awareness-raising activities and training should be made for raising awareness of employees, ensuring information sharing, and strengthening the participation of employees. Employee engagement is a key factor in the sustainability of all management processes. A more holistic approach can be achieved by including employees in safety audits, risk assessment studies, and other work in the field of security. At the same time, it is possible to find practical solutions to the problems in the safe management systems during these works as well as improvements in the system. It is necessary for the employees to explain the root causes of accidents in a simplified way, to improve the Safety Management System, and to increase employee participation [39].

The more effective the safety management systems are applied, the more success is achieved in the prevention of accidents. Identifying the causes of accidents is very important for the prevention of accidents. Accidents do not occur as a result of a single fault, but accidents are often the result of a very complicated chain of causes.

Collecting the evaluations of all management systems on a single person, and compiling the results play a key role in detecting and eliminating the failures in the system [39]. Considering the shortcomings of the operation of process security in the form of bottom-up information flow, it will have a great effect in terms of ensuring process security from top to bottom with a structure formed within the board. As Process Security Management is in an ever-changing structure, it should be continuously and systematically monitored and improved as in other management systems. One-stop control of processes such as technology, personnel exchange, process hazards and management of change increases security effects [45].

In case of initiating events in accidents, disrupting normal working conditions, or loss of control in the process, it is necessary to have barriers that interfere with the system and to regain control or to secure the process. Interventions of barriers whose purpose is to make the system safe; stopping the pump, closing the valve, transferring the product to another tank, commissioning of the cooling system, or alarming can be composed of many different measures, etc. If there is any Safety Instrumented System (SIS) and Safety Integrated Level (SIL), which are covering all these equipment and control mechanisms that make the system safe, they may change as a result of the risk assessment performed at the facility. If there no applied SIS, then it can be recommended.

For process safety, the process should be evaluated to include the least risk, and the safety integrity level requirement should be determined by applying risk analyzes to all units. As a result of the risk analysis, the risk should be reduced to an acceptable level with the use of SIS. Inactivity of a screw during maintenance, operations such as the addition of an additional pump, or equipment that is not tested will result in loss of protection functions and SIL levels after a while [23].

If there are no incidents causing damage in a facility with a potential for major accidents, it does not mean that there will be no accidents. It is also necessary to take into consideration the frequent occurrences of near misses. Over the years, the decrease in the incidence of recorded near misses, accidents, and outcome indicators in the sector indicates that risk management has been improved. However, in a facility with a potential for major accidents, it does not mean that these incidents do not occur if incidents that cause damage do not occur, and frequent occurrences of occurrences should be taken into account [46].

It is observed that an audit is also a critical prevention activity. With the internal audits to be made, the enterprises can evaluate the functionality and deficiencies of the safe management systems as well as the deficiencies in the implementation of all the documents and systems designed to prevent accident risks, and thus contribute to the sustainability and contribute to policy development [38].

The audits are carried out in two ways: internal and external audits. The objective of the audit is to understand whether the company is managed in accordance with process safety needs, objectives, and safety management policy with objective observations. Internal audits are carried out by the employees and managers of the company, while external audits are conducted by third parties and provide an unbiased perspective. In such audits, the interests of other stakeholders are evaluated as well as the interests of management. Audit results; provide information on company policies, compliance with national and international legislation, and effectiveness of the safety management system. Besides, action plans related to the results obtained can be created and improvements can be made. These audits should be performed by auditors who have knowledge and experience related to the technical issues specific to the sector and workplace where the auditing methods, safety management systems, and regulations are performed [39].

Process monitoring and frequency of observations may vary depending on the needs of the company. Many organizations often rely on routine work and systems. However, it should be noted that the current indicators may not be sufficient to measure the rapid changes in the plant, so the selection of indicators is crucial in ensuring the process safety. Deviations and acceptability levels should be determined when selecting indicators. Indicators, according to acceptable levels and deviations, should be continuously monitored and updated where necessary. The performance of the safety management system is evaluated by the results and the data obtained. Performance indicators are not alternative to audits, but rather as processes of performance measurement that provide more frequent or different information. For this reason, audits and field observations should be continued as they are determined. [39].

The implementation of incentive policies by the state or related social partners, as well as the promotion and rewarding of good practices, will also make a significant contribution to the prevention of accidents and the development of safe management systems [47]. For example, in the UK, every year the Chemical Industry Awards organizes and awards good practices in the field of the chemical industry in June [39]. American Fuel and Petrochemical Manufacturers (AFPM), which have many members outside the United States, give awards to member companies in order to promote safe work for companies with the lowest number of accidents per year and accident rates in different categories.

1.3.6. Identifying Process Hazards

Process safety is a dynamic structure, so the risk analysis methods. There are many fluctuations in risks where the measurements can be complicated. As mentioned many times, risk assessment studies have great importance to ensure safety in the process industry and to prevent major accidents. These studies are essential elements of process safety management. At the first stage, it is necessary to determine the possible risks in the effective implementation of the safe management system that industrial plants need to implement. All systems should be considered as a whole; whether or not they cause a major accident in the facility, including the design of the process, selection of materials, operation and maintenance practices, procedures, employee training, emergency plans, and changes in the material and process to identify other elements affecting the process, all hazards must be systematically identified and evaluated [48].

The data of 23030 accidents that occurred between 1998 and 2009 in the Netherlands were examined using the safety management model, and fatal and non-fatal accidents were compared by developing hazard-specific accident triangles. In the study, the common points between the less severe but more frequent accidents and the more serious but rare accidents and the fatal and non-fatal accidents were examined. The only common point was the similarity of the dangers [49]. Therefore, it is very important to identify hazards.

Since people are afraid of the concept of risk rather than the concept of danger, legal regulations, standards, and methods have always aim to reduce the risk. The risk is usually reduced by reducing the probability; however, risks can be reduced by making the actual situation less dangerous, so the first and foremost step is to identify hazards [50]. In the oil and gas industry, relatively lighter events occur more frequently in terms of their consequences than heavy losses due to the flammable and hazardous substances used and produced. In risk assessment studies, organizations need to reduce not only the risks of accidents with high probability and low levels of effective results but also the potential for accident risks with low probability and highly effective results in terms of their impact. Thus, companies will need to demonstrate that the safety management system policies are valid and applicable [51]. In Turkey, in Article 25 of Law No. 6331 mentioned that if risk assessment could not be done in the workplaces having the possibility of a huge industrial accident, jobs have to be stopped [52].

Due to hydrocarbons and sulfur content, oil has many risks. However, oil enterprises should continue to work due to energy needs. Therefore, an effective risk analysis is essential for effective process safety management.

Analysis of risks is quite difficult in the oil and gas industries due to reasons such as mixed units, large amounts of hazardous materials, working at high temperatures and pressures, uninterrupted processes, not having enough time to correct errors, too many uncertain situations, insufficient estimation of worst scenarios, and human error. In addition, there are many factors that need to be evaluated from the geographical location of the facilities, the distance between the place where the substances are transported and the places where they are stored, the storage of dangerous substances, the domino effect that will enable the growth of a possible accident due to the other facilities and the settlements. In order to prevent possible losses caused by these risks and to preserve the living conditions, the processes must be managed in a safe manner [53].

A Safety Instrumented System (SIS) consists of an engineered set of hardware and software controls that are especially used on critical process systems. A critical process system can be identified as one which, once running and an operational problem occurs, may need to be put into a "Safe State" to avoid adverse Health Safety and Environmental (HSE) consequences.

2. METHODS

In this section, information on the facility and chosen risk analysis method is introduced. Also, detailed information on the process is given along with the description of the piping and instrument diagrams (P&ID) of the facility

2.1. Purpose of Research

This study was designed as a descriptive, cross-sectional study to determine the risks of accidents at an oil pumping station and to contribute to the process safety in the plant and how to apply semi-quantitative HAZOP analysis.

2.2. Assumptions of the Study

1. It is assumed that the facility applies maintenance activities throughout its lifetime.
2. Design errors were neglected in the analysis, and it was accepted that the plant was operated in accordance with the design. The durability control of the vessels and operation materials required by the standards are excluded because these are just used in during the design phase.
3. It has been accepted that the effectiveness of protective systems and barriers is regularly checked.

2.3. Limitations of Thesis

1. The research is limited to the oil pumping station where the study is carried out.
2. The research is limited by the results for the method to be applied.
3. The research is limited to the experience of the risk assessment team and their opinions at the time of the study.

2.4. Materiel

2.4.1. Activities in the Facility

The main function of the oil pumping station where the research is conducted is to transport the oil from one point to another. The other oil pumping stations are all similar facilities and have similar activities. Thus, only one facility located at Sivas has been chosen to apply HAZOP. In order to perform this transportation purpose, many systems have been installed in the facility. The main task of the transfer of oil is carried out with the help of oil pumps. In addition to pumps, some systems involve the safe transfer of oil within the plant and other auxiliary systems. In this thesis, only oil containing systems used for the transfer of oil is examined.

2.4.2. Pumping Station Main and Auxiliary Units

1. Main oil line (MOL) pumps
2. Main oil line (MOL) filters
3. Inlet surge relief valves
4. Outlet surge relief valves
5. Inlet and Outlet Emergency Shutdown (ESD) valves
6. Gas ESD valve
7. receiver
8. launcher
9. Relief tanks
10. Reinjection pumps
11. Slop tank and pump
12. Diesel storage tank
13. Oil storage tank

14. Firewater tank

15. Firewater line

16. Fire foam line

17. Fire pumps

18. Foam tanks

19. Heating, Ventilation And Air Conditioning (HVAC) systems

20. Heating systems

21. Water treatment systems

22. Oily water system

23. Wastewater system

24. Stormwater system

25. Air compressors and lines

2.4.3. Pumping Station Main Oil Units Proses Descriptions

The pumps used in pumping stations are turned by high-powered motors. Due to the fact that the pumps are transferring large amounts of oil, they do not have the capacity to pump the oil from the 0 pressure. Pumps designed for different pressure ranges are used according to the location and task of the pump station. If the pumping station is the first station of the oil pipeline, there are buster pump systems in addition to the above-mentioned systems to generate pressure in the suction line of the main oil pumps. Since the pumping station, we will examine in our thesis is a station located on the oil pipeline, this system does not exist and the inlet pressure required by the pumps is provided by the previous station.

There are two different types of pumping stations on oil pipelines depending on the duty of use. These are to adjust the flow rate of the transported oil and to determine the energy required for the transported oil to reach the next location. The first type pumping stations perform both tasks while the second type pumping stations transfer only the pumped quantity from the previous station. There are exactly the same systems in both pump stations. The only difference is the size and arrangement of the pumps used.

Petrol enters the oil pumping station from the oil pipeline, and it first comes to the pig receiving system. From there, it passes the main pump filters and reaches the pumps. The petroleum, which is energized by the pumps, passes the pig launching section and enters the pipeline back to its next location as shown in Figure 2.1. This is the simplest description of the movement of oil in the pumping station. Of course, this is not an easy process as described here in a short way. There are many separate systems and auxiliary systems where the oil is located. The most important of these is the relief system and the slip system. Furthermore, the wax handling system used for cleaning wax, which can be called as solid oil, is one of the challenging processes.

Fuel systems that feed engines used for the operation of oil pumps, cooling water systems and lubrication systems of these engines, lubrication systems of oil pumps, ventilation systems, air systems used for the operation of many types of equipment, oily waste systems, firewater and foam systems are also been operated at the same time.

Continue the introduction of systems based on the direction of the progress of crude oil. As has been mentioned that the oil entered the station from the first pig receiving area. The task of the pig receiving unit is to remove the equipment used for cleaning the inside of the pipeline and the resulting waste from the pipeline. Actually, pig means that pipeline inspection gauge (PIG), but the PIG abbreviation became one specific word as a pig in the oil and gas industry.

As can be seen in the Figure 2.1, the oil passes through the ESD valve before reaching the pig receiving section. The ESD valve works to isolate the station in an emergency and to prevent the ingress of oil to the station. In case of the emergency and the closing of the ESD valve, a high amount of surge occurs in the pipeline. Surge can be defined as abrupt pressure increase due to rapid change in flow rate in pipeline. Surge relief valves (SV) are also included in this system to get this surge formed. SV's are transferred to surge occurred in the pipeline to the relief tanks, in order to prevent damage in the pipeline due to high pressure.

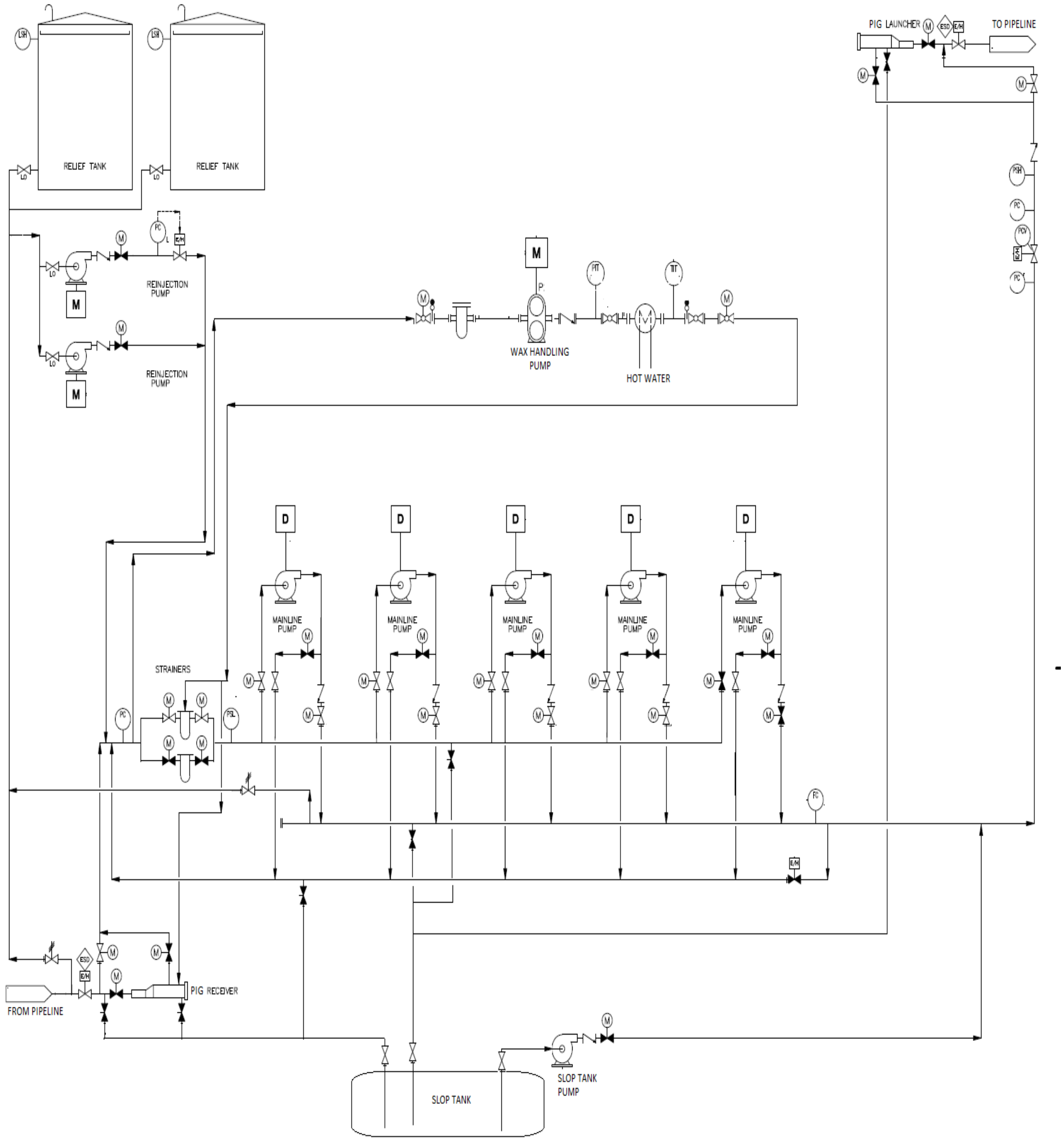

Figure 2.1: Oil Pump Station's main oil transfer system.

The oil passing through the ESD valve can enter the station directly from the pig bypass line or through the pig receiver apparatus. If there is no equipment used for line cleaning in the pipeline, the pig receiving device is isolated, and oil continues from the bypass line. But any cleaning equipment travels in the pipeline, the inlet valve of the pig receiver is fully opened, the pig kicker valves are opened and the bypass valve of the receiver is slightly closed. The bypass valve is not closed entirely due to the possible high amount of wax coming.

After the pig receiving area before the oil reaches the pumps, it passes through the filters to separate the substances likely to damage the pumps. There are two filters 501 and with the power to filter the entire pipeline capacity individually. The reason for having two filter devices is to prevent the flow of oil from the pipeline during maintenance or any blockage. Most probably, it is believed that a previous HAZOP study has taken place during the design step before the facility construction. Thus, to prevent any blockage in the pipeline, two filters were recommended. One can easily see via inspecting the P&ID that the action was completed. During this description process of the facility, it can be easily seen that many corrective actions to minimize the risk of undesired events were implemented.

After passing the filters, the crude oil reaches the pumps to get the energy it needs to flow through in the pipeline (Type of energy changes according to location of pump station, it will be a pressure or speed). In general, there is one spare pump at each station. The station understudy for this thesis can operate with four pumps, and it is sufficient enough to run with full capacity. However, as a proactive approach, one more pump is implemented. Thus, there are five pumps available. This additional pump is always ready for maintenance and unexpected failure, so that flow is not interrupted and reduce financial risk.

Since the mainline pumps take a certain time to stop and start, and there is a high risk of the possibility of potential damage, the pumps are not stopped during short-term pipeline stops. Thus, to prevent accumulation during short-term pipeline stops, the pump is then turned in the petrol station with bypass lines by controlling the flow control valve.

There are also relief valves on the pump outlet lines against any high pressure that may arise from the operation of the pumps. There are Two relief valves system at the inlet and the pump outlet where their design purpose is to direct the oil to the same relief tanks. Once more, other safety steps actions can be seen where even though one tank is sufficient, there are two tanks, and two discharge pumps were implemented. It should be emphasized here that mostly the risks minimization of unwanted situations during maintenance and repair steps were considered in the previous HAZOP study.

The ultrasonic flow meter is used to check if the oil is passing safely through the relief valves. If the pumps pump any excess amount of oil, then the oil is returned to the inlet op by using the pump station flow control valve. After then the oil reaches the outlet ESD valve through the pig launcher bypass. If there is a pig laughing programmed, the oil is directed to the pig launcher and continues through the pipeline over the launcher.

In addition to these systems that provide the movement of oil at the pump station, there are two other systems, slop and wax handling systems. The slop system is used during maintenance or inspection in the station. In addition, the oil is discharged to the slop tank in any abnormal condition. The slop system is, therefore, an indispensable part of an oil pumping station. But slop tank is one of the rare equipment that does not have a spare at the station.

The wax handling system is not available at every pumping station but only at stations where oil is transferred in cold areas. The aim is to recover the wax formed in the oil pipeline at the station. The wax received at the pig receiver is melted with heated oil and transferred back to the pipeline. In addition, the wax held in the inlet filters is cleaned by the same method.

2.4.4. Risk Ranking

To define the level of risk, a mechanism that considers the facility properties should be developed. For this, the category of probability or likelihood against the category of consequence severity should be defined by the risk assessment team. It is known that almost every project is associated with some level of risk, whether financial, cultural, or physical. Thus, in this study, the format determined by the entity is used. The table format for risk ranking is used, as can be seen in Table 2.1, which provides easiness to generate HAZOP tables. The results show the effects of risks on human, asset, environment, and company reputation. In the risk hierarchy table, the probability of the risks is expressed as A, B, C, D, E, F, G, H and their severity is expressed as numbers from 1 to 8. The probability increases from A to H, while violence increases from 1 to 8. (Table 2.1)

Risks are evaluated in four different categories in the risk hierarchy matrix. These values in the result category section are stated as health and safety, environment, reputation, financial. In the categories in which the accidents occurring in the sector and the world are evaluated, the severity value is graded between 1 and 8, and the meaning of the effects corresponding to the figures is indicated and the results of possible risks are defined. The generated tables are presented in Table 2.1.

After preparing the risk rating table and impact tables, the activities and processes performed in the pump station were examined with the experts in the risk assessment team. The accidents that are known in the world, the hazards that may occur by examining the near-record of the enterprise and the damages to be caused by these hazards have been processed in accordance with the risk matrix.

The risks identified as a result of the HAZOP study were graded and prioritized at three different levels (low, medium, high). The severity and impacts on human, environment, asset, and reputation are presented in the risk rating table together with the severity and probability. Thus, semi-quantitative HAZOP analysis was carried out by evaluating the risks obtained from HAZOP analysis according to the rating given in Table 2.1.

Table 2.1: Risk Ranking Table

					A similar event has not yet occurred in our industry and would only be a remote possibility	A similar event has not yet occurred in our industry	A similar event has occurred somewhere in our industry	A similar event has occurred somewhere within the BP Group	A similar event has occurred or is likely to occur within the lifetime of 10 similar facilities	Likely to occur once or twice in the facility lifetime	The event likely to occur several times in the facility lifetime	Common occurrence (at least annually) at the facility
					($<10^{-6}$ / yr)	(10^{-6} to 10^{-5} / yr)	(10^{-5} to 10^{-4} / yr)	(10^{-4} to 10^{-3} / yr)	(10^{-3} to 10^{-2} / yr)	(10^{-2} to 10^{-1} / yr)	(10^{-1} to 1 / yr)	> 1 / yr
Health and Safety	**Environmental Impact**	**Financial Loss**	**Reputation**	**Severity Level**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Catastrophic health/ safety (**25 or more fatalities** within or outside a facility)	Impact extensive damage to a non-sensitive environment and restored in a period of more than 5 years. Impact extensive damage to a sensitive environment and restored in a period of more than 1 year.	**> $500 Million**	**International long term negative coverage**	**A**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Catastrophic health/ safety (**10 or more fatalities)**	Impact extensive damage to a non-sensitive environment and restored in a period of around 1 – 5 years. Impact extensive damage to a sensitive environment and restored in a period of around 1 year.	**$100 Million to $500 Million**	**International long term coverage**	**B**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Very major health/safety (**2 or more fatalities** or **15 or more injuries** or health effects)	Impact extensive damage to a non-sensitive environment and restored in a period of around 1 year. Impact extensive damage to a sensitive environment and restored in a period of months.	**$25 Million to $100 Million**	**International short term coverage**	**C**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Major health/ safety (**1 fatality or 8 injuries**/health effects**)**	Impact localized damage to a non-sensitive environment and restored in a period of around 1 year. Impact localized damage to a sensitive environment and restored in a period of months.	**$10 Million to $25 Million**	**National long term negative coverage**	**D**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**

High impact health/safety (**Permanent partial disability**(health effects)	Impact localized damage to a sensitive environment and restored in a period of weeks.	**$1 Million to $10 Million**	**National long term coverage**	**E**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Medium impact health/ safety(**multiple recordable injuries**/health effects)	Impact on a non-sensitive environment and restored in a period of months. Impact to a sensitive environment and restored in a period of days.	**$100,000to $1 Million**	**National short term coverage**	**F**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
impact health/safety (**Single recordable injury** or health effects)	Impact to a non-sensitive environment and restored in a period of weeks.	**$10,000 to $100,000**	**Local media coverage**	**G**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Low impact on health/safety (Basic First aid)	Impact to a non-sensitive environment and restored in a period of days.	**< $10,000**	**No media**	**H**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**

Risk Category	**Identification**
RED	High Risk
YELLOW	Medium Risk
GREEN	Low Risk

2.4.5. Hazard and Operability Study - HAZOP

In the chemical industry, many methods, such as Failure mode and effects analysis (FMEA), what if, fault tree analysis (FTA), are used to identify hazards and take control measures to prevent major accidents. Hazard and operability study (HAZOP) method has been developed for the determination of hazardous substances in chemical industries. HAZOP is a method that gives good results, especially in complex structures in the chemical industry [54]. Its use in the chemical industry for many years has made it a standard method [55].

In the literature, there are many studies and guidelines on how to apply HAZOP in chemical plants [21]. HAZOP analysis is conducted under the leadership of a team leader by gathering experienced people with expertise in various fields. They are analyses to identify the hazards and operability problems that may occur during the design and operation of the facility. And also they detects and evaluates the deviations from the design purpose that may be detrimental to the results and the causes of these deviations [56]. HAZOP analysis can be used during the planning phase, before installation and during operation.

Since all details are studied in the HAZOP study, the process is not considered as a whole, critical equipment and lines in the process are identified and divided into smaller parts. Each selected piece is called a node. The selection of the nodes varies from system to system (56).

After the selection of the node, using the appropriate guide words for the process, systematic analysis of the system's response to the situation in case of deviation from the design purpose is examined [56]. The most prominent feature of HAZOP compared to other methods is the use of guide words. The guideline words and their meanings are presented in Table 2.2.

Table 2.2: HAZOP Guide Words and Meanings

Guide Word	Meaning
No	The negation of the Design Intent
Less	Quantitative Decrease

More	Quantitative Increase
Part of	Qualitative Decrease
As Well As	Qualitative Increase
Reverse	Logical Opposite of the Intent
Other Than	Complete Substitution

HAZOP analysis is an easily learned method. Also, it has many advantages such as; provides detailed examination, approaches to the whole process from a broad perspective, provides systematic assessment of the equipment that will be exposed to various dangerous scenarios, contributes to the detection of new dangerous situations, provides solutions and interventions related to risks, provides systematic documentation, experienced, gaining new experiences related to the process, increasing the efficiency of the equipment. Of course, there are also disadvantages of this technique; requires a lot of documents, time and effort, focuses on a single event rather than a combination of possible events, ignoring the dangers other than these words because of the limited words, relying solely on the competence of the experts involved in the team, and being limited to the experience and objectives of the team performing the analysis (50).

3. Results

The main operations carried out at the pumping station were examined in detail. Detailed Hazop study has conducted for each operation. In the Hazop study, the operation procedures of the facility were also examined and each step was examined separately. The results obtained are recorded in the table in Appendix 2.

3.1. Summary of Research

This study covers the accident risks and proposed measures obtained by HAZOP analysis performed in the petroleum pump station. The study was conducted in October 2018 and includes the findings of HAZOP analysis as mentioned in the Method section.

In this comprehensive analysis where HAZOP was chosen as the risk evaluation technique, 134 possible deviations from the design and operation objective were determined. After very detailed examinations of those deviations, 319 causes, and 770 possible consequences have been identified. These assessments values are given in Table 3.1. The deviations identified, their causes, consequences, existing preservatives and recommendations are also recorded in appropriate places in the HAZOP forms are provided in Appendix 2.

HAZOP evaluation forms summarize possible deviations, causes, results, risk rankings, existing safeguards and recommendations according to selected nodes.

3.1.1. Identification of Nodes

In addition to the basic units required at the oil pumping stations, they may include additional units due to the necessities of their location and state laws. For example, in very cold locations a complex heating system is required. There are even stations with power plants for areas where energy cut-offs are seen a lot.

In this study, we determined the units that each oil pumping station should have as a node. The equipment in these units is examined as a whole within the same nodes (Table 3.2).

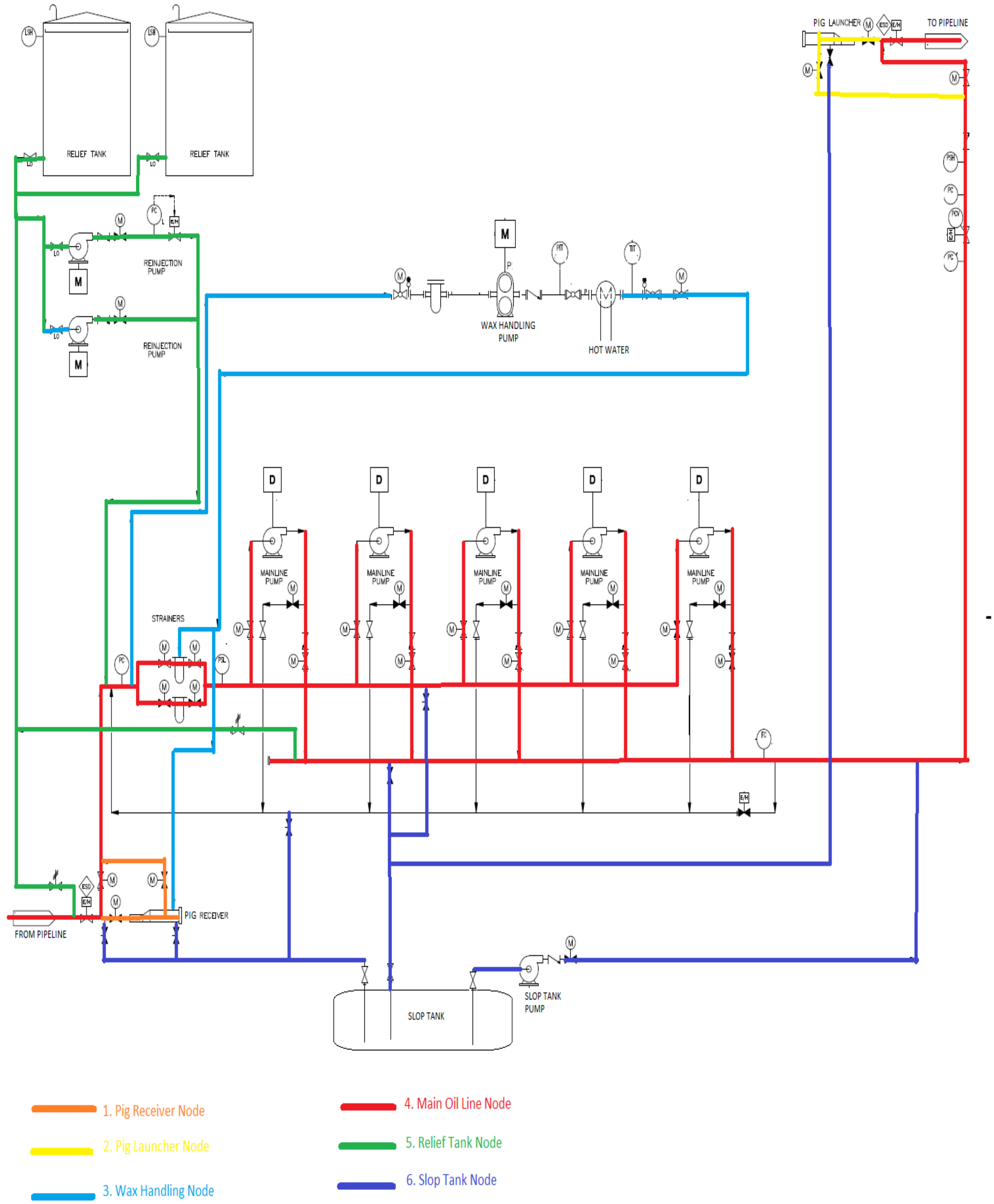

Figure 3.1: Nodes on the Diagrams

3.1.2. Deviations of Nodes

For HAZOP analysis, some catalog primary and secondary keywords are selected and used in order to find all the possible deviations. In our study, the operating procedures that are appropriate for the identified nodes are examined item by item. Any failure or incorrect operation that may occur in each item has been evaluated and listed. These listed deviations are separated according to the catalog terms and recorded in our report. We used appropriate deviation terms in the relevant sections of our study. Some deviation terms are used in the same steps. This is because we evaluate each step separately, and the difference is that the deviation terms for these steps cause the same results. Parameter, deviation and possible causes listed in Appendix B.

Table 3.1: Numerical values of HAZOP Study Results

	Node	Deviation	Causes	Consequences	Safeguards	Recommendations
1	Pig Receiving	37	90	183	117	22
2	Pig Launching	21	46	111	78	17
3	Wax Handling System	19	41	109	107	11
4	Main Oil Line	17	43	245	193	14
5	Relief System	19	46	116	190	15
6	Slop System	21	53	122	298	5
	TOTAL	134	319	892	983	84

Table 3.2: Nodes and equipment are in each unit.

	Node	Equipment's
1	Pig Receiving	trap, trap door, valves (MOV, PSV and HV) pressure transmits, signaler , nozzles, Temperature transmitters
2	Pig Launching	trap, trap door, valves (MOV, PSV and HV) pressure transmits, signaler , nozzles, Temperature transmitters
3	Wax Handling System	Pump, Filter, Heat Exchangers, valves (MOV, PSV and HV) pressure transmits, Temperature transmitters
4	Main Oil Line	Pumps, Filter, Flow Meter, Control Valves (PCV and FCV), Valves (MOV, PSV and HV) Pressure transmits, Temperature transmitters
5	Relief System	Pumps, Filter, Surge Valves, Control Valves (PCV and FCV), Valves (MOV, PSV and HV) Pressure transmits, Temperature transmitters, Level Switches, Level Transmitters, Flow Switch,
6	Slop System	Pump, Filter, Valves (MOV, PSV and HV) Pressure transmits, Temperature transmitters, Level Switches, Level Transmitters, Flow Switch, Frame arrester,

3.1.3. Deviations Causes

In our HAZOP analysis, the causes of deviation determined in each node were evaluated individually. As a result of the evaluations, many different reasons are listed for some deviations. For some deviations, all of these reasons are listed but for some deviations, most effective ones are selected. This is because some of the factors have a negligible effect on risk ratings. In some deviations, no significant cause could be identified, or this deviation was the result of another deviation that we had previously evaluated. For such deviations, "No significant causes identified" term is used.

We collected the causes of deviation under 11 main headings. When the determined causes of deviation are examined, it is seen that the reason of the deviation is the equipment failure with a rate of 46.49% and the wrong operation followed by a rate of 20.66. (Table 3.3)

Table 3.3: Deviations numerical values

	Main Causes of Deviations	**Number**	**Percentage**
1	Omitted Operation	32	11.81
2	External or Internal Fire	11	4.06
3	Inadequate Maintenance	3	1.11
4	Operational Failure	5	1.85
5	Out Of Range	11	4.06
6	Wrong Equipment	7	2.58
7	Wrong Operation	56	20.66
8	Wrong Placed Equipment	6	2.21
9	Equipment Failure	126	46.49
10	Safety System Faılure	9	3.32
11	Simops	5	1.85

In addition to that, omitted operation ranks third with 32 causes, followed by the external and internal fire with 11 causes.

When we go down to the detail of the equipment failure, which highest number of causes of deviation determined, it is observed that the valve error is the most. 62 valve failure is determined as the cause. 26 of these valve failures were caused by mechanical reasons, 14 were caused by mechanical or human error, 10 were caused by mechanical, electrical or human error, 6 were caused by a blockage, 4 were caused by direct human error, 1 by electrical and corrosion errors.

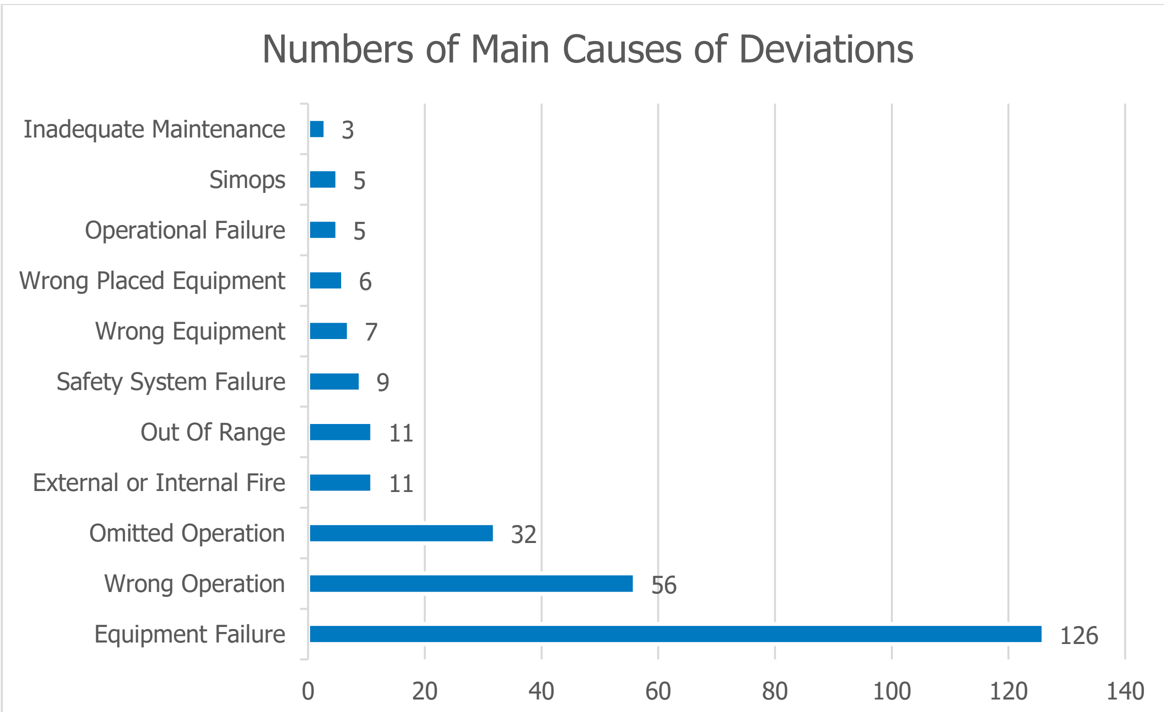

Figure 3.2: Deviations numerical values graphic

Valve failure is followed by pipe failure with 19 numbers, 15 of which are due to corrosion and 4 are a blockage. The third reason is the transmitter failure with 13 numbers. And they are followed by pump malfunctions with 13 numbers, 5 numbers for tank corrosion, filter blockage, vent blockage and utility equipment failure with 3 numbers, 2 nozzle blockage and seal failure.

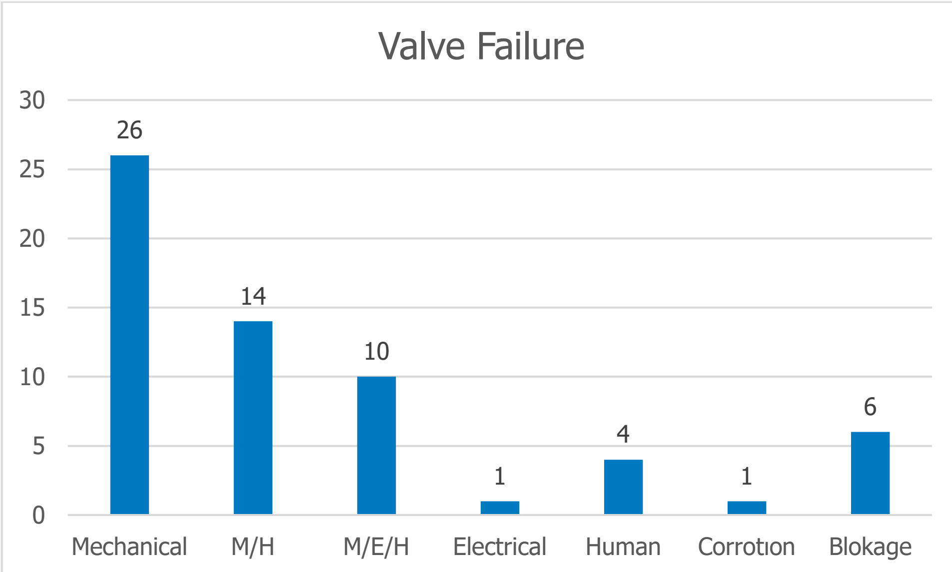

Figure 3.3: Valve Failure Graphic

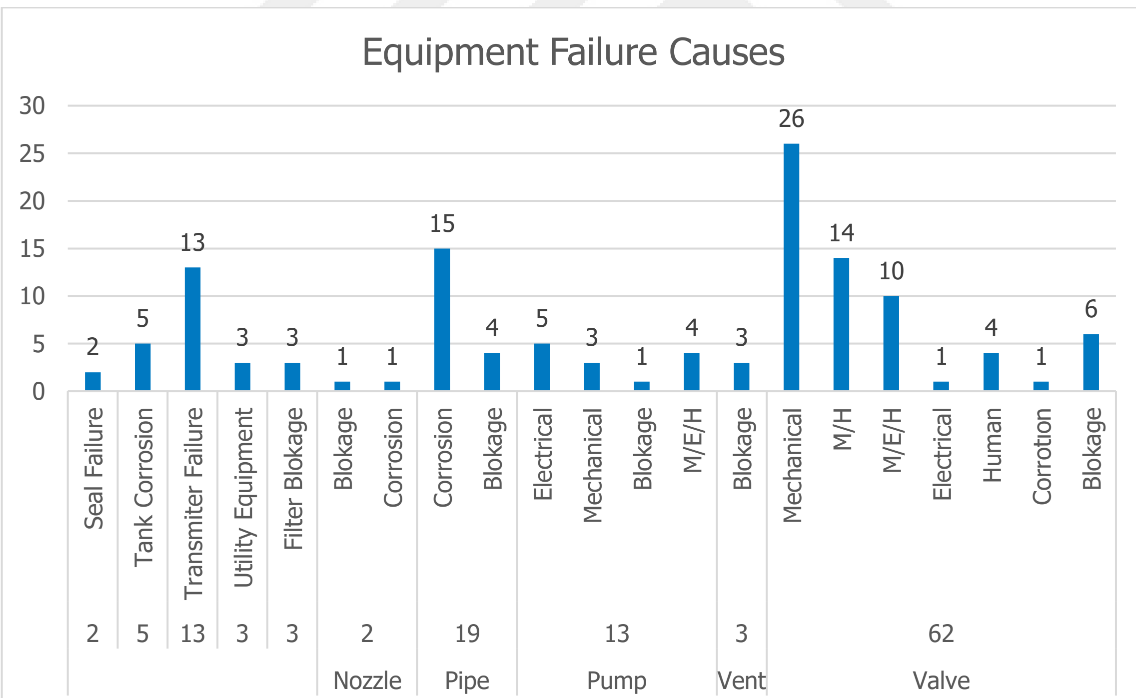

Figure 3.4: Equipment failure causes Graphic

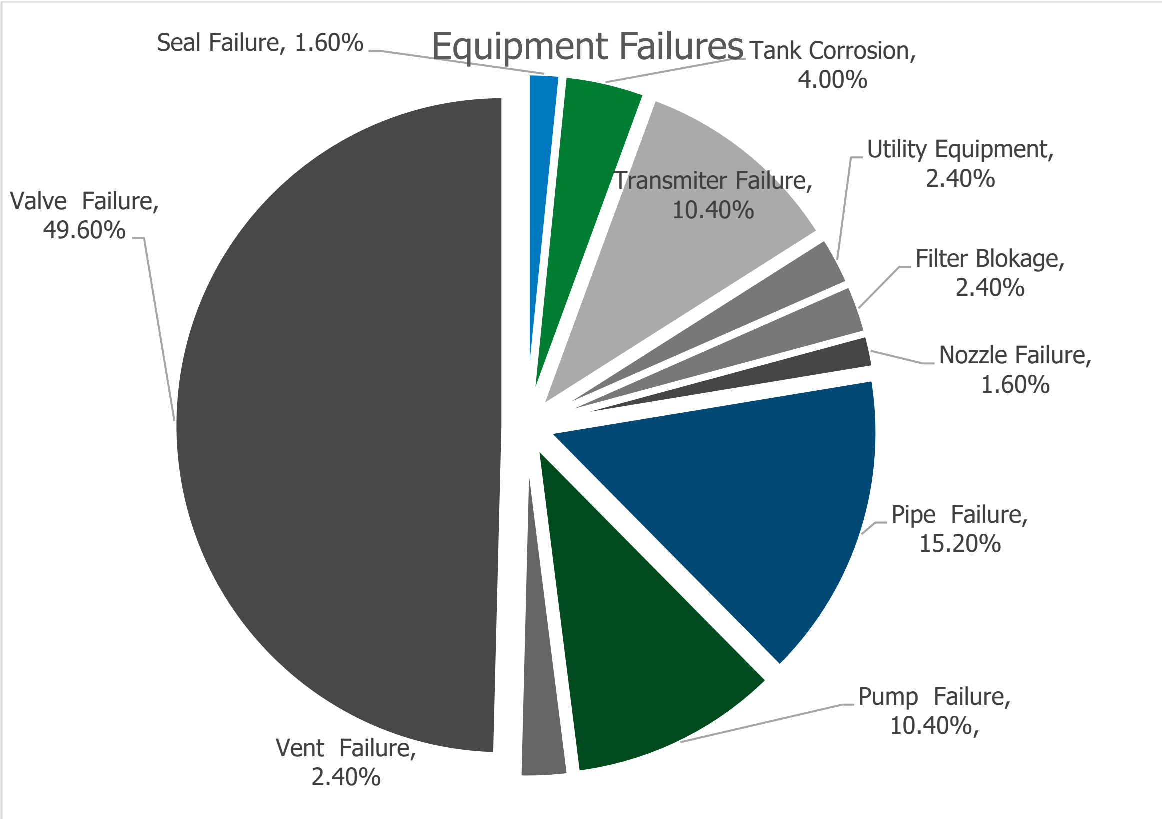

Figure 3.5: Equipment Failure Graphic

3.1.4. Risk Rankings

Once the results of the deviations were identified, the possible effects of these results on each of the four different risk categories (Health and Safety, Environment Impact, Financial Loss, Reputation) were evaluated. In the risk ranking stage, the worst scenarios were evaluated and the policy of staying on the safe side was studied. On the other hand, in the light of the literature, frequency and severity values have been assigned to the statistics of the sector and the world, accident and near-miss records and field observations. Thus, HAZOP analysis was performed. The obtained results are evaluated according to the risk rating table presented in Table and risk levels (low, medium, high) are determined in terms of their effects on financial loss, environment impact, health and safety and reputation.

As a result of the analysis 248 deviations obtained, the damage to be caused by 197 was in the low risk group and the damage to 51 was in the medium risk group. No accident risk was identified in the high-risk group. It is proposed to increase the measures in these sections according to the degree of risk during the analysis.

Table 3.4: Risk ranking analysis level results

	Risk Level	Number	Percentage
1	Low	197	79.44
2	Medium	51	20.56
3	High	0	0
	Total	248	

Of the identified risks, 89 were financial loss, 65 were the environmental impact, 9 were in reputation and 85 were in health and safety. It was determined that accident risks would cause the most financial loss and then affect health and safety.

Table 3.5: Risk ranking analysis effected area results

	Risk Level	Number	Percentage
1	Health and Safety	85	34.27
2	Environment Impact	65	26.21
3	Financial Loss	89	35.89
4	Reputation	9	3.63

As a result of the risk analysis, it was found that 13 of 85 (33.27%) risks affecting health and safety were in the middle risk group and 72 of them were in the low risk group. 65 (26.21%) of the risks determined in terms of their effects on the environment; 5 of them are in the middle risk group and 60 of them are in the low risk group. 89 (35.89%) of the risks determined in terms of financial loss effects are; 29 were in the middle risk group and 60 were in the low risk group. The 9 risks (3.63%) determined in terms of reputation effects are; 4 were in the middle risk group and 5 were in the low risk group. The graph of the relevant distribution is shown in Figure 3.5.

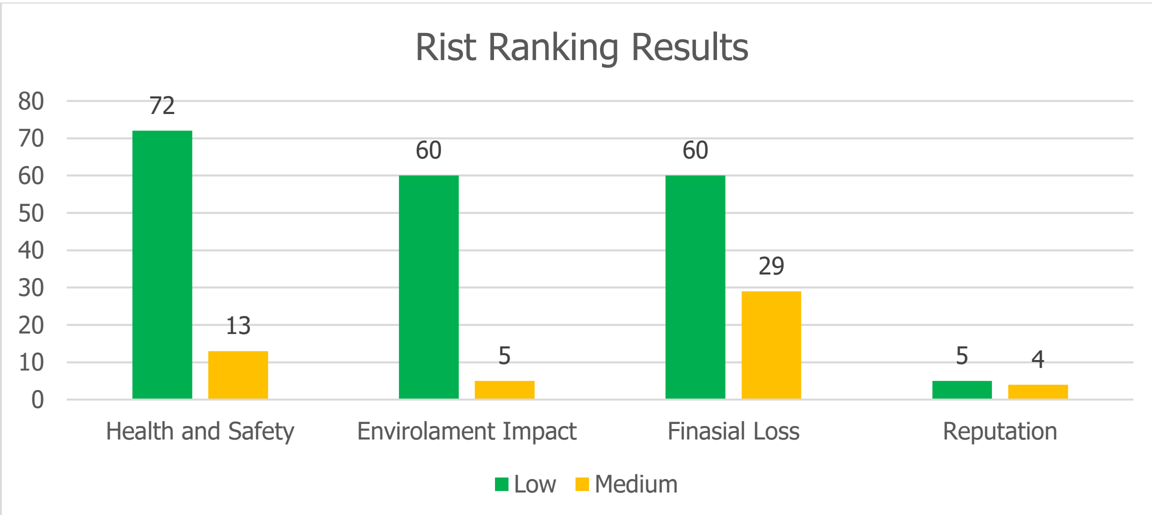

Figure 3.6: Risk ranking results Graphic

When we look at the risk ranking for the nodes, we see that the maximum risk is at the Slop Tank node with 51 risk rankings, then at the Relief Tank node with 50 risks and then the Main Oil Line (46), Pig Receiver (42), Wax Handling (31) and Pig Launcher (28). (Figure 3.6)

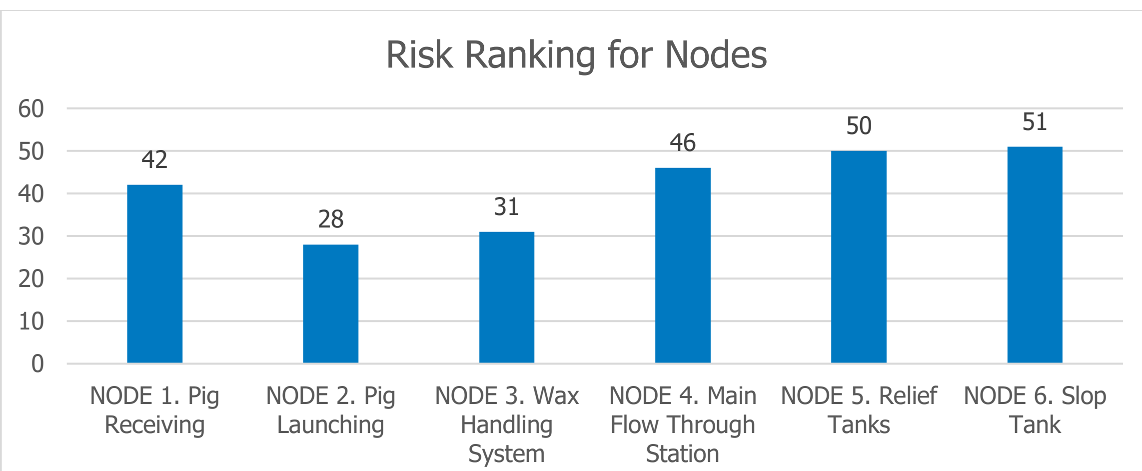

Figure 3.7: Risk ranking for nodes Graphic

When we examine each node individually, the risk in Pig Receiver Node includes 42 risk operations, distribution is as follows: Health and Safety 15 low risk and 1 medium risk with a total of 16, Environmental Impact wıth an 13 low risk a total of 13, Financial Loss 10 low risk and 2 medium risk with total 12 and only one low risk for Reputation.

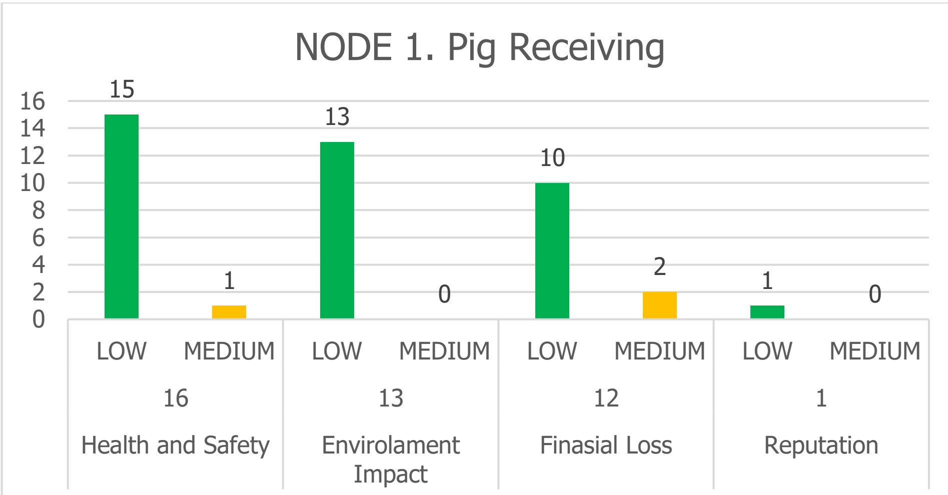

Figure 3.8: Node 1. Pig receiving risk ranking Graphic

The risk in Pig Launching Node includes 28 risk operations, distribution is as follows: Health and Safety 8 low risk and 1 medium risk with a total of 9, Environmental Impact wıth a 12 low risk a total of 13, Financial Loss 6 low risk and 1 medium risk with total 7 and no risk for Reputation.

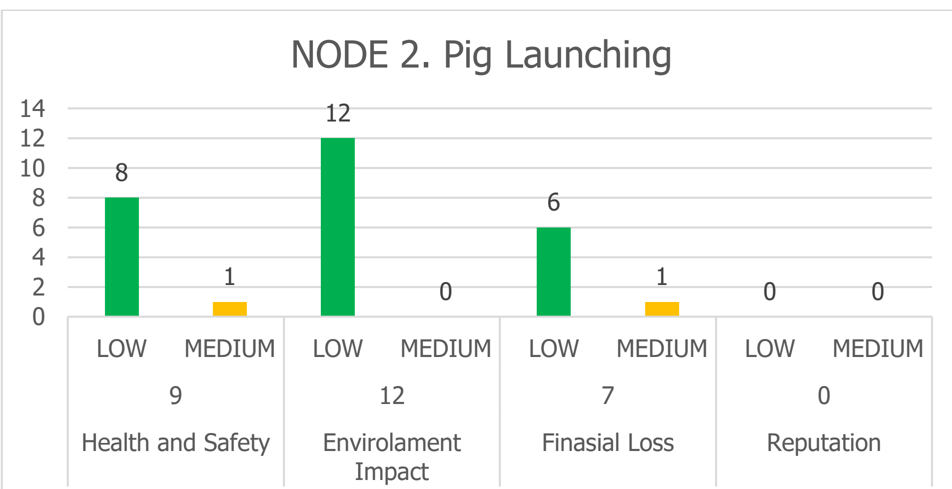

Figure 3.9: Node 2. Pig Launching risk ranking Graphic

At the Wax Handling Node, there are 31 risky operations, risk distribution is like that: Health and Safety 7 low risk and 4 medium risk with a total of 11, Environmental Impact wıth a 4 low risk a total of 4, Financial Loss 14 low risk and 2 medium risk with total 16 and no risk for Reputation.

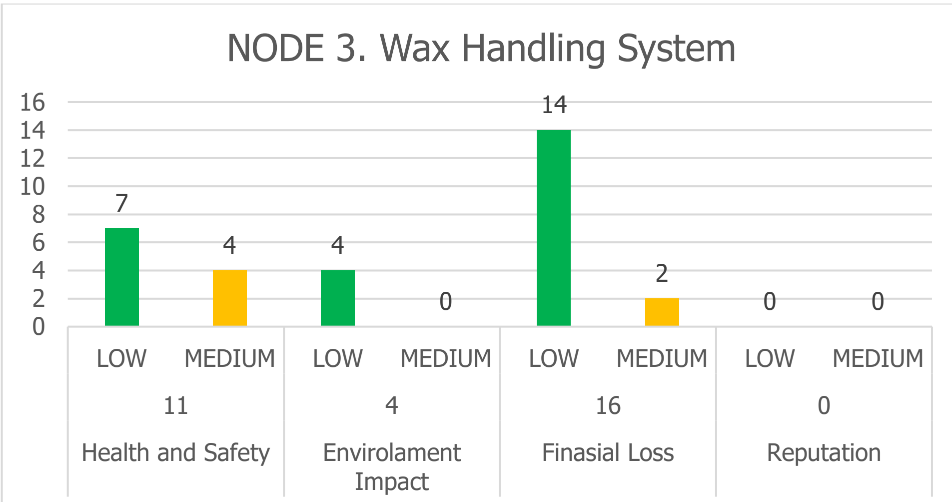

Figure 3.10: Node 3. Wax handling System risk ranking Graphic

When we come to the Main Oil Line node we can easily see that the number of risky operations is increasing. This operation is the main purpose of the station and it includes 46 risk operations. The highest Financial Loss risk is in this node with a 20 risk and risk ranking continuous 17 for Health and Safety, 8 for Environmental Impact and 1 medium risk for Reputation.

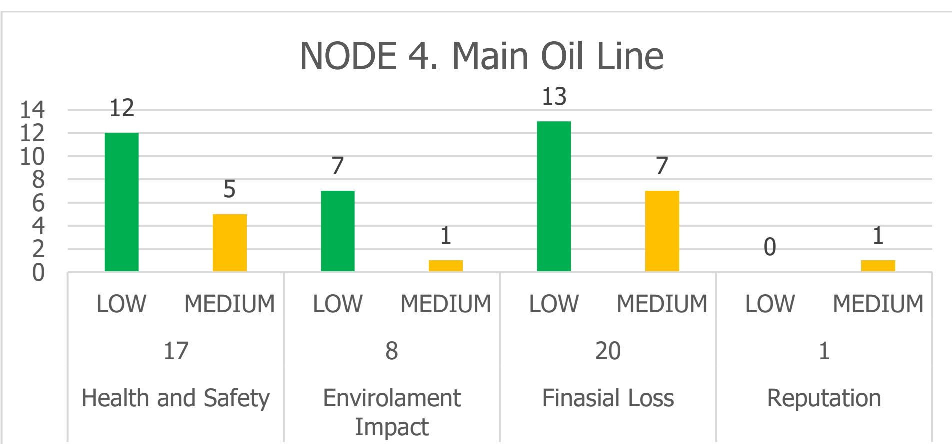

Figure 3.11: Node 4. Main Oil Line risk ranking Graphic

The highest Health and Safety (18) risk and Reputation (7) are in the Relief Tanks node. Risk ranking is continuous with 10 for Environmental Impact and 15 for Financial Loss.

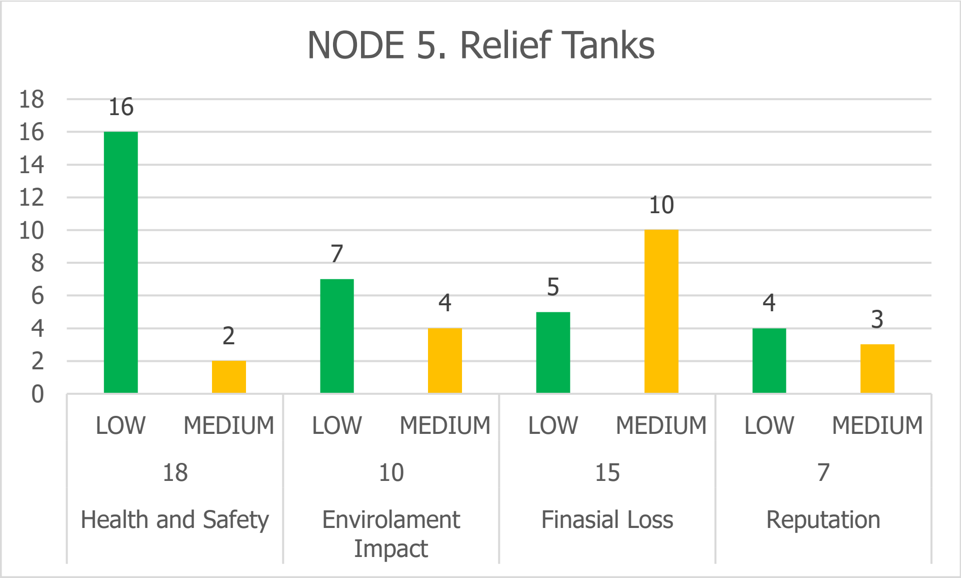

Figure 3.12: Node 5. Relief tanks risk ranking Graphic

The highest Environmental Impact is in the Slop Tank node with a number of 18 Risks. Also in this node, there are 14 Health and Safety, 18 Financial Loss and no Reputation risks.

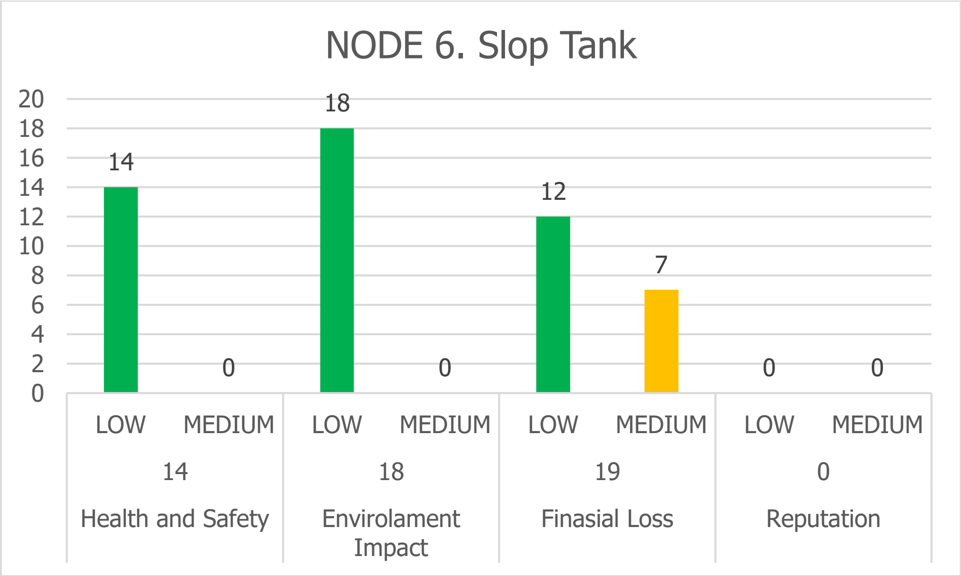

Figure 3.13: Node 6. Slop tank risk ranking Graphic

After identified these risks, the existing barriers and systems at the facility were examined and added to the list. It has been found that there are many security barriers in place to prevent possible unexpected consequences. There are barriers such as the presence of a fully equipped control system over the Supervisory Control and Data Acquisition (SCADA) system, the existence of a safety system built on the same system, the availability of spare equipment waiting on standby in the facility, the presence of interlock system valves for some very critical operations, and the operation of trained personnel.

These existing barriers are at a level that will prevent many of the risks we have identified. Nevertheless, we have had recommendations for 84 risks which we believe are insufficient. These 84 recommendations are included in the recommendations section of our HAZOP report.

4. Conclusion

As mentioned in the introduction, crude oil continues to be one of the most important energy sources in today's economy. The cheapest and safest transportation method of crude oil is still transported by pipelines.

Although it is the safest method, when we look at the results of our study, 248 risks were identified for only 1 pump station. Of course, considering the number of stations on the oil pipeline and the length of the pipe, it is obvious that the number of risks is quite high.

If we take a look again at the numerical data in our study. For the Crude Oil Pump Station, which we examined with 6 nodes, 134 deviations identified, 319 causes of these deviation and 892 results of the causes and the deviations were determined. In order to control these negative situations, 983 barriers were detected in the station and 84 recommendations were given for the cases where these barriers were insufficient.

The maximum deviation was detected in the Pig Receiver node with 37 deviations, followed by Pig Launcher and Slop System with 21 deviations, Wax Handling and Relief System with 19 deviations, and Main Oil Line with 17 deviations. Although the most number of deviation identified in Pig Receiving operation and it is seen as the riskiest operation. However, as a result of our study, it is seen that the slope system is detected as the riskiest operation.

As a result of our study, 51 risks in Slop System, 50 in Relief System, 46 in Main Oil Line, 42 in Pig Receiving, 31 in wax handling and 28 in pig Launching were determined. These results show that Slop and Relief systems which are not part of normal operation and designed for maintenance and abnormal situations are the riskiest systems. Although there is a lower deviation they are having more risks. This is caused by the main reason that they are not part of normal operation and then because of that low number of barriers applied to these systems. Another reason is that there is a high amount of oil in these sections and the consequences of an accident are high.

When we look at the possible causes of accidents, we see that most of the reasons can be caused by equipment failure with % 46.49 and most of the failure at equipment is valves with % 49.60. And also Pipe Failure with % 15.20, Pump Failure with %10.40, Tank Corrosion with %4, Vent Failure, Filter Blockage and Utility Equipment Failure with %2.40 and seal and Nozzle failures with %1,60.

The second cause of the accident is the wrong operation with 56 (%20.66). This means human error. No matter how competent personnel is employed in each enterprise, human-induced errors will always exist.

Identified 248 risks, 197 were low level (79.44%) and 51 Medium level (20.56%) risks are includes. Among these risks, which will cause Financial Losses with 89 (35.89%), are at the highest level. That followed by Health and safety with 85 (34.27%), Environmental impact with 65 (26.21%) and 9 Reputations (3.63%).

Thus, our aim is to analyze one pump station of the crude oil pipeline according to the HAZOP process. After completing the HAZOP study we will select major scenarios with unacceptable levels to apply SIS where it is needed to reduce risks of crude oil pump station operation which may impact health and public safety, worker safety in the workplace, economic losses, the environment and the company’s reputation. Although it was planned to perform SIS application after HAZOP analysis, it was determined that an SIS was performed for the pump station, which was taken as a sample, during the design and construction phase. As a result of this SIS, it was determined that the pumping station was built with all necessary safety instrumentation. Therefore no additional SIS could be performed.

To mention some SIS applications in the station where we study. The interlock system is designed for the pig receiver and all critical valves are interlocked according to the opening sequence. The key cannot be removed from the valve before the previous valve operation is completed and cannot be switched to the next valve operation. The same system also installed to the pig launcher. Also pressure control valves placed at any point. 3 pressure transmitters are installed for the output line and when 2 of them show high pressure then the pumps will be stopped. For slop and relief tanks, high high alarm switches are placed next to high alarm switches. When the high high alarm received the pipeline automatıcally shot down by SCADA system. Also slop tank designed and installed as double shelled and there is a liquid between two shells. If the hole is opened inside or out site of the slop tank the level of the liquid reduced and indicator switch give alarm to the control room.

There is an indicator switch on the pipeline near to the station and it indicates the pig. When pig reaches this switch ESD override automatically activated by SCADA system to protect hitting of pig to the ESDV. Also fire and gas detectors located different locations that fire and gas can be seen during routine and non-routine operations. When they identify any fire or gas, site siren activated and the pipeline automatically shot down. SCADA system also checking all the values received from all transmitters, indicators, signals, switches, etc. and doing related action identified by the operator and procedures.

We could suggest some additional recommendations like; full automation control of Pump Station from SCADA system but in real time it will be not applicable. Because conditions are changing all time. We can suggest additional slop tank or additional slop tank pump for slop operations. But failure of slop tank and slop tank pump just effect the oil flow not affect the operation safety. We can suggest some HV may replace with MOV and can control from CR.

The most important outcome of this study was to see how the design step has its benefit as a risk reduction safety layer. Thus, engineering design step becomes very crucial in terms of safety of the process and as well as provides less cost during the operation stage. Also, implementing SIS on the design step for this pump station provides guidance for developing maintenance and repair systems for the operators from the startup.

84 recommendations were given as a result of these nonconformities determined after our study. Of course, these recommendations include our own opinions and experiences. Therefore, the risk of accidents is not reduced to zero as a result of following these recommendations. Once these recommendations are followed, a HAZOP study must be renewed. The new HAZOP study will certainly show that the risk of an accident will continue every time.

References

1. Joseph P. Riva, Priscilla G. McLeroy, Gordon I. Atwater, Encyclopedia Britannica, 2-16-2018
2. https://www.statista.com/topics/1783/global-oil-industry-and-market/
3. OPEC Monthly Oil Market Report, 12.02.2018
4. An Introduction to THE PETROLEUM INDUSTRY, Alphonsus Fagan, 1991, GOVERNMENT OF NEWFOUNDLAND AND LABRADOR
5. Lees F P., Loss prevention in the process industries, London: Butterworth and Co Publisher Ltd., 1980.
6. DeWolf, Glenn B., Process safety management in the pipeline industry: parallels and differences between the pipeline integrity management (IMP) rule of the Office of Pipeline Safety and the PSM/ RMP approach for process facilities, Journal of Hazardous Materials 104, 2003, 1(3): 162 - 192.
7. Crowl DA., Louvar JF., Chemical process safety fundamentals with application, 2nd ed., New Jersey, Prentice Hall PTR, 2002.
8. AIChE, CCPS, Guidelines for Auditing Process Safety Management Systems, A John Wiley and Sons, 1993
9. Crowl DA., Louvar JF., Chemical process safety fundamentals with application, 2nd ed., New Jersey, Prentice Hall PTR, 2002.
10. AIChE, CCPS, Guidelines for risk based process safety, New Jersey, Wiley and Sons, 2007.
11. Sales J., Mushtaq F., and Christou MD., Analysis of major accidents reported to the MARS database during the period 1994 – 2000. Luxembourg, EC, 2007.
12. Okoh, Peter, and Haugen S., A study of maintenance-related major accident cases in the 21st century, Process Safety and Environmental Protection, 2014, (92): 346-356

13. Marsh, The 100 Largest losses 1972 – 2011, Large Property Damage Losses in the Hydrocarbon Industry, Marsh and McLennan, 2011.

14. Kletz TA., HAZOP and Hazan, 4th ed., Warwickshire, IChemE, 2001.

15. EC., Guidelines on a major accident prevention policy and safety management system, as required by Council Directive 96/82/EC (SEVESO II). EC, 1998.

16. Kidam K., and Hurme M., Method for identifying contributors to chemical process accidents, Process Safety and Environmental Protection, 2013, 91, 367-377

17. Buzzelli DT., Restoring public confidence in the safety of chemical plants, Plant/ Operations Progress, 1990

18. CMA, Process safety management (control of acute hazards), Washington DC, CMA, 1985.

19. API, Api presentation to U.S. CSB panel discussion process safety indicators for major accident prevention, API

20. NSW Government Department of Planning, Kurnell Peninsula land use safety study, Sidney: NSW Government Department of Planning, 2007

21. Kletz TA., The origins and history of loss prevention, Process Safety and Environmental Protection 77, 1999, 3, 109-116.

22. Macza, Murray, A Canadian perspective of the history of process safety management legislation, 8th Internationale Symposium Programmable Electronic System In Safety-Related Applications, Cologne, 2008, 12-22.

23. CCPS, Guidelines for hazard evaluation procedures, 3rd ed. Hoboken, New Jersey, John Willey and Sons Inc, 2008

24. Kraus RS., Developing a process safety management programme, ILO Encyclopedia of Occupational Health and Safety, edited by Micheal McCann ve Jeanne M. Stellman, 77, Geneva, International Labor Organization, 2011.

25. ISO 45001:2018 Occupational Health and Safety System Management,

26. Gupta AK., and Nair SS., Chemical (ındustrial) disaster management, trainer's module, National Institute of Disaster Management, New Delhi, 2012, 143.

27. Kwon, Hyuck-myun, The effectiveness of process safety management (PSM) regulation for chemical industry in Korea, Journal of Loss Prevention in the Process Industries, 2006, 19 (1): 13 -16

28. Hopkins A., Working paper 53 thinking about process safety indicators, Oil and Gas Industry Conference, Manchester, Australian National University, 2007, 1-16

29. IEC, IEC 618822: 2001 Hazard and operability studies (HAZOP studies)- application guide, Genova, IEC Yayınları, 2001.

30. Jones S., Kirchsteiger C., and Bjerke W., The importance of near-miss reporting to further improve safety performance, Journal of Loss Prevention in the Process Industries,1999, 12, 59 -67

31. Mason, Eileen, Elements of process safety management: part 1, Chemical Health and Safety, 2001, 22 - 24

32. Occupational Safety and Health Administration; Standards - 29 CFR

33. PSM Covered Chemical Facilities National Emphasis Program, CPL 03-00-021, OSHA Instruction,2017

34. CCPS, Guidelines for Risk Based Process Safety, Willey, 2007

35. API, Api presentation to U.S. CSB panel discussion process safety indicators for major accident prevention, API, 23 Temmuz 2012.

36. CCPS, Process safety leading and lagging metrics, New Jersey, Wiley and Sons, 2011.

37. SAChE Committee, What's process safety Arkansas, 2008.

38. EC., F - Seveso study of the effectiveness of the Seveso ıı directive final report. European Commission, 2008.

39. HSE, Developing process safety indicators A step-by-step guide for chemical and major hazard industries, Richmond, 2006.

40. OECD, Guidance on safety performance indicator, Environment, Health and Safety Publishing, 2008.

41. Reason J., Managing the risks of organizational accidents, Ashgate Publishing Limited, 1997.

42. SAChE Committee, Safety and chemical engineering education. http://www.sache.org/beacon/files/2014/04/tr/read/2014-04-Beacon-Turkish-s.pdf. 08.2014.

43. IOGP, Asset integrity- the key to managing major incident risk report No.145. London, OGP, 2008.

44. Rademaeker ED., Suter G., Pasman HJ., Fabiano B., A review of the past, present and future of the European loss prevention and safety promotion in the process industries, Process Safety and Environmental Protection, 92 (4): 2013.

45. İnanç D., Büyük kazaları önlemek için sağlık, güvenlik ve proses güvenliği entegrasyonu, I. Uluslararası Proses Güvenliği Sempozyumu ve Sergisi Yayınları, İstanbul, 2014.

46. PSA, Summary Report 2013 - Norwegian continental shelf- trends in risk level in the petroleum activity, Stavanger, Director for professional competence, PSA, 2014.

47. Kletz TA., An obituary: ICI's contribution to process safety and why it came to an end, Journal of Loss Prevention and Process Industries, 2010, 23, 954 - 957.

48. Pasman H., Rogers W., How can we use the information provided by process safety performance indicators? Possibilities and limitations, Journal of Loss Prevention in the Process Industries, 2014, 30, 197 – 206.

49. Bellamy LJ., Exploring the relationship between major hazard, fatal and non-fatal accidents through outcomes and causes, Safety Science, 2014.

50. Mannan S., Lees process safety essentials, IChemE. Publication, 2014.

51. PSA, Summary Report 2013 - Norwegian continental shelf- trends in risk level in the petroleum activity, Stavanger, Director for professional competence, PSA, 2014.

52. ÇSGB, İş Sağlığı ve Güvenliği Kanunu, 30.06.2012 tarih 28339 sayılı Resmi Gazete "İş Sağlığı ve Güvenliği" Kanunu, Resmi Gazete, 30 Haziran 2012.

53. Meissner RE., Shelton DC., Plant layout: part 1, minimizing problems in the plant layout, Chem Eng.,1992, 99 (4): 81

54. Taylor J R., Risk analysis for process plant, pipelines and transport. London, E & FN Spon, 1994.

55. Lawley HG., Operability studies and hazard analysis, Chemical Engineering Progress, 1974, 4 (70): 45 - 56.

56. BSI, Hazard and operability studies (HAZOP studies)- application guide, BS IEC: 61882:2001, London, British Standard Publication, 2001

APPENDICES

Appendix – A: HAZOP Parameters, Deviations and Possible Causes

PARAMETERS	DEVIATION,	POSSIBLE CAUSES
Flow	High	● Increased pumping capacity ● Increased suction pressure ● Reduced delivery head ● Greater fluid density ● Exchanger tube leaks ● Restriction orifice plates not installed ● Cross-connection of systems ● Control faults ● Control valve trim changed ● Running multiple pumps
	Less	● Restriction ● Wrong routing ● Filter blockage ● Defective pump(s) ● Fouling of vessel(s), valves, orifice plates ● Density or viscosity changes ● Cavitation ● Drain leaking ● Valve not fully open
	None	● Wrong routing ● Blockage ● Incorrect slip plate ● One-way (check) valve in backward ● Pipe or vessel rupture ● Large leak ● Equipment failure ● Isolation in error ● Incorrect pressure differential ● Gas locking
	Reverse	● Defective one-way (check) valve ● Siphon effect ● Incorrect pressure differential ● Two-way flow ● Emergency venting ● Incorrect operation ● Inline spare equipment ● Pump failure ● Pump reversed

Level	High	● Outlet isolated or blocked ● Inflow greater than outflow control failure ● Faulty level measurement ● Gravity liquid balancing ● Flooding ● Pressure surges ● Corrosion ● Sludge
	Low	● Inlet flow stops ● Leak ● Outflow greater than the inflow ● Control failure ● Faulty level measurement ● Draining of vessel ● Flooding ● Pressure surges ● Corrosion ● Sludge
Pressure	High	● Surge problems ● Connection to high pressure ● Gas (surge) breakthrough ● The inadequate volume of vents ● Incorrect vent set pressure for vents ● Relief valves isolated ● Thermal overpressure ● Positive displacement pumps ● Failed open PCV ● Boiling ● Freezing ● Chemical breakdown ● Scaling ● Foaming ● Condensation ● Sedimentation ● Gas release ● Priming ● Exploding ● Imploding ● External fire ● Weather conditions ● Hammer ● Changes in viscosity/density
	Low	● Generation of vacuum conditions ● Condensation

		● Gas dissolving in liquid ● Restricted pump/compressor line ● Undetected leakage ● Vessel drainage ● Blockage of blanket gas regulating valve ● Boiling ● Cavitation ● Freezing ● Chemical breakdown ● Flashing ● Sedimentation ● Scaling ● Foaming ● Gas release ● Priming ● Exploding ● Imploding ● Fire conditions ● Weather conditions ● Changes in viscosity/density
Temperature	High	● Ambient conditions ● Fouled or failed exchanger tubes ● Fire situation ● Cooling water failure ● Defective control valve ● Heater control failure ● Internal fires ● Reaction control failures ● Heating medium leak into the process ● Faulty instrumentation and control
	Low	● Ambient conditions ● Reducing pressure ● Fouled or failed exchanger tubes ● Loss of heating ● Depressurization of liquefied gas—Joule Thompson effect ● Faulty instrumentation and control
Part of	Concentration wrong	● Leaking isolation valves ● Leaking exchanger tubes ● Phase change ● Incorrect feedstock specification ● Process control upset ● Reaction by-products ● Ingress of water, steam, fuel, lubricants, corrosion

		products from the high pressure system ● Gas entrainment
As well as	Contaminants	● Leaking exchanger tubes ● Leaking isolation valves ● Incorrect operation of the system ● Interconnected systems ● Wrong additives ● Ingress of air: shutdown and start-up conditions ● Elevation changes and fluid velocities ● Ingress of water, steam, fuel, lubricants, corrosion ● Products from the high-pressure system ● Gas entrainment ● Feed stream impurities (e.g., mercury, H_2S, CO_2)
Other than	Wrong material	● Incorrect or off-specification feedstock ● Incorrect operation ● Wrong material delivered
Relief system		● Relief philosophy (process and fire) ● Type of relief device and reliability ● Relief valve discharge location ● Pollution implications ● Two-phase flow ● Low capacity (inlet and outlet)
Corrosion/erosion		● Cathodic protection arrangements (internal and external) ● Coating applications ● Corrosion monitoring methods and frequencies ● Materials specification ● Zinc embrittlement ● Stress corrosion cracking ● Fluid velocities ● Sour service (e.g., H_2S, mercury)
Abnormal operation		● Purging ● Flushing ● Start-up ● Normal shutdown ● Emergency shutdown ● Emergency operations ● Inspection of operating machines ● Guarding of machinery
Maintenance/procedures		Isolation philosophy ● Drainage ● Purging ● Cleaning

		● Drying ● Access ● Rescue plan ● Training ● Pressure testing ● Work permit system ● Condition monitoring ● Lift and manual handling
Sampling/procedures		● Sampling procedure ● Time for analysis results ● Calibration of automatic samplers ● Reliability and accuracy of the representative sample ● Diagnosis of results
Action		Overkill ● Underestimated ● None ● Reverse ● Incomplete ● Knock-on ● Wrong action
Sequence		● Operation too early ● Operation too late ● Operation left out ● Operation performed backward ● Operation not completed ● Supplemental action is taken ● Wrong action in operation
Safety systems		● Fire and gas detection and alarms ● Emergency shutdown (ESD) arrangements ● Firefighting response ● Emergency training ● TLVs of process materials and method of detection ● First aid/medical resources ● Vapor and effluent disposal ● Testing of safety equipment ● Compliance with local and national regulations
Global		● Layout and arrangement ● Weather (temperature, humidity, flooding, winds, sandstorm, blizzards, and so on) ● Geological or seismic ● Human factors (labeling, identification, access,

		instructions, training, qualifications, and so on) ● Fire and explosion ● Adjacent facility exposures

Appendix – B: HAZOP Study of Petroleum Pipeline Pump Station

					Risk Matrix				
Node	Deviation	Causes	Consequences	CAT	S	L	RR	Safeguards	Recommendations
1. Pig Receiving	1.Inspect the Pig receiver - omitted	Can be completely omitted.	The probability to proceed with Pig Receiver door open leading to an oil spill. Leading to oil spill out of the door when filling the receiver in preparation of pig.	S	G	3	4	1. Operator Training Competence and Awareness - Can visually see if the Pig Receiver door open. 2. Key Interlock system prevents opening if the Pig Receiver door opens out of sequence. 3. Electrical Interlock system prevents remote valves opening if the Pig Receiver door open.	1. Include a check on the level in the Slop Tank in the pre-checks of Pig Reception Procedure and if practicable, empty the slop tank prior to receipt of pig.
			No significant consequences identified (NSCI)	R					
			Oil spillage from Pig Receiver as the door is open while filling.	E	H	3	3	1. As above 2. Pig receiver is in a bunded area and is located adjacent to a spill pit.	
			The probability to proceed with Slop Tank full leading to a production delay.	F	H	3	3	1. Operator Training Competence and Awareness - pre-checks include checking that the Slop Tank is empty prior to pig receiving. 2. Operator Training Competence and Awareness - Slop Tank Level alarm High may alert an operator prior to pig receiving. 3. Slop tank pumps start automatically in the high level event in the Slop Tank	
		partially omitted	Visual inspection of the receiver system omitted. Potential for a						2. Should provide instruction on the pressure indicators indicate 0 as required.

			leak to be missed. NSCI - does not present the potential for large leaks.						
			2. NSCI	S					
			3. NSCI	R					
			4. No significant consequence	E					
			5. Check the pressure in Pig Receiver. If this is omitted, then it may be missed that a valve is leaking resulting in the potential for not having the ability to depressurize the pig receiver. Leads to delays on pigging operations and wax accumulation within the pipeline. NSCI - Can postpone pigging operation for 1 week.	F					
	2.Inspect the Pig receiver - too short/too long - too late/too early	1. No significant causes identified							
	3. Inspect the Pig receiver - wrong order	1. No significant causes identified							

	4. Inspect the Pig receiver - wrong action	1. No significant causes identified							
	5.Line up Pig Receiver - omitted	1. Omit to open vent valves to the closed drain.	1. Potential to trap air and oil gas within the Pig Receiver. Potential to push trapped air and gas into the pipeline with potential for internal pipeline explosion if ignition. Potential to damage MOL Pumps as trapped air will enter the pipeline and towards pump suction.					1. Unable to assess, see recommendation.	3. If a receiver is lined up without it being vented, there is a possibility of trapped air/gas vapor to be sent forward into the pipeline when the receiver is lined up. Potential to push trapped air and gas into the pipeline with potential for internal pipeline explosion if ignition. Potential to damage MOL Pumps as trapped air will enter the pipeline and towards pump suction. Evaluate the above scenario and consequences. Determine if they are credible. Also, if required, implement appropriate remedial actions.
		2. Omit to open vent valve on the open drain	1. The operator does not get confirmation that the Pig Receiver is full of oil and consequently gas/vapor may be trapped in the Pig Receiver. See the above cause.						

		3. Omit to fill Pig Receiver with oil - No significant causes identified							
		4. Omit to pressurize the Receiver	1. NSCI	S					
			2. NSCI	R					
			3. NSCI	E					
			4. Receiver MOV may damage valve seats or difficulty in opening MOVs due to pressure difference. NSCI	F					
		5. Omit to open up the Receiver kicker valves	1. The oil will not flow through the Pig Receiver leading to the inability to receive the pig. The pig would stick on the barred T. But this is a recoverable situation as a pig can still be sent to the receiver following corrective action. May be some damage, especially to foam pig. NSCI						
		6. Omit to open the tundish valves	1. NSCI	S					
			2. NSCI	R					
			3. Leading to overflow of tundish and oil spillage on site.	E	G	3	4	1. Oil spill kit (drum based) is available on site for mopping up of small leaks. 2. The mechanical interlock will prevent the failure to open this valve. 3. Operator Training Competence and Awareness - pig receiving is a local	

								manual operation and may see the overfilling of the tundish. 4. The spill from the tundish is contained and should be directed to the Oily Water Treatment Package.	
			4. NSCI	F					
	6. Line up Pig Receiver - incomplete	1. Incomplete to open vent valves to the closed drain.	NSCI						
		2. Incomplete to open vent valve on the open drain	NSCI						
		3. Incomplete to fill Pig Receiver with oil	Partly filled receiver leading to gas/air being left inside the receiver and compressed when the receiver is pressurized. Potential for a larger atmosphere to be created compared to the equivalent step in omission deviation. – see recommendation.						4. If a receiver is lined up without it being vented, there is a possibility of trapped air/gas vapor to be sent forward into the pipeline when the receiver is lined up. Potential to push trapped air and gas into the pipeline with potential for internal pipeline explosion if ignition. Potential to damage MOL Pumps as trapped air will enter the pipeline and towards pump suction. Evaluate the above scenario and consequences. Determine if they are credible. Also, if required, implement appropriate remedial actions.
		4.Incomplete to pressurize the Receiver	NSCI						

		5. Incomplete to open up the Receiver kicker valves	NSCI						
		6. Incomplete to open the tundish valves -	NSCI - see omission deviation.						
	7. Line up Pig Receiver - valve error	No significant causes identified							
	8. Line up Pig Receiver - too short/too long - too late/early	1. Line up not done in time so that pig hits closed valve – Blocked pipeline, for example, a stuck pig at the barred tee or Emergency Shutdown Valve	NSCI – recoverable situation with minimal impact for damage to pigging valves.						
		2. Open the kicker line bypass quickly	1. NSCI	S					
			2.NSCI	R					
			3. Pig Receiver fills up too fast If Pig Receiver is filled with oil, this will lead to uncontrolled pressurization leading to an increased likelihood of a leak from the pig receiver door.	E	H	3	3	1. Pig receiver is in a bunded area and is located adjacent to a spill pit. 2. Operator Training Competence and Awareness - operator training and supervision should ensure that he is diligent.	
			4.NSCI	F					
		3. Possible to close before	NSCI						

		liquid seen at tundish -							
	9. Line up Pig Receiver - wrong order	No significant causes identified							
	10. Line up Pig Receiver - wrong action	Failure to set pig signaler –	Pig signaler is 1 km away from site and operators may not set due to remote location/human error. A particular problem in winter as there is no access road especially because of the snow. NSCI - there is a mechanical counterweight on the pig signaler which auto resets. A signal is still sent to the Integrated Control and Safety System (ICSS) to alert that the pig has passed. On all other stations, the pig signaler must be manually reset.						5. There are logistical issues associated with resetting the pig signaler. This is a particular problem in winter as there no access roads to the pig signalers at some stations - especially in the snow. On some stations, there is a mechanical counterweight on the pig signaler which auto resets. A signal is still sent to the ICSS to alert that the pig has passed. On all other stations, the pig signaler must be manually reset. Evaluate if similar measures or other means of automatically resetting should also but put in place at stations where a manual reset of the pig signaler is required.
	11. Line up Pig Receiver – extra action/SIM OPs	Draining to Slop Tank while completing Pig Receiver line up.	1. NSCI	S					
			2.NSCI	R					
			3. Overfilling of Slop Tank leading to an oil spill in slop tank boundary. NSCI	E					
			4.NSCI	F					

	12. Receiving Pig & Isolate receiver – omitted - incomplete	1. Control room operator forgets to instruct the operator.	The pig may not enter the receiver. NSCI – situation retrievable should pig become stuck.						
		2. omitted strainer.	1. NSCI	S					6. This step states that should there be a high dP across the online strainer, then the standby strainer should come online. Review whether this step should be included for the work instructions. If so revise the work instructions to include this step.
			2.NSCI	R					
			3. NSCI	E					
			4. Low MOL pump suction pressure as strainers may become blocked and a possibility to strainer damage due to high dP across the strainer.	F	G	3	4	1. Three strainers available, so if one is damaged another two are available. 2. Differential pressure transmitters across strainers should cause the flow to be directed to the standby strainer. 3. Low frequency event, not observed in operation.	
		3. Forget to set the override on the ESDV	1. May trap the pig in the ESD valve if an ESD occurs while the pig passing through the ESD valve. Leading to the inability to isolate the station when an ESD scenario has occurred.	S	F	3	5	1. İnlet MOV's can be used to isolate the station if the ESDV is not available. 2. Operator Training Competence and Awareness - control room operator may also track the ESD override during pig receipt as well as the site operator. 3. Emergency Shutdown (ESD) override can also be completed at the SCADA screen.	
			2.NSCI	R					
			3. NSCI	E					
			4. May trap the pig in the ESD valve if an ESD occurs while the pig passing through the ESD valve. Leading to damage to the valve and pig. If the pig gets stuck in the ESD valve, there will be a requirement to	F	D	3	7	1. As above. 2. Pipeline repair team - may be possible to put a hot tap in to bypass the stuck valve whilst stuck pig retrieval is taking place. 3. The alarm on the pig signaler which should prompt an operator to apply ESD valve override.	

			drain the line and cut into the line to retrieve the pig.						
		4. omit to throttle back the bypass valve	A pig will stick on barred T. NSCI - see a previous consequence.						
		5. Omit to use the pig detector.	NSCI - as in practice this is not done. - In practice can only be done if pinger is attached to pig.						
		6. Omitted fully close the Pig Receiver kicker valve.	Pig is not pushed towards the Pig Receiver door. NSCI - if a pig was too far into the barrel, then the trap can be boxed up and the pig shunted towards the door.						
		7. Omit to log time of pig arrival.	NSCI - data can be retrieved from SCADA.						
		8. Omit to inform the Local Control Room (LCR) operator.	1. NSCI	S					
			2.NSCI	R					
			3. NSCI	E					
			4. Potential for pipeline shutdown	F	G	3	4	Operator Training Competence and Awareness - The operator is aware of the requirements and in constant contact with the LCR.	
		9. Omit to close the kicker valve.	If the kicker line valve not closed, there is potential for Pig Receiver to remain pressurized and						

			inability to drain the receiver. NSCI - interlocks will prevent the start of pig draining operation until the valve is closed.						
		10. Omit to dewax the pig and Pig Receiver.	1. NSCI	S					
			2.NSCI	R					
			3. Large amounts of wax taken from the receiver.	E	H	3	3	If significant wax remains when the door is opened, the door can be re-closed and further dewaxing applied.	
			4. NSCI	F					
	13. Receiving Pig & Isolate receiver - valve error	1. Emergency Shutdown (ESD) override not applied.	If an ESD happens as the pig is passing, the ESD valve may close on the pig. NSCI - see cause 3 receiving pig isolate procedure deviation.						
		2. over throttle the bypass	Potential to - cause surge event if this valve is over throttled during high flow rate in the main pipeline. - Potential for lower suction inlet pressure on the MOL Pumps NSCI						
		3. Failure to throttle bypass	The pig will not enter the Pig Receiver leading to operation delay. NSCI- recoverable situation						
			1. NSCI	S					

		4. Failure to close kicker valve	2.NSCI	R					
			3. NSCI	E					
			4. Inability to isolate and drain the Pig Receiver.	F	G	3	4	Operator Training Competence and Awareness - The valve is pressure tested before use therefore failure should be identified.	
		5. Failure to close kicker	1. NSCI	S					
			2.NSCI	R					
			3. NSCI	E					
			4. Inability to isolate and drain the Pig Receiver.	F	G	3	4	Operator Training Competence and Awareness - The valve is pressure tested before use therefore failure should be identified.	
		6. Failure to close isolation valve	1. NSCI	S					
			2.NSCI	R					
			3. NSCI	E					
			4. Inability to isolate and drain the Pig Receiver.	F	F	3	5	Operator Training Competence and Awareness - The valve is pressure tested before use therefore failure should be identified.	
	14. Receiving Pig & Isolate receiver - too late/early - too long/too short	1. wait for the pig to come into the pig trap and trigger pig signaler that confirms arrival.	Leading to more flow through the Pig Receiver as the pig may have arrived. NSCI - delay to a pigging, recoverable situation.						
		2. open bypass valve too before/after	NSCI						
	15. Receiving Pig & Isolate receiver -	1. Instruct the operator that the pig is imminent - Completed before distant pig	NSCI						

	wrong order - wrong action	signaler is initiated.							
		2. If the isolation valve is closed before fully opening the inlet valve	The shutdown can occur due to high pressure. NSCI						7. The flow path representation could be placed on SCADA indicates whether the flow path is open through the station. Review and update cause and effect diagrams including the flow path availability actions.
		3. Completed in the wrong order.	NSCI						
		4. Start dewaxing before the kicker valves have been closed.	NSCI						
	16. Drain the Pig Receiver – omitted	1. Omitting to confirm the drain and bleed valves to ensure double block and bleed integrity.	Failure to identify any passing of the main isolation valve Unable to drain and isolate the receiver. Pig not removed. NSCI - No immediate impact on oil pipeline throughput.						
		2. Forget to confirm the Slop Tank level.	Potential overfilling of Slop Tank in slop tank boundary. NSCI						
		3. Omit to monitor the Slop Tank level during draining activity.	Potential overfilling of Slop Tank. NSCI						
		4.fail to monitor pressure	Potential splashing at the tundish. NSCI						

		5. Wait for Slop Tank level stabilization and confirm from the control room omitted.	1. May not complete Pig Receiver draining. Potential for oil spill when the Pig Receiver door opened. Potential to contaminate the operator.	S	G	4	5	1. If a significant quantity of oil within the receiver, the door band lock may prevent it from being opened due to the pressure behind the door. 2. Designed for the operator to stand at the side when the Pig Receiver door is opened. 3. Site standard Personnel Protective Equipment (PPE) may protect the operator from exposure to oil 4. Medical facilities including first aider, doctor, infirmary and ambulance are available on site and may reduce the severity of any injury.	
			2. NSCI	R					
			3.NSCI	E					
			4. NSCI	F					
	17. Drain the Pig Receiver - valve error	1. Drain valves (to close drain header) passing e.g.	Overfilling of Slop Tank NSCI - see slop tank node						
		2. Drain valves (to open drain header) passing - Cavity drains from MOVs left open or passing.	1. NSCI	S					
			2.NSCI	R					
			3. Flow through to tundish. Possible spill as a tundish drain valve closed. May lead to oil flow to Oily Water Treatment via the bund drain.	E	H	5	5	1. The interlock system should ensure that the drain valves are not opened until the tundish valve is open. 2. Operator Training Competence and Awareness - operator may see tundish overflow and open the tundish drain valve. 3. Operator Training Competence and Awareness - outflow from the oily water separator is analyzed and monitored. If overloaded, then operations would be halted.	
			4.NSCI	F					

		3. Unable to close the tundish outlet valve	1. Hydrocarbon fumes generated at the tundish. Potential for fire in the open drains if ignited. Unable to assign a consequence, see recommendation.	S				1.Key interlock on the valve	8. Should the valve on the tundish outlet be left open, the potential exists for hydrocarbons to be emitted from the tundish especially when the slop tank is being filled. The hazardous area classification must be reviewed, which indicate flammable atmospheres (zone 0, 1 and 2) are emitted from the slop tank. The worst case scenario recognized that the potential for the hydrocarbons to be ignited and the flame to propagate back through the drain line to the slop tank. Assess whether the above scenario of hydrocarbons being emitted from tundishes and ignited is credible. Also assess if ignition occurs, if flame propagation back to the slop tank can occur. If so, evaluate existing safeguards. If required, install additional safeguards.
								2. Operator Training Competence and Awareness - operation of the pipeline would not occur if the tundish valve could not be closed. 3. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work	

								having ignition potential evaluated. 4. Other drainages to the Slop Tank could be displacing the fumes back up in the event of tundish valve failure can be closed.	
			2. NSCI	R					
			3.NSCI	E					
			4. Potential for water ingress into the Slop Tank (rain/snow). NSCI	F					
	18. Drain the Pig Receiver - too short/long - too late/early - wrong order - wrong action - extra action - SIMOPs	1. Leave for less than stated 15 minutes.	Unable to confirm valve integrity as a pressure test is invalidated. Leading to the inability to drain/depressurize the Pig Receiver. NSCI						
		2. additional users of the Slop Tank (SIMOPS)	Potential for an overflow of Slop Tank. NSCI						
	19. Remove Pig from Receiver - omitted - incomplete	1. Open the bleed screw without slackening first to allow telltale check for pressure inside.	1. Potential for a bleed screw to be projected with force from the pig trap door/receiver. Potential fatality if the operator struck by bleed screw.	S	E	3	6	1. Operator Training Competence and Awareness - The receiver should be depressurized and drained prior to this activity. 2. Operator Training Competence and Awareness - The operator should check that there is no pressure behind the bleed screw prior to opening. 3. The key interlock sequence should prevent pressure behind the Pig Receiver door resulting in the ejection of the bleed screw with force as a receiver should be	

								depressurized prior to this step. 4. The bleed screw is attached to a chain that may hold the bleed screw if projected with force.	
			2. Potential for a bleed screw to be projected with force from the pig trap door/receiver. Potential fatality if the operator struck by bleed screw will affect privilege to operate in the future.	R	G	3	4	1. As above 2. Incident Management Team have personnel trained and authorized to provide accurate information to the media and public.	
			3.NSCI	E					
			4. NSCI	F					
		2. Forget to locate gas detectors in the vicinity of the door opening.	NSCI - H2S is to be checked using gas detectors, but the oil is sweet presently (no H2S present).						9. There have to step highlighting what the operator should do in the event of H2S identification or LEL detection by the gas detectors in Procedure. It has been suggested that an H2S awareness training procedure exists which gives guidance of actions to be taken when H2s is identified, A reference to the H2S awareness procedure should be made, or supplementary actions should be incorporated into Pig Reception Procedure providing guidance of actions to be taken in the event of H2S identification.

									Guidance on response to LEL detection is also required in the the Pig Reception Procedure
		3. Omit to remove the pig from Pig Receiver.	Next time to pig receive operation conducted there would already be a pig in the Pig Receiver. NSCI as Pig Receiver barrel designed to take 2 pigs.						
		4. Forgetting to inspect the pig for damage (including photographing pig).	1.NSCI	S					
			2. NSCI	R					
			3. Potential to send damaged pig if the pig is not inspected prior to next pigging operation. May fail to identify damaged (dented) pipeline if pig not inspected consistently over time. This may result in pipeline failure (fatigue crack) before damage is detected	E	E	3	6	1. Operator Training Competence and Awareness - Control room monitors pig conditions by review of photographs taken and would become aware if the inspection is consistently being missed. 2. Operator Training Competence and Awareness - operators are trained and competent and aware of the requirement to inspect the pig on removal. 3. Operator Training Competence and Awareness - pig receiving and launching reports are completed during every pig operation. 4. ILI pigging is carried out once every 2 years and is preceded by sending a gauging pig through the pipeline which should detect any dents. 5. Piping intruder detection system where present should hear any activities likely to result in pipeline denting.	
			4. NSCI	F					
			1.NSCI	S					

		5. Forget to clean the sealing faces of the pig trap door.	2. NSCI	R					
			3. Potential oil leak at the Pig Receiver door when pressurized during the next pigging operation.	E	G	4	5	1. Operator Training Competence and Awareness - filling operation is a manual operation and the operator should be aware of any leak from the Pig Receiver door. 2. The leak is not likely to spray, but rather ooze out from the door. 3. Pig receiver drip tray is present which should catch any leaked oil. 4. Bund drain should direct any overspill from the drip tray to the oily Water Treatment Package	
			4. NSCI	F					
		9. Forget to check the condition of the pig trap.	NSCI						10. The potential for operators when adhering to instruction to enter the Receiver in order to remove wax deposition. The standing instruction which states do not place any part of the head or body inside the Receiver is to be inserted.
	20. Remove Pig from Receiver - valve error	1. Isolation valves passing whilst the Pig Receiver door is open.	1.NSCI	S					
			2. NSCI	R					
			3. Leading to oil spill - of limited volume (m3).	E	G	3	4	1. Pressure build up tests should be completed and should have identified valves passing prior to the door opening. 2. Operator Training Competence and Awareness - MOV valve cavity vents should be checked as part of the procedure prior to door opening as part of the operating instruction. 3. Isolation valves cannot be opened in remote when the door is open due to logic interlock. 4. Isolation valves cannot be opened	

								locally when the door is open due to key interlock. 5. ESD pushbutton at the pigging station can be activated to isolate Pig Receiver from the pipeline. 6. Oil spill kit (drum based) is available on site for mopping up of small leaks. 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. - Oil Spill Booklet Planned drill exercises are conducted by Emergency Response (ER) teams. Response Team is available onsite (ERTAO) 8. The bunded area should contain spillage.	
			4. NSCI	F					
	21. Remove Pig from Receiver - too short/long - too late/early - wrong order - wrong action - extra action - SIMOPs	Opening of Pig Receiver door prior to full depressurization/ draining.	1. The pig trap door opens violently because of pressure behind the door, leading to potential injury/fatality of the operator.	S	E	3	6	1. Bandlock door is designed not to open under pressure. 2. The use of the bleed screw should ensure that the operator is aware of the pressure behind the door and should not open. 3. Operator Training Competence and Awareness - pressure gauges are available and may inform the operator of pressure within the Pig Receiver. 4. Operator Training Competence and Awareness - following of procedure should ensure no pressure behind the door when it is opened. 5. Site standard PPE may protect the operator or limit injury. 6. Medical facilities including first aider, doctor, infirmary and ambulance.	11. The pressure gauges on the Pig Receiver is not readily visible to the operator when he is positioned to open the door. Pig receivers pressure gauges must be positioned so that they can be readily seen by the operator when he is positioned to open the door. This enables the operator to confirm the Pig Receiver is vented to the atmosphere. If practicable, position a pressure gauge that can be readily seen by the operator when he is in a position to open the receiver door.

								7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO	
			2.NSCI	R					
			3. NSCI	E					
			4.NSCI	F					
	22. Reinstate Pig receiver - omitted - incomplete - valve error - too short/long - too late/early - wrong order - wrong action - extra action - SIMOPs	1. Inspection of the door seal omitted.	NSCI - potential for minor door leak sees forget to clean sealing faces of pig trap door cause.						
		2. Forget to screw on the safety bleed screw.	1.NSCI	S					
			2.NSCI	R					
			3. Inability to repressurize Pig Receiver as there is a hole resulting in loss of containment.	E	G	3	4	1. Emergency Shutdown (ESD) pushbutton at the pigging station can be activated to isolate Pig Receiver from the pipeline. 2. Oil spill kit (drum based) is available on site for mopping up of small leaks. 3. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. - Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 4. The bunded area should contain spillage. 5. Operator Training Competence and Awareness - During refilling operator will observe a leak.	
			4. Inability to repressurize Pig	F					

			Receiver as there is a hole. NSCI						
		3. Forget to fit metal-bonded seal.	1. Potential for oil leaks from door NSCI - forget to clean sealing faces of the pig trap door.						
		4. Omit to ensure the balance line valve is open.	1. Potential for pressure in the receiver to vary. Possible pressure builds up behind the pig. Leading to a pig being moved forward by the residual trapped pressure with the oil behind the pig being coming out of the receiver and causing injury. Oil contamination/exposure - of nearby operator	S	G	3	4	1. Balance line valve is never closed during normal operations. 2. Operator Training Competence and Awareness - following work instruction that requires the pig to be in the major barrel before removal. 3. Site standard PPE may protect the operator or limit injury.	
			2.NSCI	R					
			3. Potential for pressure in the receiver to vary. Possible pressure builds up behind the pig. & loss of oil NSCI see above	E					
			4.NSCI	F					
	23. Preparation for Maintenance - omitted	1. Unable to isolate the receiver for internal inspection. Positive isolation	1.NSCI	S					12. It is not possible to isolate the Receiver or Launcher for internal inspection during normal operation when there is line flow. Positive isolation is stated as mandatory should
			2.NSCI	R					
			3.NSCI	E					
			4. The pipeline will need to be shutdown	F	E	3	6	1. None	

	- incomplete - valve error - too short/long - too late/early - wrong order - wrong action - extra action - SIMOPs	is stated as mandatory should vessel entry be required. But this can only be done if the pipeline is shutdown	should an internal inspection be needed.						vessel entry be required. But this can only be done if the pipeline is shutdown. Vessel entry / intrusive maintenance is not a common/regular occurrence. Also, the work instructions should make it clear that for vessel entry, special instructions are required.
		2. omitted electrical isolation of MOVs	1. Spurious opening of valves resulting in loss of isolation with a potential large volume of oil entering pig trap. Potential for serious injury/fatality	S	E	3	6	1. Positive isolation required for entry - so a failure of valve isolation would have no effect 2. Permit to Work (PTW) should ensure isolations in place 3. MOVs cannot be operated local or remote when the hand switch is at off position. Site practice is to lock MOVs at off position	
			2. NSCI	R					
			3. Spurious opening of valves resulting in loss of isolation with a potential large volume of oil entering pig trap leading to spill if the door is open	E	F	3	4	1. as above 2. Software interlock prohibits isolation MOVs being opened when the door is open	
			4. NSCI	F					
	24. Reinstatement after Maintenance - omitted - incomplete	1. Omit to ensure all instrument valves are open and instrument vent/drain valves are closed.	1. Incorrect instrument readings - the potential for the operator to be misled Pressure indicators on the Launcher / Receiver will not indicate when there is pressure in the						

	- valve error - too short/long - too late/early - wrong order - wrong action - extra action - SIMOPs		pig launcher/receiver. Leading to a multiple of hazardous scenarios where pressure indication is relied upon. The worst case scenario is when there is a pressure within the pig launcher/receiver. See the opening of the pig receiver/launcher door when pressurized.						
		2. omit to close the trap door	1. The door is open - possible loss of containment. But in practice not considered a credible scenario						
	25. In Line Inspection (ILI) Pigging	1. Issue of trolley used to take the ILI pig out of the Pig Receiver. ILI pig magnets caused the trolley to stick the pig when the pig was lifted to the crane, the trolley remained attached and also lifted.	1. Trolley falls from height on to the operator	S	E	3	6	1. Pigging operation is carried out under the vendor's instructions & the vendor may if required to bring own (stainless steel) trolley. 2. Lifting operation would be stopped immediately the trolley was seen to lift 3. Lifting is carried out away from Pig Receiver. 4. Slings will be used to fix the trolley to the ground.	
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					
	26. Flow -no -more	1. No significant causes identified							
	27. Pressure - more	1. Receiver door end pressure	1. NSCI						

		gauge only reads up to 6 barg,							
	28. High temperature -more	1. External fire	1. Potential overpressure of the Pig Receiver. Leading to joint / flange failure or possible vessel rupture.	S	F	3	5	1. Low occupancy - operators will not be present 2. PSV designed for fire relief (ref. API 521). 3. Fire team will respond in case of fire with hoses	
			2. NSCI	R					
			3. NSCI	E					
			4. Potential overpressure of the Pig Receiver. Leading to joint / flange failure or possible vessel rupture. Damage to equipment and postponement of pigging but not effect pipeline operation	F	F	3	5	1. As Above	
		2. After hot washing - in excess of design of 80C	1. Potential for operators to be scalded if cold was system fails and Pig door opened.	S	F	4	6	1. Operator Training Competence and Awareness - operators are aware of plant status. 2. Site standard PPE - gloves should provide protection 3. TI may alert operators	
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					
	29. Instrumentation - late -after	1. Failure of Emergency Shutdown (ESD) override - does not work when initiated	1. ESDV may close on pig Fail to isolate the station as ESDV not closed. Leading to additional inventory	S	F	2	4	1. The integrity of the override ESD system 2. SCADA confirms override status active 3. Beacon shows whether the override is active. If not active then ESDV can be	

			being fed to an onsite loss of containment incident.					manually locked open by isolating hydraulics. 4. Low frequency event as the following would have to co-exist - loss of ESDV integrity - pig inline - Emergency Shutdown (ESD) event on the station 5. If SCADA does not confirm ESD override then with supervisor access the ESDV can be made by the SCADA to stay open.	
			2. NSCI	R					
			3. NSCI	E					
			4. ESDV may close on pig and damage valve & pig Long pipeline shutdown required to retrieve pig & complete repairs.	F	d	2	6	1. as above	
		2. ESD override times out following an ESD event but before the pig has been taken into the Pig Receiver.							13. The ESD override times out following an ESD event but before the pig has been taken into the pig receiver may cause confusion as to whether to reset the override while the override is on or wait until it has timed out and reapplied. At the end of set minutes, the ESDV valve will close if an ESD has occurred during the override period. It was unclear if the ESD override can be reapplied when the initial override is still counting down When the ESD override has expired, there is a

									visual notification on the control panel. It is unclear if the operator should reapply the override once this notification has occurred. The visual notifications on the control panel relating to the ESD override should be confirmed i.e. - when the override should be reapplied - why there is a minute application on the override.
	30. Maintenanc e -valve error -as well as	1. Failure of the bypass valve	1. This valve is not a double block and bleed and is being used to provide positive isolation. There is no additional spectacle blind on this valve; hence does not provide positive isolation as required	S	F	4	6	1. Pressure build up test completed prior to the door opening.	14. There is a potential for the Pig Receiver and Pig Launcher door to be opened while isolated from the pipeline that is above 50 barg only by a normal ball valve (- bypass on kicker line). Replace receiver/launcher kicker line bypass valve with DBB valves or provide (and use) other means of isolation.
								2. Bandlock door should not open under pressure. 3. The catastrophic leak should not occur, consequently, the leak should not be a full bore but markedly less.	15. It is not possible to isolate the Receiver or Launcher for internal inspection during normal operation when there is line flow. Positive isolation is stated as mandatory should vessel entry be required. But this can only be done if the pipeline is shutdown. Vessel entry / intrusive maintenance is not a common/regular occurrence.
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					

									Also, the work instructions should make it clear that for vessel entry, special instructions are required.
	31. Low temperature -less	1. Pigging in low temperature No significant causes identified Pigging is only completed when the pipeline is warm.							
	32. Safety -no	1. Possible for vent line to be blocked with wax so that when this line is used to vent the pig trap prior to the door opening, the venting operation will not be successful.	1. Potential for oil to remain within the pig Receiver. Potential exposure of the operator to oil.	S	F	4	6	1. Before venting/draining of the Pig Receiver, there is wax handling operation which should decrease the amount of wax in the pig receiver.	16. There is a possibility for the wax to block the vent of the pig Receiver. While considered that the Pig Receiver would most likely be vented through its drains, there remained the possibility of oil being retained in the trap and released through the door when it is opened. Evaluate the benefits of installing heat tracing and lagging on the pig receiver vents and if deemed suitable, install.
								2. Pig Receiver cannot be depressurized if the vent line is blocked. 3. Bandlock doors may not open due to pressure from significant volumes of oil behind the door. 4. Pig receiver area is bunded and connected to the Oily Water Treatment Package M55090 system; therefore should contain the spill.	17. These instructions clearly state that before commencing work, the operator should know the location of the nearest safety shower and by inference confirm that it is working. There are no emergency showers at the station and to

								5. Slop Tank level is monitored and may provide an indication of the oil still contained within the Pig Receiver when the vent line is opened i.e. provide an indication of vent line blockage. 6. Two vent lines are available in the case of one vent line being blocked. 7. Site standard PPE may protect the operator from exposure to oil 8. Medical facilities including first aider, doctor, infirmary and ambulance.	comply with the Procedures such emergency showers must be installed. Review the requirement for emergency showers implicit in the Procedures. Following this review, either install emergency showers if required or update the operating Procedures to remove reference to emergency showers.
			2. NSCI	R					
			3. Potential for oil to remain within the pig Receiver. Leading to oil spill when the door is opened.	E	G	4	5	1. As above 2. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. NSCI	F					
		2. Manual handling of normal pig Pig cradle is heavy and is moved by manual handling. The pig retrieving tool is manual winching. Including Injury (finger crushing) caused during taking the pig out of the receiver.	1. Crushing/trapping/impact strain/injuries Slipping and tripping hazard potential increased during the snow.	S	F	5	7	1. At least 2 operators during the pig retrieving operation. 2. Site standard PPE may protect the operator or limit injury. 3. Operator Training Competence and Awareness - operators trained in manual handling. 4. Manual handling risk assessment has been completed.	18. The potential for serious personal injuries during the manhandling of pigs in launching & receiving operations. Installing of mechanical handling of pig suggested.
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					

	33. Equipment Integrity - more -late - after	1. Corrosion due to sulfate reducing bacteria (SRB).	1. NSCI	S					19. There is the potential for corrosion due to sulfate-reducing bacteria (SRB) in the Pig Receiver and associated pipework. Ensure that when the Pig Receiver and Pig Launcher is internally inspected that it includes checks for SRB induced corrosion.
			2. NSCI	R					
			3. Pitting corrosion and potentially resulting in penetration of the pig traps and or associated pipework Leading to loss of containment.	E	G	4	5	1. Preventative Maintenance (PM) including intrusive internal inspection of the Pig Receiver every 5 years. 2. Preventative Maintenance (PM) for UT inspection of the bottom of Pig Receiver for internal corrosion. 3. Corrosion allowance on the Pig Receiver.	
			4. Pitting corrosion and potentially resulting in penetration of the pig traps 3and or associated pipework	F	G	4	5	1. as above	
		2. Corrosion Under Insulation (CUI) - can be for extended periods as unseen - can be more severe than typical corrosion if lagging is wet	1. A leak can be more severe than typical corrosion if lagging is wet. Potential for fire, if ignition occurs, leading to injury to operators (pool fire)	S	F	2	4	1. Corrosion Under Insulation (CUI) survey and asset integrity managing plan. 2. Low occupancy around Pig Receiver 3. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 4. Site standard PPE - Flame retardant PPE (FR-PPE) obligable to use. 5. Oil spill emergency response plan for the pump station and pipeline should locate the spill, mitigate the effects of the	20. Corrosion Under Insulation (CUI) is a potential source of failure of pipework and Relief Tanks, Receivers, Launchers and any other insulated equipment in pump and intermediate stations. CUI assessment and inspection program must be scheduled.

								spill and clean up. Booklet Planned drill exercises are conducted by ER teams. ERTAO 6. Oil spill kit (drum based) is available on site for mopping up of small leaks. 7. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. NSCI	R					
			3. The leak can be more severe than typical corrosion if lagging is wet. This will result in ground contamination onsite	E	G	4	5	1. Corrosion Under Insulation (CUI) survey and asset integrity managing plan by integrity contractor are under way at Pump stations.	
			4. Corrosion penetration of pipework leading to large leak which would then need to be repaired. An enlarged inspection program would then be required. The possible shutdown of the pipeline while repairs/replacement are carried out.	F	E	4	7	1. As above	
	34. Human Factors -wrong action	1. Crane handling of the pig by Jib cranes & chain block used to move pig from receiver cradle to ground	1. NSCI						

		& then onto Launcher cradle. Pig has to be rolled along the ground to Launcher area							
	35. Chemical Hazards -more	1. NORM - Natural occurring Radioactive Materials No significant causes identified - tested & no significant amounts found							
	36. Sampling - more - late	1. No significant causes identified In practice, no samples are taken.							
	37. Equipment Siting - as well as	1. The pig receiving area is open (with roof only) & during adverse/extreme weather operations are difficult. Note - walls have been removed to aid ventilation & so prevent the build-up of hydrocarbon							21. The pig launching and receiving area is open (with roof only) and exposed and consequently during adverse/extreme weather operations are difficult. Note - walls have been removed to aid ventilation & so prevent the build-up of hydrocarbon vapors. Assess the shelter provided in the pigging area. Evaluate whether more protection against extreme weather can

		vapors. see recommendation							be provided while maintaining adequate ventilation.
		2. The tundish valve of the pig receiver is located in a pit below ground under grating with limited access.	1. Access to the valve is difficult especially in snow conditions where the pit is full of snow. Leading to potential injury/strain/trapping	S	G	3	4	1. Operator competency, training and awareness - manual handling training.	22. Access to some of the pig receiver open drain tundishes is poor and requires improvement. Identify which of the drains on the station has poor access. Consult with operators to become aware of the issues. Implement improved access to the tundish drain valve.
			2. NSCI.	R					
			3. NSCI.	E					
			4. NSCI.	F					
2. Pig Launching	1. Inspection of Pig Launcher - omitted - incomplete - valve error - too short/long - too late/early - wrong order - wrong action - extra action - SIMOPs	1. pig launching carried out directly after a long shutdown.	1. NSCI.	S					
			2. NSCI.	R					
			3. NSCI.	E					
			4. Possible gel formation within the pipeline. Leading to a stuck pig in the pipeline for a prolonged period of cold weather while waiting for the temperature to rise.	F	D	2	6	1. The pipeline is buried which may alleviate the effects of low ambient temperature. 2. Operator Training Competence and Awareness - operators trained to follow the procedure that stipulates that pig operations should not be completed in the cold pipeline.	
		2. Omitting to check Pig Launcher pressure indicators are 0 barg.	1. Failure to identify pressure build-up in the Pig Launcher. Leading to pressure released unexpectedly from the vent line. NSCI						23. Pig Launching Procedure should provide instruction on what to do if the pressure indicators indicate 0 as required.
	2. Load Pig - omitted - incomplete - valve error - too	1. Check isolation and kicker valve integrity could be omitted.	Unable to identify if MOV's are passing. Unable to confirm isolation. Possible for the opening	S	E	3	6	1. Bandlock door should not open under pressure. 2. Bleed screw should be used to check if the Pig Launcher is pressurized. 3. Operator Training Competence and	24. Pig Launching Procedure, there is a requirement to confirm that the Pig Launcher is at atmospheric pressure. However, the Procedure does

	short/long - too late/early - wrong order - wrong action		of Pig Launcher door under pressure.					Awareness - The operator is trained to follow the procedure which requires venting prior to the opening of the Pig Launcher door. 4. Pressure indicators are located on the Pig Launcher and should indicate pressure within the pig launcher.	not specified how this is to be achieved. Include the reference in Pig Launching Procedure to pressure indicators which are to be used to check the pressure in the Pig Launcher.
			2. NSCI	R					
			3. Unable to identify if MOV's are passing. Unable to confirm isolation. Possible for the opening of Pig Launcher door under pressure. Potential for oil leak from the opened Pig Launcher door.	E	G	3	4	1. As above 2. Pig Launcher is located in a bunded area. 3. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. NSCI	F					
		2. PI installed at MOV's incorrectly or not at all.	1. NSCI - valve check confirming valve is not pressurized can be used instead to confirm no pressure.						
		3. Omitted to close all cavity drains for MOV's after checking them.	1. NSCI	S					
			2. NSCI	R					
			3. Potential for oil to be discharged from the open cavity drain.	E	G	3	4	1. Operator Training Competence and Awareness - operation is completed manually and the operator should see if there is a leak. 2. Rate of discharge limited due to a small drain and which could eventually lead to an overflow at the tundish. 3. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. NSCI	F					

		4. Confirm that pig signalers are set correctly.	1. NSCI - physical flag is a secondary signal confirming electronic signal on SCADA.						
		5. Omit to check that the pig is suitable for launching. The previous incident where the front cover of the pig detached during a run and the time of arrival changed due to degraded flow characteristics of the pig.	1. NSCI	S					
			2. NSCI	R					
			3. NSCI	E					
			4. Pig damaged or bolts loosened leading to a risk of parts of pig detaching during pigging potentially causing damage to strainers and / MOL Pumps at the downstream station.	F	F	5	7	1. Strainers at the downstream stations should catch any particles that may damage MOL Pumps 2. Preventative Maintenance (PM) work orders on the pigs, with actions to replenish pig nuts and bolts annually. 3. The pig should be inspected after receiving the pig and prior to re-launch during the next pigging operation.	
		6. Wrong action - Transfer the pig using the pedestal crane to the pig handling trolley the wrong way round.	1. Potential to insert the pig in the Pig Launcher incorrectly leading to damage to pig and reduced cleaning efficiency. NSCI						
		7. Fail to open tundish valve.	1. NSCI	S					
			2. NSCI	R					
			3. Potential to overflow the tundish.	E	G	3	4	1. Operator Training Competence and Awareness - - operator should notice the overflowing of the tundish. 2. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. NSCI	F					
			1. NSCI	S					

		8. Too short/long - open the telltale valve too quickly.	2. NSCI	R					
			3. Potential to overflow the tundish.	E	H	3	3	1. Operator Training Competence and Awareness - - operator should notice the splashing at the tundish. 2. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. NSCI	F					
		9. Fail to close the tundish drain valve	1. Hydrocarbon fumes generated at the tundish. Potential for fire in the open drains if ignited. Unable to assign a consequence, see recommendation.	S				1. Key interlock on the valve 2. Operator Training Competence and Awareness - operation of the pipeline would not occur if the tundish valve could not be closed. 3. Site ignition controls - equipment in hazardous areas is ATEX rated and where required work is evaluated for ignition potential 4. Other drainages to the Slop Tank could be displacing the fumes back up in the event of tundish valve failure can be closed.	25. Should the valve on the tundish outlet be left open (receiver/launcher), the potential exists for hydrocarbons to be emitted from the tundish especially when the slop tank is being filled. The hazardous area classification drawing which indicates flammable atmospheres (zone 0, 1 and 2) are emitted from the slop tank The worst case scenario recognized that was the potential for the hydrocarbons to be ignited and the flame to propagate back through the drain line to the slop tank. The potential for a major accident. Assess whether the above scenario of hydrocarbons being emitted from tundishes and ignited is credible. Also assess if ignition occurs, if flame propagation back to the slop tank can occur. If so, evaluate existing safeguards. If

									required, install additional safeguards.
			2. NSCI	R					
			3. Potential to overflow the tundish.	E					
			4. Potential for water ingress into the Slop Tank (rain/snow). NSCI	F					
		10. omitted & door not closed	1. Possible ejection of the bleed screw. Projectile leading to possible injury	S	F	3	5	1. Operator Training Competence and Awareness - - training & supervision should ensure adherence of Work Instruction Pig Launching Procedure 2. Low occupancy - probably no one present when a failure occurs. 3. PPE may protect the operator from flying bleed screw. 4. Medical facilities including first aider, doctor, infirmary and ambulance.	
			2. NSCI	R					
			3. Possible door seal leak - leading to a small loss of oil from Pig Launcher	E	H	4	4	1. See above 2. Oil spill kit (drum based) is available on site for mopping up of small leaks. 3. Any foreseeable spill should be contained by the site drainage system	
			4. A possible leak from bleed screw - leading to a small loss of oil from Pig Launcher	E	H	4	4	1. As above	
			5. NSCI	F					
	3. Fill Launcher with oil	1. Valve error - drain valve not closed.	1. see Slop Tank overfill						

	- omitted - incomplete - valve error - too short/long - too late/early - wrong order - wrong action - extra action - SIMOPs	2. vent line valves fail to close	1. Overspill at tundish - fail to open tundish valve.						
		3. omit to open balance line	1. NSCI	S					26. Pig Launching Procedure requires the balance line to be opened. Failure to perform this step could result in possible damage to Launcher isolation valve MOV when pig hits the valve (with more force than usual as not 'cushioned by oil' & valve may be closed). Review the safeguards and evaluate whether additional protection measures to prevent failure to perform this step is required.
			2. NSCI	R					27. If the balance line valve is not open when the Pig Launcher is lined up, there is a possibility of trapped air/gas vapor to be sent forward into the pipeline, with potential for internal pipeline explosion if ignition occurs. Evaluate the above scenario and consequences. Determine if they are credible. Also, if required, implement appropriate remedial actions.
			3. NSCI	E					
			4. Fail to fill the trap with oil. Leading to possible damage to Launcher isolation valve MOV when pig hits the valve (with more force than usually as not cushioned by oil & valve may be closed). Replacement costs and interruption to the pigging schedule	F	G	3	4	1. Operator Training Competence and Awareness - - training & supervision should ensure adherence to Procedures 2. The pig Launcher does not provide a tight fit and consequently, the oil will pass between the pig and the Pig Launcher wall.	
			5. Fail to fill the trap with oil. Leading to - a possible slug of air introduced into the pipeline.	F					

		4. Open the kicker bypass valve quickly	1. NSCI	S					
			2. NSCI	R					
			3. Pig Launcher fills up too fast If the pig receiver is filled with oil, this will lead to uncontrolled pressurization leading to an increased likelihood of a leak from the pig receiver door.	E	H	3	3	1. Pig Launcher is in a bunded area and is located adjacent to a spill pit. 2. Operator Training Competence and Awareness - operator training and supervision should ensure that he is diligent.	
			4. NSCI	F					
		5. Failure to check outline vent valve HV.	1. NSCI - Slop Tank will fill if left open.						28. Confused with the terminology used in the Pig Launching Procedure Review terminology used throughout the Procedure. Associated with 'slowly opening valves' and 'crack open'. Ensure it is clear whether it is meant for the valve to be party opened only (cracked) or fully opened slowly.
		6. failure to ensure that someone is monitoring the Slop Tank	1. Potential overflow of Slop Tank. NSCI. - see Slop Tank node						
		7. Open the bypass valve for too long	1. Exceed 5 barg in Pig Launcher any defects to cause a problem would not be realized as the system would not be tested up to 5 barg e.g.						

			Pig Launcher door seal not tested. NSCI.							
		8. Not open the kicker bypass valve for a long enough time.	1. NSCI	S						
			2. NSCI	R						
			3. Not reach the station discharge pressure. Pig Launcher not fully pressurized. Potential inability to rapidly isolate Pig Launcher if significant door leak occurs.	E						
			4. Not reach the station discharge pressure. Launcher not fully pressurized. Potential inability to rapidly isolate Pig Launcher as with kicker valve unable to isolate Pig Launcher from the pipeline if significant door leak occurs. Possible door seal leak - leading to a small loss of oil from Pig Launcher.	E	G	4	5	1. See above 2. Oil spill kit (drum based) is available on site for mopping up of small leaks. 3. Any foreseeable spill should be contained by a site drainage system		
			5. Not reach the station discharge pressure. Pig Launcher not fully pressurized. Potential to damage kicker line valve seals due to uncontrolled pressure. NSCI.	F						

	4. Isolate and drain the pig launcher - omitted - incomplete - valve error - too short/long - too late/early - wrong order - wrong action - extra action - SIMOPs	1. failure to apply ESD override	1. ESDV may close on pig Fail to isolate the station as ESDV not closed. Leading to additional oil from the pipeline being fed to an onsite loss of containment incident.	S	F	2	4	1. SCADA confirms override status active 2. Beacon shows whether the override is active. If not active then ESDV can be manually locked open by isolating hydraulics. 3. MOV bypass valve can be closed and kicker line bypass valves MOV can be closed thus reducing the additional backflow from the pipeline into the station. 4. Low frequency event as the following would have to co-exist - loss of ESDV integrity - pig in line - Emergency Shutdown (ESD) event on the station 5. If SCADA does not confirm Emergency Shutdown (ESD) override then with supervisor access the ESDV can be made by the SCADA to stay open. 6. Due to the short distance between Pig Launcher and ESD valve, the likelihood of pig getting trapped is minimal.	
			2. NSCI	R					
			3. NSCI	E					
			4. ESDV may close on pig and damage valve & pig Long pipeline shutdown required to retrieve pig & complete repairs.	F				1. as above	
		2.fail to test double block and bleed integrity on MOV	1. NSCI. - Pig Launcher may fill with oil and pressurize before the next use.						

		3. Too short - less than 15 min.	1. NSCI. - Pig Launcher may fill with oil and pressurize before the next use.						
	5. Isolate & Drain Launcher Isolate and drain the pig launcher - omitted - incomplete - valve error - too short/long - too late/early - wrong order - wrong action - extra action - SIMOPs	1. fail to confirm that there is sufficient capacity within Slop Tank	1. Potential for Slop Tank overfill. NSCI. - see Slop Tank node.						
		2. Fail to warn area authority that H2S gas is present, close drain valve and evacuate the area.	1. NSCI. - As a warning in the wrong step of the procedure. See recommendation.						29. A warning exists on Procedure relating to the detection of H2S and Hydrocarbon gas using a personal detector. This warning is in the wrong place in the Procedure as relates to opening a valve to the closed drain system. It would be more appropriate to place this warning when a valve to the open drain system via the tundish is opened. Relocate the warning at any other appropriate step. In addition, reword the warning to include appropriate response to the detection of hydrocarbon gas as well as to the detection of H2S.
		3. Not confirming the Slop Tank level is increased.	1. If the Slop Tank level is not increasing the Pig Launcher is not draining. NSCI.						
		4. Fail to close vent valves.	1. Pig launcher is open to the atmosphere until the next time this is						

			used. If there is a leak into Pig Launcher from e.g. passing kicker valves, isolation valve this may lead to hydrocarbon vapors being displaced from the launcher to the tundish area. NSCI.						
	6. Prep Launcher for Maintenance - omitted - incomplete - valve error - too short/long - too late/early - wrong order - wrong action - extra action - SIMOPs	1. Unable to isolate the Pig Launcher for internal inspection. Positive isolation is stated as mandatory should vessel entry be required.	1. NSCI	S					30. It is not possible to isolate the Receiver or Launcher for internal inspection during normal operation when there is line flow. Positive isolation is stated as mandatory should vessel entry be required. But this can only be done if the pipeline is shutdown. Also, the work instructions should make it clear that for vessel entry, special instructions are required.
			2. NSCI	R					
			3. NSCI	E					
			4. The pipeline will need to be shutdown should an internal inspection be needed.	F	E	3	6	1. None	
		2. Electrical isolation of MOV's.	1. Spurious opening of valves resulting in loss of isolation with a potential large volume of oil entering pig trap. Potential for serious injury/fatality	S	E	3	6	1. Positive isolation required for entry - so a failure of valve isolation would have no effect 2. PTW should ensure isolations in place 3. MOVs cannot be operated local or remote when the hand switch is at off position. Site practice is to lock MOVs at off position	31. Procedure Preparation of Pig Launcher for Maintenance is unclear as to whether to the steps described relate to intrusive or nonintrusive maintenance. Certain of appear to appropriate for intrusive maintenance, but it is unclear whether all steps necessary for intrusive maintenance are included.
			2. NSCI	R					
			3. Spurious opening of valves resulting in loss of isolation with a potential large volume	E	F	2	4	1. As above 2. Software interlock prohibits isolation MOVs being opened when the door is open	

			of oil entering pig trap leading to spill if the door is open						
			4. NSCI	F					
	7. Reinstate the pig launcher - omitted - incomplete - valve error - too short/long - too late/early - wrong order - wrong action - extra action - SIMOPs	1. Omit to ensure all instrument valves are open and instrument vent/drain valves are closed.	1. Incorrect instrument readings - the potential for the operator to be misled Pressure indicators on the Pig Launcher /Pig Receiver will not indicate when there is pressure in the pig launcher/receiver. Leading to a multiple of hazardous scenarios where pressure indication is relied upon. The worst case scenario is when there is a pressure within the pig launcher/receiver. See the opening of the pig receiver/launcher door when pressurized.						
	8. ESD during pig launching Critical / Abnormal Situation - omitted - incomplete - valve error - too short/long	1. Assess the position of a pig using pig transponder.	1. Pig transponder is not always attached to the pig (only used as required). - see recommendation						32. Procedure addressing ESD during pig launching does not consider possible alternative means of isolating station if the ESD valve is not available. This would be the case if an ESD situation arose while the override was applied to ESD Valve and the location of the pig was unclear. Review and assess whether it would be

	- too late/early - wrong order - wrong action - extra action - SIMOPs								appropriate in these circumstances to close the kicker line MOV and launcher bypass MOV to achieve station isolation in the absence of availability of ESDV. If so, update the work instruction accordingly and issue.
	9. Flow -no -more - as well as	1. Reverse flow - from drains back to Pig Launcher while pig trap door is open.	1. Escape of hydrocarbons through the Pig Launcher door. Leading to a spill of oil Leading to release of gas, if ignited could cause a small flash fire.	S	G	3	4	1. The drain valve is key interlocked and in a closed position when the Pig Launcher door is open. 2. Gas vapors should not reverse flow out of the Slop Tank as inlet dip pipes kept below liquid level to form a seal. 3. The inlet valves on the header inlets to the Slop Tank are locked open. 4. Operator competency, training and awareness - operator should not stick head within the Pig Launcher. 5. Site standard PPE may protect the operator or limit injury. 6. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Planned drill exercises are conducted by ER teams. ERTAO 7. Gas detectors monitoring LEL and should alert operators at 10 % LEL.	
			2. NSCI.	R					
			3. NSCI.	E					
			4. NSCI.	F					
	10.Pressure -more	1. Pig Launcher door end pressure gauge	1. NSCI - when the pressure exceeds 6barg the needle will remain						

		only reads up to 6 barg,	at 6barg (and NOT return to 0barg). So the operator will know if pressure exceeds 6 barg.						
	11. Equipment Siting -as well as	1. Pig launching area is open (with roof only) & during adverse/extreme weather operations are difficult.							33. The pig launching and receiving area is open (with roof only) and exposed and consequently during adverse/extreme weather operations are difficult. Note - walls have been removed to aid ventilation & so prevent the build-up of hydrocarbon vapors. Evaluate whether more protection against extreme weather can be provided at the station while maintaining adequate ventilation.
	12. Sampling -more	1. No significant causes identified							
	13. Chemical Hazards -more	1. No significant causes identified							
	14. Human Factors - wrong action	1. Crane handling of the pig by Jib cranes & chain block used to move pig from receiver cradle to ground & then onto	1. NSCI						

		Launcher cradle. Pig has to be rolled along the ground to Launcher area							
	15. Equipment Integrity -more -late	1. Corrosion due to sulfate reducing bacteria (SRB).	1. NSCI	S					
			2. NSCI	R					
			3. Pitting corrosion and potentially resulting in penetration of the pig traps and or associated pipework Leading to loss of containment.	E	G	4	5	1. Preventative Maintenance (PM) including intrusive internal inspection of the Pig Receiver and Pig Launcher every 5 years. 2. Preventative Maintenance (PM) for UT inspection of the bottom of Pig Receiver and Pig Launcher for internal corrosion. 3. Corrosion allowance on the Pig Receiver and Pig Launcher.	34. There is the potential for corrosion due to sulfate reducing bacteria (SRB) in the Pig Receiver and associated pipework. Ensure that when the Pig Receiver and Pig Launcher is internally inspected that it includes checks for SRB induced corrosion.
			4. Pitting corrosion and potentially resulting in penetration of the pig traps and or associated pipework	F	G	4	5	1. As above	
	16. Safety -no	1. Manual handling of normal pig Pig cradle is heavy and is moved by manual handling. The pig retrieving tool is manual winching. Including Injury (finger crushing) caused during	1. Crushing/trapping/impact strain/injuries Slipping and tripping hazard potential increased during the snow.	S	F	5	7	1. At least 2 operators during the pig retrieving operation. 2. Site standard PPE may protect the operator or limit injury. 3. Operator Training Competence and Awareness - - operators trained in manual handling. 4. Manual handling risk assessment has been completed.	35. The potential for serious personal injuries during the manhandling of pigs in launching & receiving operations. installing of equivalent means of mechanical handling of pig
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					

		taking the pig out of the receiver.							
	17. High temperature -more	1. External fire	1. Potential overpressure of the Pig Launcher. Leading to joint / flange failure or possible vessel rupture.	S	F	3	5	1. Low occupancy - operators will not be present 2. Pipework designed for fire relief (ref. API 521). 3. The fire team will respond in case of fire with hoses where there is no firefighting provision is immediately present).	
			2. NSCI	R					
			3. NSCI	E					
			4. Potential overpressure of the Pig Launcher. Leading to joint / flange failure or possible vessel rupture. Damage to equipment and postponement of pigging but not effect pipeline operation	F	F	3	5	1. As above	
	18. Low temperature -less	1. Pigging in low temperature No significant causes identified Pigging is only completed when the pipeline is warm.							
		2. Due to low ambient temperature (-30 °C), the Pig Launcher door	1. NSCI	S					36. The door seals used on the pig launcher and pig receiver do not provide a complete seal at low ambient temperatures (-30 °C) and consequently oil leaks from the door.
			2. NSCI	R					
			3. A leak from door seal whilst Pig Launcher filling.	E	H	7	7	1. Medical facilities including first aider, doctor, infirmary and ambulance. 2. PPE may protect the operator from flying bleed screw.	

		seal becomes brittle.						3. Low occupancy - probably no one present when a failure occurs. 4. Operator Training Competence and Awareness - - training & supervision should ensure adherence of Work Instruction Pig Launching Procedure 5. Oil spill kit (drum based) is available on site for mopping up of small leaks. 6. Any foreseeable spill should be contained by a site drainage system 7. A Spare door seal is kept at a site at a warm location which can be used in low ambient conditions.	Provide seals are suitable for use at low ambient temperatures.
			4. NSCI	F					
	19. Maintenanc e -less -late -as well as -part of	1. Failure of bypass valve	1. This valve is not a double block and bleed and is being used to provide positive isolation. There is no additional spectacle blind on this valve; hence does not provide positive isolation as required by standards.	S	F	4	6	1. Pressure build up test completed prior to the door opening.	37. There is a potential for the Pig Receiver and Pig Launcher door to be opened while isolated from the pipeline that is above 50 barg only by a normal ball valve. Replace receiver/launcher kicker line bypass valve with DBB valves or provide (and use) other means of isolation
								2. Bandlock door should not open under pressure. 3. The catastrophic leak should not occur, consequently, the leak should not be a full bore but markedly less.	
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					
	20. Instrumenta tion -part of	1. Failure of Emergency Shutdown (ESD) override - does	1. ESDV may close on pig Fail to isolate the station as ESDV not closed.	S	F	2	4	1. The integrity of the override ESD system 2. SCADA confirms override status active	

	-late -after	not work when initiated	Leading to additional inventory being fed to an onsite loss of containment incident.					3. Beacon shows whether the override is active. If not active then ESDV can be manually locked open by isolating hydraulics. 4. Low frequency event as the following would have to co-exist - loss of integrity - pig in line - Emergency Shutdown (ESD) event on the station 5. If SCADA does not confirm ESD override then with supervisor access the ESDV can be made by the SCADA to stay open.	
			2. NSCI	R					
			3. NSCI	E					
			4. ESDV may close on pig and damage valve & pig Long pipeline shutdown required to retrieve pig & complete repairs.	F	D	2	6	1. as above	
		4. Mechanism/malfunction key interlock system.	1. The worst case scenario would be door opening whilst pig launcher under pressure. There are various layers of protection that would prevent this e.g. Bandlock NSCI. - As a scenario of the door opening under pressure has been addressed elsewhere.						38. The key interlock mechanisms used in conjunction with the Pig Receiver and Pig Launcher are known to cause key sticking on occasions. When this happens, it may be necessary either to use duplicate keys or to dismantle the mechanism to remove the key. This potentially bypasses the intent of the interlock mechanisms. Review the design of the key interlock mechanisms used in conjunction with the Pig

									Receiver and Pig Launcher and identify whether an improved design is possible to minimize the sticking of the keys. If so, and reasonably practicable then upgrade the mechanism to one where the keys do not stick.
	21. Environmental -as well as	1. It is more difficult to clean the pigging floor area on the stations where the floor is concrete compared with those that have an epoxy coated floor.	1. NSCI	S					39. Some floor areas on the station have been epoxy coated. Confirm that these coatings do not insulate the operator or equipment from the ground thus preventing electrostatic charges to safely dissipate to earth. If the epoxy coating does insulate operator or equipment from the ground then remedial action is to be taken.
			2. NSCI	R					
			3. Minor spills are not adequately cleaned and soaked into the concrete.	E	H	6	6	1. Operator competency, training and awareness - housekeeping protocol should ensure the area is kept clean as much as is possible	
			4. NSCI	F					
3. Wax Handling System	1. No Flow	1. To Inlet Strainers - valve on inlet line closed in error or associated spectacle blind in close position	1. NSCI.	S					
			2. NSCI	R					
			3. NSCI.	E					
			4. Low inlet/suction pressure on Flushing Oil Pump Pumps Leading to pump damage - rotary positive displacement rotary - run dry can cause damage	F	H	4	4	1. Operator competency, training and awareness -operators are trained operating plants. - Valve positions checked 2. Operator competency, training and awareness - PTW & isolation certificates should ensure spectacles and hand valves are in the correct position. 3. Valve normally opened. 4. Flushing Oil Pump Pumps has own protection system - temperature/vibration	

		2. To Inlet Strainers - PSV on Flushing Oil Pump Pumps discharge- lifted	1. Oil circulating around Flushing Oil Pump Pumps and not being pumped forward Oil heats up - NSCI.	S					
			2. NSCI	R					
			3. NSCI.	E					
			4. Oil circulating around Flushing Oil Pump Pumps and not being pumped forward - delay in dewaxing. Possible damage to flushing Oil Pump Pumps.	F	H	4	4	1. Operator competency, training, and awareness -CRO should notice required discharge pressure not reached. 2. Flushing Oil Pump Pumps has own protection system - temperature/vibration 3. Pressure transmitters may alert the operator to low pressures in the discharge line.	
		3. To Inlet Strainers - Blocked line upstream of Flushing Oil Pump Pumps due to drawing wax into suction line during pigging.	1. NSCI.	S					
			2. NSCI	R					
			3. NSCI.	E					
			4. Delay in dewaxing of Inlet Strainers NSCI.	F					
			5. Potential damage to Flushing Oil Pump Pumps	F	H	6	6	1. Heat tracing may melt wax in line. 2. Flushing Oil Pump Pumps not operated until the pig is in the trap & therefore wax should not be drawn into the line. 3. Pressure transmitter PIT may alert the operator to low pressures in the discharge line.	
		4. To Inlet Strainers - MOV on the inlet to Flushing Oil Pump Pumps closed in error or associated	1. NSCI.	S					
			2. NSCI	R					
			3. NSCI.	E					
			4. NSCI.	F					
			5. Low inlet/suction pressure on Flushing Oil Pump Pumps	F	H	4	4	1. Operator competency, training and awareness - Operators are trained operating plants.	

		spectacle blind in close position	Leading to pump damage - rotary positive displacement rotary - run dry can cause damage					- Valve positions checked 2. Operator competency, training and awareness - PTW & isolation certificates should ensure spectacles and hand valves are in the correct position. 3. HV - normally opened. 4. Flushing Oil Pump Pumps has own protection system - temperature/vibration 5. CRO may see on SCADA valve in the wrong position	
		5. To Inlet Strainers - filter blocked	1. NSCI.	S					
			2. NSCI	R					
			3. NSCI.	E					
			4. Low inlet/suction pressure on Flushing Oil Pump Pumps Leading to pump damage - rotary positive displacement rotary - run dry can cause damage	F	H	4	4	1. Flushing Oil Pump Pumps has own protection system - temperature/vibration 2. PDI - local gauge may alert the operator to take corrective action.	
		6. To Inlet Strainers - HV - on Flushing Oil Pump Pumps suction closed in error	1. NSCI.	S					
			2. NSCI	R					
			3. NSCI.	E					
			4. Low inlet/suction pressure on Flushing Oil Pump Pumps Leading to pump damage - rotary positive displacement rotary - run dry can cause damage	F	H	4	4	1. Operator competency, training and awareness - operators are trained in operating the plant. - Valve positions checked 2. Operator competency, training and awareness - PTW & isolation certificates should ensure spectacles and hand valves are in the correct position. 3. HV - normally opened. 4. Flushing Oil Pump Pumps has own protection system - temperature/vibration	

		7. To Inlet Strainers - Pump discharge on HV- closed in error	1. NSCI.	S					40. PSV at downstream on Flushing Oil Pump Pumps has to be set point even under deadhead conditions. Review the set point PSV and modify it if appropriate.
			2. NSCI	R					
			3. NSCI.	E					
			4. High pressure on Flushing Oil Pump Pumps Leading to pump being deadheaded - No significant consequences identified	F					
		8. To Receiver & then to Strainers- issue due to line spec break. - MOV to receiver closed in error - HV downstream of MOV closed in error	1. Potential to overpressure pipework/flange if MOV closed leading to pipework rupture/flange failure. Downstream of MOV as this is where the spec break is. Leading to - pool oil fire - oil mist & flammable atmosphere, flash fire Note; operator probable nearby when the pump is running.	S	E	3	6	1. PSV may prevent pipework rupture/flange failure.	41. There is the potential to overpressure pipework/flange on the Wax Handling System if MOV is closed while the Flushing Oil Pump is pumping. This could lead to pipework rupture/flange failure. This is particular at concern downstream of MOV as this is where the spec break from class 600# to class 300# is. Leading to - oil pool fire - oil mist & flammable atmosphere, flash fire with potential for fatalities. There is no SCADA interlock to prevent the start-up of the pump when the MOV is closed. Assess whether it is appropriate to include an interlock on the pump to prevent the start-up of the pump when the MOV is

									closed. If appropriate install such an interlock.
								2. Pressure transmitter PIT sending high alarm 3. Procedure station suction pressure is below maximum suction pressure. 4. Flushing Oil Pump Pumps protection system should trip the pump drive on high vibration & temp 5. Fixed and portable firefighting equipment is on site and if employed may control or extinguish the fire. 6. Site standard PPE may protect the operator or limit injury. 7. Medical facilities including first aider, doctor, infirmary and ambulance are available on site and may reduce the severity of any injury. 8. Site ignition controls - equipment in hazardous areas is ATEX rated and where required work is evaluated for ignition potential.	42. There is the potential to overpressure pipework/flange on the Wax Handling System if MOV is closed while the Flushing Oil Pump is pumping. This could lead to pipework rupture/flange failure. This is particular at concern downstream of MOV as this is where the spec break from class 600# to class 300# is. This leading to - oil pool fire - oil mist & flammable atmosphere, flash fire with potential for fatalities. Note: operators are in attendance when the system is running. Evaluate whether fitting flange guards to exposed flanges on the hot oil system would reduce risk. Install flange guards if they enhance safety.
			2. NSCI	R					
			3. NSCI.	E					
			4. If the pump does not trip & PSVs lift then the Slop Tank may be overfilled. See Slop Tank node.	F					
		9. To Receiver & then to Strainers-Discharge side of Pig Receiver - Valves closed in error	1. Failure at the trap (rated 300#) - probably at the flange. Leading to loss of oil. leading to - pool oil fire	S	E	3	6	1. Receiver PSV may prevent overpressure 2. PSV on Wax Handling unit may prevent overpressure 3. Fixed and portable firefighting equipment is on site and if employed may control or extinguish the fire.	

			- oil mist & flammable atmosphere, flash fire					4. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 5. Site standard PPE may protect the operator or limit injury.	
			2. NSCI	R					
			3. NSCI.	E					
			4. If the pump does not trip & PSVs lift then the Slop Tank may be overfilled. See Slop Tank node.	F					
		10. To Receiver & then to Strainers- MOV associated hand and checked valves downstream of the MOV closed in error MOV Hand valves or Check valves	1. Failure at the trap (rated 300#) - probably at the flange. Leading to loss of oil. Leading to - pool oil fire - oil mist & flammable atmosphere, flash fire - possible explosion as a congested area. If a leak in the gallery area then the Piping House above may be affected.	S	E	3	6	1. Receiver PSV may prevent overpressure 2. PSV on Wax Handling unit may prevent overpressure 3. Fixed and portable firefighting equipment is on site and if employed may control or extinguish the fire. 4. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 5. Site standard PPE may protect the operator or limit injury.	
			2. NSCI	R					
			3. NSCI.	E					
			4. Damage to Piping House due to fire/explosion	F	D	2	6	1. As above 2. Fire and Gas detectors will initiate station ESD that will stop the Flushing Oil Pump	
			5. If the pump does not trip & PSVs lift then the Slop Tank may be overfilled.	F					

	2. Less Flow	1. To Inlet Strainers - HV on inlet line closed in error or associated spectacle blind in close position	1. NSCI	S					
			2. NSCI	R					
			3. NSCI.	E					
			4. Low inlet/suction pressure on Flushing Oil Pump Pumps Leading to delay in dewaxing of Strainers - eventual inlet strainer blockage would stop oil flow in the pipeline	F	H	2	2	1. Standby Inlet Strainer can be brought on line	
		2. Passing relief valve(s)	1. For effect on Slop Tank 2. Reduced flow leading to slower dewaxing operations - No significant consequences identified.						
		3. To nozzles on Pig Receiver due to wax blockage or some closed nozzle valves	1. Incomplete dewaxing identified when the launcher is opened. Repeat dewaxing operations will be carried out. Problems resolved within one week (i.e. before the next pig to be launched) will not have any impact on pipeline operations. NSCI.						
	3. More Flow	1. Flushing oil pump speed control failure (high)	1. High flow but low temperature resulting in inefficient flushing - delay to dewaxing operations. (also see No						

			Flow for a deadheaded pump) - NSCI.						
		2. When flushing the suction strainers High Pressure Pump started in error by operator.	1. High pressures produced in Class 300 pipework downstream of MOV with potential to rupture the pipework leading to escape of high pressure hot oil in an area where an operator is likely to be present during this operation. Possible spray release from ruptured flange leading to flash fire if ignited resulting in a potential fatality	S	E	2	5	1. The High Pressure Pump has yet to be successfully commissioned, however, commissioning may happen in the future 2. Operator competency, training and awareness - Trained operators should be aware that the high pressure pump should not be switched on during Suction strainer flushing 3. Inlet and outlet manual valves at High Pressure Pump are normally closed and would need to be opened for this scenario to occur. 4. The High Pressure Pump automatically begins at low speed and requires additional incorrect action to increase the pump. 5. PSV downstream of MOV may relieve sufficient pressure to prevent rupture. 6. PAH should alarm locally and alert the operator to the high pressure and take corrective action. 7. Site standard PPE - FR-PPE obligable to use. 8. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 9. Medical facilities including first aider, doctor, infirmary and ambulance are available on site and may reduce the severity of any injury.	
			2. NSCI.	R					
			3. High pressures produced in Class 300	E	G	3	4	1. as above 2. Fire and Gas system should detect the	

			pipework downstream of MOV with potential to rupture (flange leak) the pipework leading to escape of high pressure hot oil onsite, within buildings or bunded areas.					leak within the Piping House and ESD the pumps, reducing the volume of the leak 3. Oil spill response plan and kit	
			4. NSCI.	F					
	4. Part of Flow	1. No significant causes identified.							
	5. Other than Flow	1. No significant causes identified.							
	6. Wrong Percentage	1. No significant causes identified.							
	7. Wrong Material	1. No significant causes identified.							
	8. High Pressure	1. Blocked in the section between MOV and HV on the Wax Handling inlet.	1. NSCI. - see recommendation						43. There are some sections of the station pipework that can be locked in but do not have thermal relief valves, for example, Station Outlet Emergency Shutdown (ESD) Valve to Launcher Bypass valve MOV, Station Inlet ESD Valve to Bypass MOV at the station on Wax Handling Inlet line. Conduct a review of locked in sections to establish whether adequate protection against thermal expansion of crude oil has been provided for each relevant section. Provide adequate protection where this does not currently exist.

	9. Low Pressure	1. Pump suction valve MOV closed - see No Flow							
		2. Low Flushing Oil Pump pressure - See Less Flow							
		3. Cooling of hot oil in locked in section causing a partial vacuum							
	10. High Temperature	1. No oil flow through heat exchanger while hot water is being supplied from the heating system with oil left in a heat exchanger.	1. Heating of oil left inside the heat exchangers up to (worst case) up to heating medium temp NSCI.						
		2. Power failure wax handling flushing pump stopped & MOVs closed but heating circulation pump kept running with oil trapped in a heat exchanger. Leading to oil spill from heat exchanger flange.	1. Leading to oil spill from heat exchanger flange - potential fire risk.	S	F	5	7	1. PSV should reduce the severity of the leak	44. A power surge caused trips that resulted in the wax handling Flushing Oil Pump stopping and MOVs closing but heating circulation pump kept running with oil trapped in a heat exchanger. This lead to an oil spill from the heat exchanger flange. It is also known that PSV lifted but obviously did not prevent failure of the gaskets/bolts/nuts. Additional evidence suggests that the flanges failed below their

		It is known that SV and PSV were lifted. Flanges failed below design pressure.							design pressure. Ensure that on the loss of power, the wax handling unit is left in a safe state and that no areas can become over-pressurized.
								2. Fixed and portable firefighting equipment is on site and if employed may control or extinguish the fire. 3. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 4. Site standard PPE may protect the operator or limit injury. 5. Medical facilities including first aider, doctor, infirmary and ambulance are available on site and may reduce the severity of any injury.	45. Review and assess the design of the heat exchanger flange and the service condition which it experiences and identify and implement any modifications to minimize the risk of failure below its design pressure.
			2. NSCI.	R					
			3. Leading to oil spill from heat exchanger flange - ground contamination (reported to be around 5 liters leak).	E	H	6	6	1. Bunded area & should contain small leaks 2. PSV should reduce the severity of the leak 3. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERTAO	
			4. NSCI.	F					
		3. Passing heat exchanger tubes - due to corrosion on the oil side - oil came out the water PSVs & contaminated the	1. Loss of oil - out of water PSVs which are set at a lower pressure that the oil If ignite a fire will result. Leading to injury/ fatality	S	E	4	7	1. Fire and gas detection system may alert the operator 2. An annual inspection of a heat exchanger 3. Fixed and portable firefighting equipment is on site and if employed may control or extinguish the fire.	46. Should there be a tube failure in the wax handling system heat exchangers the oil may well enter the water heating side and be ejected out of the water PSVs. Hot oil is ejected into the work

		water distribution system						4. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Planned drill exercises are conducted by ER teams. ERTAO 5. Medical facilities including first aider, doctor, infirmary and ambulance are available on site and may reduce the severity of any injury. 6. Low occupancy - Operators only enter four times per day to complete checklists	place presents a significant hazard. Corrosion of the heat exchangers has happened on several occasions. On one occasion the oil entering the heating side lifted the PSVs on the heating circuit and was ejected into the workplace. A review of the heat exchanger system shall be performed to identify both means to reduce the corrosion of the heat exchangers tubes and to identify any practical means to reduce the consequences if a leak occurs. This review should include consideration of separating the wax handling system water heat system such that contamination of the system would not affect other users' heating water systems. Implement the results of the review.
			2. Loss of oil - Heating system Boiler contaminated see Diesel Fuel System Deviation	S					
			3. NSCI.	R					
			4. Oil flow inside utilities building	E	G	5	6	1. The building is closed and should contain the spill. 2. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			5. Maintenance cost Bundle (tubes)	F	F	5	7	1. As above	

			replacement Heat Exchanger replacement						
		4. External fire - e.g. from an oil leak, pallets Loss of oil will add fuel to an existing fire. Possible Delayed pigging	1. NSCI.	S					
			2. NSCI.	R					
			3. Loss of oil - may be consumed by the fire - remaining oil should be contained. NSCI.	E					
			4. Equipment damage / pipe rupture.	F	F	3	5	1. Fixed and portable firefighting equipment is on site and if employed may control or extinguish the fire. 2. The system is insulated which will provide protection from thermal radiation 3. When not in use system is isolated & depressurized	
		5. Omitting of final flush with cool oil Resulting in hot Pig receiver to temperature.	1. Hand burns when opening the door, taking the pig out	S	G	4	5	1. PPE - gloves should protect hands from burns. 2. Operator competency, training and awareness - Work Instructions require a cold flush after the hot flush 3. Operator competency, training and awareness - experienced operators who know not to proceed with pig removal if the pig receiver is too hot	
			2. Hot oil results in higher vapor pressure and subsequently more hydrocarbons in the atmosphere. If ignited - flash fire	S	E	3	6	1. as above 2. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 3. Before the pig retrieval gas detector placed at the door & also operators wait before for a period before removing the pig.	
			3. NSCI.	R					
			4. NSCI.	E					

			5. NSCI.	F					
		12. Flushing Oil Pump can overheat due to mechanical failure (e.g. bearing failure causing friction between twin screws)	1. NSCI	S					
			2. NSCI	R					
			3. NSCI.	E					
			4. Pump damage & delay in pigging	F	G	4	5	1. The pump protection system (temp & vibration) should stop the pump before it is damaged. 2. Routine maintenance should ensure that the pump is in a healthy state 3. Operator competency, training and awareness - operators check the pump oil level when it is online.	
	11. Low Temperatur e	1. - No flow of heating fluid - Heat exchanger fouling reducing heat transfer - Fluid flowing too fast - Temperature controller TIT failing low	1. Loss of heating resulting in inefficient wax flushing NSCI. - as recoverable / manageable/ low impact						
		2. An extended shutdown of pipeline in winter conditions can cause difficulty in restarting the wax handling system due to gelling or wax buildup in the wax handling system.	1. NSCI	S					
			2. NSCI	R					
			3. NSCI.	E					
			4. Delay to wax handling operations. Potential for some delay (estimate 1 week) to pigging operations. NSCI.	F					
			5. Delay to wax handling operations. The worst-case could be delay until summer	F	G	3	4	1. Pipeline planned shutdowns are planned to avoid an extended shutdown which could lead to significant gelling problems (typically less than 60 hours)	

			conditions result in the de-gelling of the blockage. Excessive buildup of wax in the upstream section of the pipeline as pigging cannot be completed. An extended pigging program will be implemented to slowly clear the wax following line warm up.					2. The actual worst-case unplanned shutdown to date was 15 days (summer) with no detrimental effect on the wax handling systems. 3. Wax handling system can be dismantled and cleaned when blockages occur.	
	12. Reaction	1. No significant causes identified.							
	13. Relief	1. Valve closed on line to PSV or blocked with wax	1. PSV is not available on demand to relieve high pressure in the system, resulting in potential flange rupture and loss of containment of oil. Potential for spray release and flash fire if ignited. Potential for fatality if the operator is located at the ignited leak.	S	E	3	6	1. Valves are locked open. LOLC register checks carried out bi-weekly 2. Lines upstream of the Flushing Oil Heat Exchanger to some PSVs are insulated and heat traced 3. Infrequent demand on PSVs (only 1 or 2 cases know to date where PSV in the wax handling systems have lifted) 4. High Pressure from deadheaded Flushing Oil Pump should be prevented by pump pressure protection system 5. Routine preventative maintenance of the PSVs may identify blockages and root cause. 6. Site standard PPE - FR-PPE obligable to use. 7. Oil spill kit (drum based) is available on site for mopping up of small leaks. 8. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up.	

								Planned drill exercises are conducted by ER teams. ERTAO 9. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated.	
			2. NSCI.	R					
			3. NSCI.	E					
			4. NSCI.	F					
	14. Rupture/Leak	1. See rupture leak on Main Oil Lines nodes							
		2. Tube rupture within the Wax Handling System heat exchanger. See High Temperature deviation							
	15. Instrumentation	1. Hot Oil outlet temperature controller TIT or associated valve failure resulting in incorrect oil temperature. See High and Low temperature deviations							
	16. Chemical Hazards	1. No significant causes identified.							47. There is a drain valve HV on the inlet line to PSV. Unable to identify a purpose for this valve. The inclusion of unused valves
		1. Corrosion at drain line valve	1. NSCI.	S					
			2. NSCI.	R					

	17. Equipment integrity	HV upstream of PSV may be a deadleg - no use for this valve has been identified.	3. Possible loss of product following corrosion, leading to a small oil spill.	E	G	4	5	1. The valve is blanked, which should minimize the risk of leakage. 2. Daily walk around should identify any corrosion or leakage from this valve 3. The hot oil system can be isolated, as it is only used intermittently	on a piping system is poor engineering practice and can lead to unintended leakage paths. Review the requirement for this valve and remove it if not required. If this valve is required, ensure that it is included in any deadleg register for the pump stations.
			4. NSCI.	F					
	18. Abnormal Operation	1. Following isolation of the wax handling unit (when not in use) repressurizing of the system requires opening of MOV against a high differential pressure. Note: wax handling system remained pressurized when not in use prior to heat exchanger tube failure issue, but on manufacturer's advice changed to depressurizing between uses).	1. NSCI.	S					48. Following isolation of the wax handling unit (when not in use) repressurizing of the system requires opening of MOV against high differential pressure. Note: The wax handling system remained pressurized when not in use prior to the heat exchanger tube failure issue, but on manufacturer's advice changed to depressurizing between uses. In this circumstance, the valve will not open using an actuator, requiring manual opening against a high torque, with the potential for valve seat damage. Review with relevant valve manufacturers whether it is acceptable to open any station MOVs manually at a torque above the actuator torque limit. If not, ensure that this
			2. NSCI.	R					
			3. NSCI.	E					
			4. Valve will not open using an actuator, requiring manual opening. (Torque limit on the actuator of MOV gives a fault setting rather than opening with high torque.) Site practice is to open manually at higher torque, resulting in a potential for seat damage.	F	G	6	7	1. Other valves can provide required isolation.	

									practice is not implemented on site.
	19. Maintenanc e	1. Discharge nozzle is at the top of the heat exchanger may promote corrosion because of oil backflow resting on tubes	1. Oil passing into the heating system see deviation on high temperature	S					
			2. NSCI.	R					
			3. NSCI.	E					
			4. Loss of heat exchange and delay in dewaxing	F	G	3	4	1. Preventative Maintenance (PM) Maintenance on heat exchanger	
		2. Removal of tubes from heat exchanger using a mobile crane	1. Supported at one end for removal. Potential for tubes to fall when another end is extracted from the exchanger. Possible personal injury/fatality due to falling tubing	S	E	4	7	1. Operator competency, training and awareness - Operator should comply with lifting plan which should ensure he is not below tubes while they are being extracted. 2. Control of Work Procedures. 3. Infrequent operation - annual. 4. Site standard PPE may protect the operator or limit injury.	49. The current practice for extracting the heater tubes from Heat Exchanger has the potential to result in the tubes falling from height when extracted, as they are supported from one end only during extraction. This could result in fatality for any personnel in the vicinity when the tubes fall. Review the lifting plan for this operation and introduce more robust measures to prevent falling of the unsupported end during extraction.
			2. NSCI.	R					
			3. NSCI.	E					
			4. Supported at one end for removal. Potential for tubes to fall when another end is extracted from the exchanger. Possible replacement costs for damaged tubing.	F	G	5	6	1. As above. 2. It may be possible to repair a tube bundle rather than a full replacement.	
		3. Inner tubes of the heat exchanger tube bundle cannot be visually	1. Corrosion pitting of the external surfaces of the inner tubes of the bundle cannot be detected, leading to the	S	E	4	7	1. Fire and gas detection system may alert the operator 2. Fixed and portable firefighting equipment is on site and if employed may control or extinguish the fire.	50. Inner tubes of the heat exchanger tube bundle cannot be visually inspected during annual maintenance. Corrosion pitting of the external surfaces

		inspected during annual maintenance.	potential for incipient corrosion failure not being detected. Resulting in the loss of oil - out of water PSVs which are set at a lower pressure that the oil If ignite a fire will result. Leading to injury/ fatality					3. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERTAO 4. Medical facilities including first aider, doctor, infirmary and ambulance are available on site and may reduce the the severity of any injury. 5. Low occupancy - Operators only enter four times per day to complete checklists	of the inner tubes of the bundle cannot be detected, leading to the potential for incipient corrosion failure not being detected. This would result in loss of oil to the hot water system, and then out of water PSVs which are set at a lower pressure that the oil (known incident). If ignited a fire will result, with the potential to lead to injury/ fatality. Consider enhanced inspection activities for the tube bundle, in addition to the visual inspection, to ensure that corrosion of the inner tubes of the bundle is detected.
			2. Corrosion pitting of the external surfaces of the inner tubes of the bundle cannot be detected, leading to the potential for incipient corrosion failure not being detected. Resulting in the loss of oil - Heating system Boiler contaminated see Diesel Fuel System Deviation	S					
			3. NSCI.	R					
			4. Oil flow inside utilities building	E				1. As above. 2. The building is closed and should contain the spill.	

								3. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			5. Maintenance cost Bundle (tubes) replacement Heat Exchanger replacement	F	F	5	7	1. As above	
4. Main Oil Line	1. No Flow	1. Pump Suction - Emergency Shutdown Valve (ESDV) closed caused by - human error - SCADA error/false signal	1. Pressure buildup in pipeline upstream of Emergency Shutdown Valve (ESDV) resulting in potential overpressure of the pipeline above Maximum Allowable Operating Pressure (MAOP) leading to pipeline failure resulting is a large offsite oil leak and fire if ignited. Potential fatalities to anyone nearby to ignited release.	S	E	2	5	1. The surge relief system should divert flow to the Relief Tank ensuring that Maximum Allowable Operating Pressure (MAOP) is not exceeded and loss of containment does not occur.	
								2. Block valves upstream should limit the quantity released 3. The upstream station will trip on the loss of the "open" signal from the Emergency Shutdown Valve (ESDV) (ICSS). 4. Operator Training Competence and Awareness - The operator should rapidly identify that the upstream station is continuing to pump at a closed Emergency Shutdown (ESD) and trip the upstream station. 5. Operator Training Competence and Awareness - the station control room operator should rapidly identify that the upstream station is continuing to pump at a closed Emergency Shutdown (ESD) and request a trip of the upstream station. 6. Operator Training Competence and Awareness should ensure that the Emergency Shutdown Valve (ESDV) valve is not closed in error. 7. Low Low Pump Suction Pressure alarm should warn the station operator allowing corrective action to be taken.	51. Station Inlet ESD valve closure (caused by, for example, human error or ICSS error/false signal) there could be overpressure of the upstream pipeline potentially resulting in pipeline failure. Pipeline failure would result in significant safety and environmental risk. If Station Inlet ESD closure (in the absence of any safeguards such as the surge system) can result in pipeline overpressure (including surge pressure) which exceeds the pipeline MAOP sufficiently to result in line rupture. If pipeline rupture is not found to be a credible consequence, then this HAZOP should be reviewed to consider the actual consequences of the identified maximum overpressure. For example, a low level of

								8. The leak detection system should alert the operator and enable an early response to any loss of oil. 9. Pipeline design includes additional design integrity at sensitive locations for example river and road crossings.	overpressure beyond the MAOP may not be sufficient to fail the pipeline
								10. PTW should ensure (by installing an over-ride) that the valve positioner is not contacted/closed in error during maintenance on the valve. 11. Local manual Emergency Shutdown (ESD) pushbuttons have protection covers which should prevent accidental activation. 12. Maintenance and testing of the ICSS should ensure that the likelihood of a false signal is reduced to a low level. 13. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. 14. Internal inspection using ILI pigging should ensure that any pipeline weaknesses are identified and repaired. 15. Fire & Gas (F&G) system should detect fire and initiate station Emergency Shutdown (ESD) and alert operator. 16. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated.	
			2. Pressure buildup in pipeline upstream of Emergency Shutdown Valve (ESDV) resulting in potential	R	D	3	7	1. As above 2. Incident Management Team has personnel trained and authorized to provide accurate information to the media and the public.	

			overpressure of the pipeline above MAOP leading to pipeline failure resulting is a large offsite oil leak and fire if ignited. The worst-case could be a spillage into River. Oil Spill Response: Requires transboundary response for the Tier 2-3 spill. Response details are given in the containment manual and OSRP. Impact: Environmental and Social River Crossing: 1. Wildlife Protection Area 2.Bird and Fish sensitivity on River 3.Ecological Special Response Area 4.Archaeological site Forest 6. Ecological Sensitive Area This will result in adverse national and international media coverage. The actual severity of the outcome will depend on the extent to which the pipeline is over pressured (the line	E	D	3	7	1. Block valves upstream should limit the quantity released 2. Surge Relief System should divert flow to the Relief Tank ensuring that MAOP is not exceeded and loss of containment does not occur. 3. The upstream station will trip on the loss of the "open" signal from the Emergency Shutdown Valve (ESDV) (ICSS). 4. Operator Training Competence and Awareness should ensure that the valve is not closed in error. 5. Pipeline design includes additional design integrity at sensitive locations for example river and road crossings. 6. PTW should ensure (installing an over-ride) that the valve positioner is not contacted/closed in error during maintenance on the valve. PTW Procedure 7. Local manual Emergency Shutdown (ESD) push-buttons have protection covers which should prevent accidental activation. 8. Maintenance and testing of the ICSS should ensure that the likelihood of a false signal is reduced to a low level. 9. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up.	
				F	C			1. As above	

			has a variable rating), and the location at which the release occurs (e.g. over a water course, compared to over ground).						
		2. MOL Pumps Suction - Pig Receiver Bypass valve MOV closed	1. No additional significant consequences identified (see cause 1).						
			2. NSCI						
			3. NSCI						
			4. Closure of Pig Receiver Bypass valve MOV valve will result in a "loss of flow path". This will cause the station outlet Emergency Shutdown Valve (ESDV) to close. Station Shutdown (SSD) is executed on pressure high alarm. This will send SSD to the upstream station. No significant consequences.						
		3. MOL Pumps Suction - MOV upstream of Station Inlet Strainers or MOV downstream closed in error.	1. Overpressure of Class 150 pipework in pump station upstream of closed MOV resulting in rupture and loss of containment within the station. Leading to oil fire	S	F	3	5	1. Surge Relief system should divert flow to the surge Relief Tank ensuring that MAOP is not exceeded and loss of containment does not occur.	52. There is the potential for large oil spills within the station. This could result in oil or and contaminated firewater flowing offsite. There are adequate plans in place to deal with contaminated firewater and prevent environmental damage. These plans must

			within the station and potential injury.						ensure that a full assessment is made of the potential volume of contaminated firewater, its pathways, receptors and its disposal.
								2. The station will trip on the loss of the "open" signal from the valve MOV (ICSS).	53. There are an Oil Spill Response Procedure and Containment Site manuals in place to tackle oil spills. These documents are out of date. As a matter of urgency, these documents must be updated.
								3. Operator Training Competence and Awareness - The operator should rapidly identify that the upstream station is continuing to pump at a closed valve and trip the upstream station.	54. The Fire Response Plan for the pump station is out of date. As a matter of urgency, these documents must be updated.
								4. Operator Training Competence and Awareness - the station control room operator should rapidly identify that the upstream station is continuing to pump at a closed valve and request a trip of the upstream station. 5. Standby Station Inlet Strainer Motor Operated Valve (MOV) valves open automatically where manual valves on the online strainer are closed via the ICSS. 6. Fire & Gas (F&G) system should detect fire and initiate station Emergency Shutdown (ESD) and alert operator. 7. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 8. Operator Training Competence and Awareness - Operator should initiate	55. On the pipeline that procedures critical to safety have not been kept up to date, for example, Oil Spill Response Plan Procedure, Containment Site Manuals and Fire Response Plan. Allowing such procedures to become out of date is indicative that Safety Management Systems are failing. Its safety management systems to ensure that safety critical documents are current and effective. As a minimum, there must be an effective audit and review procedure of all key documents.

								station shutdown on the detection of fire if not already shut by the ICSS. 9. Site standard PPE - FR-PPE obligable to use. 10. Medical facilities including first aider, doctor, infirmary and ambulance are available on site and may reduce the severity of any injury.	
			2. No significant additional consequences	R					
			3. Overpressure of Class 150 pipework in pump station upstream of closed MOV resulting in rupture and loss of containment within the station. Large oil leak estimated up to 1000m3. Potential to leave site boundary at PT1.	E	F	3	5	1. As above 2. Oil spill response teams. Planned drill exercises are conducted by ER teams. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. - Emergency Response Procedure - Oil Spill Response Plan and Oil Spill Containment Booklet	
			4. Overpressure of Class 150 pipework in pump station upstream of closed MOV resulting in rupture and loss of containment within the station. This will result in pipeline operational interruption of one week to effect repairs. (estimate $25M per day)	F	D	3	7	1. As above 2. Pipeline repair team and spares/equipment are available for class 150 pipework.	
		4. MOL Pumps Suction - Single	1. No significant additional consequences						56. No satisfactory explanation for why this issue

		Main Oil Line Pumps (MOL) inlet Motor Operated Valve (MOV) closed in error when pump online.	2. No significant additional consequences						has not been successfully resolved was given. Nor was any justification given for the pump station to operate with this matter unresolved. To leave such issues unexplained and not justified is a clear failing of safety management systems.
			3. No significant additional consequences						
			4. Decreased suction pressure - potential cavitation damage to associated MOL pump.	F	G	4	5	1. PALL should trip MOL Pumps before damage is caused. 2. The station control system will increase the speed of the online Main Oil Line Pumps (MOL) and or bring online the standby MOL pump as required to reduce suction pressure to set point.	
			5. Increased suction pressure on remaining online Main Oil Line Pumps (MOL) resulting in heavy knocking of the engines due to overloading of the pumps. This will cause engine damage and potential MOL pump damage if not detected for some time.	F	G	4	5	1. Main Oil Line Pumps (MOL) Engines have heavy knocking protection which should trip engine.	
		5. MOL Pumps Discharge - Main Oil Line Pumps (MOL) discharge MOV closed (and recycle valve is closed) - Single Main Oil Line Pump (MOL) discharge check valve HV failed closed	1. High pressure (within MOL Pumps discharge pipework design pressure) on Main Oil Line Pumps (MOL) discharge. The pump will overheat on deadheading resulting in pump seal damage within minutes. If all seal oil is lost to the pipeline, the loss of crude oil containment	S	F	3	5	1. Main Oil Line Pumps (MOL) High high discharge temperature trip TAHH 2. Main Oil Line Pumps (MOL) high high discharge pressure trip PAHH 3. Seal oil low level alarm, operator to investigate. 4. Seal oil low low level alarm and the trip of Main Oil Line Pumps (MOL) engine 5. High temperature trip TAHH on Main Oil Line Pumps (MOL) case on the engine control system. 6. Control of Site for ignition -	

			via the damaged seal will result. The potential of oil spray which if ignited could result in an injury.					ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 7. Site standard PPE - FR-PPE obligable to use. 8. Fire & Gas (F&G) system should detect fire and initiate station Emergency Shutdown (ESD) and alert operator. 9. Manual activation of foam deluge on MOL pumps should extinguish a fire at the MOL Pumps	
			2. No significant additional consequences	R					
			3. No significant additional consequences	E					
			4. High pressure (within MOL Pumps discharge pipework design pressure) on MOL pump discharge - pump deadheaded. The pump will overheat on deadheading resulting in pump seal or impeller damage within minutes. Single MOL pump to be repaired.	F	G	3	4	1. Temperature high high trip TAHH on MOL Pumps discharge should trip the pump. 2. Discharge pressure high high trip PAHH on MOL Pumps discharge should trip the pump. 3. MOL Pump spares; 1 impeller in the country and seals available on site. 4. Standby MOL Pump available. 5. High temperature trip on MOL Pumps case on the engine control system should stop the MOL pump engine.	
		6. MOL Pumps Discharge - - MOV valve, upstream of the pressure controller, to the Pig Launcher, closed	1. High pressure (within pump discharge pipework design pressure) on Main Oil Line Pumps (MOL) discharge. The pump will overheat on deadheading resulting	S	F	3	5	1. Main Oil Line Pumps (MOL) high high discharge temperature trip TAHH 2. High temperature trip on MOL Pumps case on the engine control system should stop the MOL pump engine. 3. Seal oil low level alarm, operator to investigate. 4. PCV bypass is available to the operator	

		- MOV to the Launcher closed - PCV driven closed - Pump discharge manifold check valve HV failed closed - Pig Launcher Bypass valve MOV closed - Station Outlet Emergency Shutdown Valve (ESDV) closed	in pump seal damage within minutes. If all seal oil is lost to the pipeline, the loss of crude oil containment via the damaged seal will result. The potential of oil spray which if ignited could result in an injury.					to manually relieve pressure. 5. Seal oil low low level alarm and the trip of Main Oil Line Pumps (MOL) engine 6. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 7. Fire & Gas (F&G) system should detect fire and initiate station Emergency Shutdown (ESD) and alert operator. 8. Manual activation of foam deluge on MOL pumps should extinguish a fire at the MOL Pumps 9. Site standard PPE - FR-PPE obligable to use. 10. Station discharge surge relief should relieve the pressure safely 11. Main Oil Line Pumps (MOL) high high discharge pressure trip PAHH 12. For Pig Launcher Bypass valve MOV and Emergency Shutdown Valve (ESDV) PAHH high high pressure trip should prevent overpressure by tripping the station Emergency Shutdown (ESD). 13. Position sensors on MOVs indicated on ICSS, should alert the operator to valves moving off set position.	
			2. No significant additional consequences	R					
			3. No significant additional consequences	E					
			4. All pumps deadheaded. High pressure in MOL Pumps discharge	F					

			pipework but within design pressure. All online pumps will overheat resulting in pump seal or impeller damage in minutes. No significant additional consequences.						
		7. MOL Pumps Discharge - Loss of external electrical power to the station resulting in loss of power to all online MOL Pumps packages	1. No significant additional consequences	S					
			2. No significant additional consequences	R					
			3. No significant additional consequences	E					
			4. Loss of MOL Pumps axillaries including seal oil (electrically driven pump). On the loss of seal oil pressure the MOL pump trips. Mechanical seal failure which requires replacement. Pumps will stop resulting in a loss of flow until electrical power is restored.	F	F	4	6	1. Dynamic Uninterruptible Power Supply (UPS) provides sufficient power to run essential services at the station including the MOL Pump auxiliaries for 20 minutes or until the emergency generators kick in. 2. Control power and 380V Uninterruptible Power Supply provides sufficient power for control systems even if dynamic Uninterruptible Power Supply fails. 3. Emergency generators should kick in within 20 seconds to provide sufficient power to run essential services at the station including the MOL pumps axillaries 4. Secondary external electrical supply 5. Maintenance and testing of dynamic Uninterruptible Power Supply. Due to inconsistencies in external supply, the system is frequently in use to maintain frequency so it is proven in use.	

								6. Maintenance and testing of Emergency generators (duty and standby)	
		8. MOL Pumps Discharge - Loss of local electrical power to the online MOL Pumps package	1. No significant additional consequences	S					
			2. No significant additional consequences	R					
			3. No significant additional consequences	E					
			4. Loss of MOL Pumps axillaries including seal oil (electrically driven pump). On the loss of seal oil pressure the MOL pump trips. Mechanical seal failure which requires replacement. The pump will stop resulting in a loss of flow until electrical power is restored. At higher flowrates, online MOL Pumps will trip sequentially due to overload. At lower flow rates, the other pumps will increase speed to maintain flow.	F	G	5	6	1. Standby MOL Pump available and should be started by the station operator.	
	2. Less Flow	1. MOL Pumps Suction - Station strainer blockage	1. No significant additional consequences	S					
			2. No significant additional consequences	R					
			3. No significant additional consequences	E					
			4. Low MOL Pumps Suction pressure	F					

			cavitation damage to the MOL Pump. NSCI see no flow							
		2. MOL Pumps Discharge - Station recycle valve FCV open in error	1. NSCI - the worst case could be pumps trip out causing interruption to oil flow.							
		3. MOL Pumps Discharge - MOL Pump recycle valve MOV is open in error	1. MOL Pumps may not reach the required flow. NSCI							
		4. MOL Pumps Discharge - - Main Oil Line PSV open in error/passing	1. Filling of Slop Tank resulting in high level (Station Emergency Shutdown (ESD) activated) or overfill. NSCI							
		5. MOL Pumps pressure controllers PIT error for example calibration error.	1. Loss of efficiency on MOL Pumps or worst case pump trip. NSCI							
	3. More Flow	1. MOL Pumps Suction - Additional MOL pump starts in error	1. High pressure on discharge side leading and low suction pressure and potential cavitation damage to online MOL Pumps. NSCI							
		2. MOL Pumps Discharge - Impeller modification	2. Potential for more flow compared to the original design as a modified impeller has							

			been installed to reduce pump pulsation. NSCI						
	4. Contamination/ Composition	1. During maintenance involving welding on pipework or MOL Pumps equipment may be water filled. This water is drained to the Slop Tank and subsequent transfer to Relief Tank and main oil line	1. No significant additional consequences	S					
			2. No significant additional consequences	R					
			3. No significant additional consequences	E					
			4. Off specification oil to customers. Estimate 2m3/day water required to cause specification to be breeched.	F	G	4	5	1. Relief tank reinjection take off point is elevated above 1 m 2. Operator training competency and awareness procedure is to drain water from Relief tank before reinjection	
		2. Debris in line for example from damaged pig or bolts arriving at the station, at the suction nozzle	1. No significant additional consequences	S					
			2. No significant additional consequences	R					
			3. No significant additional consequences	E					
			4. Damage to MOL Pumps or Inlet Strainers or metering equipment.	F	F	5	7	1. Inlet Strainers always on line and should prevent debris from reaching more sensitive equipment 2. Metering equipment protected by strainers	
	5. High Pressure	1. Blockage of mainline e.g. Pig stuck at inlet side barred tee or at an Emergency	1. No significant additional consequences	S					
			2. No significant additional consequences	R					
			3. No significant additional consequences	E					

		Shutdown Valve (ESDV) valve	4. A potentially significant delay in pigging of line (weeks or months) leading to the possibility of degradation of line capacity due to excessive wax buildup Trapping pig in Emergency Shutdown (ESD) valve with an inability to isolate station inlet or outlet and damaging the Emergency Shutdown Valve (ESDV). The station would have a reduced ability to isolate in an emergency (Motor Operated Valve (MOVs) only available). Pipeline unavailable until pig removed May require an outage of 1 week to cut out a blocked section of line and or ESDV	F	D	4	8	1. Preventative maintenance on pigs should ensure they are kept in good condition and therefore less likely to get stuck 2. Correct selection of pigs should reduce the likelihood of getting stuck 3. Routine pigging operations should prevent wax buildup to a level which may cause a pig to stick 4. The pig tracking system will track pig which should help identify the location of a stuck pig 5. Pigging procedures ensure Emergency Shutdown Valve (ESDV) closure is held open prior to pig arrival, preventing the pigging from getting stuck at the ESDV 6. During pig launching and receiving, the operators apply Emergency Shutdown (ESD) overrides under Station Pigging procedures, Control of Protective System Overrides and Alarm Blocks. 7. Stopple kits available (Pipeline repair kit) to bypass the Emergency Shutdown (ESD) Valve, subject to risk assessment.	
		2. Any valve closure on the suction side No additional causes							
		3. Multiple MOL Pump trips	1. Surge event upstream of MOL Pumps potentially resulting in	S	F	3	5	1. Surge relief system should protect pipeline and pipework from damaging overpressure	

			overpressure and probable flange failure at Class 150 pipework leading to loss of containment. If ignited large fire causing injury					2. Pump Station fire detection. Fixed fire protection. Fire Emergency Response team - may limit the extent of the fire damage and escalation 3. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 4. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERTAO 5. Fixed and portable firefighting equipment is on site and if employed may control or extinguish the fire. 6. Site standard PPE - FR-PPE obligable to use.	
			2. NSCI						
			3. Surge event upstream of MOL Pumps potentially resulting in overpressure and probable flange failure at Class 150 pipework leading to loss of containment on site	E	F	4	6	1. As above 2. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERTAO	
			4. Surge event upstream of MOL Pumps potentially resulting in overpressure and probable flange failure at Class 150 pipework leading to loss of containment on site, Time to repair damaged flange estimated 1 to 2	F	E	4	7	1. As above 2. Spare gaskets available for all flanges on site 3. Repair kit available centrally in country	

			days note basis less than 1 day no loss						
		5. Thermal expansion in isolated or locked in sections of the line due to solar gain	1. No significant additional consequences	S					
			2. No significant additional consequences	R					
			3. Flange leak resulting in a small volume of oil released to relieve the pressure. Possible rest of isolated line could drain out	E	H	4	4	1. Large sections of station pipework and equipment are indoors and are not subject to solar gain 2. Thermal Relief valves in place for most sections (exception Station Outlet Emergency Shutdown Valve (ESDV) to Launcher Bypass valve MOV) 3. Station Outlet Emergency Shutdown Valve (ESDV) to Launcher Bypass valve MOV has a high pressure alarm set point should alert station operator to increase in pressure and take corrective action prior to damaging overpressure 4. Pipework painted white to reduce solar gain	
			4. NSCI	F					
		6. Failure of high pressure discharge override PIC	1. Cascade mode failure - on high discharge pressure Integrated Control and Safety System (ICSS) will not reduce the MOL Pump Engine speed and or close the discharge pressure control valve. Overpressure but within hydro test pressure. No loss of containment will occur. NSCI	S					

			2. NSCI	R					
			3. NSCI	E					
			4. Without ideal "Cascade" control this high discharge pressure override will not occur. There is an increased risk of MOL pumps tripping resulting in an interruption to Main Oil flow and surge event.	F	G	5	6	1. Operator training competency and awareness - pump station control room operators will identify abnormally high discharge pressure and take corrective actions to ensure high pressure does not occur. 2. Control Room operators are also monitoring pipeline pressures and can warn the pump station of unexpected high pressure 3. Surge relief system 4. PAHH on station discharge	
	6. High Temperature	1. External fire	1. Escalation to - power and control cable damage - transformer fire - generator fire - canteen build could initiate or be engulfed by fire - pump house building fire - a possible leak of oil from the failed flange - a natural gas fire within the pump house - loss of Emergency Shutdown Valve (ESDV) function (fail safe) Potential injury	S	F	4	6	1. Fixed and portable firefighting equipment is on site and if employed may control or extinguish the fire. 2. Trained firefighters on site 3. Fire & Gas (F&G) system should detect fire and initiate station Emergency Shutdown (ESD) and alert operator. 4. Portable firefighting equipment 5. Fixed firefighting system 6. Physical curtains at individual MOL Pump gas skid to improve gas detection 7. Manual alarm call points 8. Fixed foam deluge at MOL Pump 9. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 10. Emergency Shutdown Valve (ESDV) is fail safe closed on loss of control or power 11. Weekly emergency equipment tests	57. The workshop does not have fixed fire protection systems on the pump station. Review the fixed fire protection of buildings and facilities stations and ensure that all stations are similarly protected. Where protection is not provided, justification must be documented.

								12. AFFF Foam is effective at temperatures down to -10oC	
			2. NSCI						
			3. Contaminated firewater. See No Flow.						
			4. Escalation to - power and control cable damage - transformer fire - generator fire - canteen build could initiator be engulfed by fire - pump house building fire - possible leak of oil from the failed flange - a natural gas fire within the pump house - loss of Emergency Shutdown Valve (ESDV) function (fail safe) Potential damage to essential equipment, for example, electrical switch rooms resulting delays of weeks to restart of the pipeline.	F	D	4	8	1. As above	
		2. Internal fire No causes identified see maintenance							
		3. MOL Pump Lube oil	1. No significant additional consequences	S					

		circulation failure	2. No significant additional consequences	R					
			3. No significant additional consequences	E					
			4. Overheating of MOL Pump bearings and or gearbox resulting in equipment damage. - MOL Pump bearing worn - MOL Pump Engine bearing wear	F	F	4	6	1. Operator training competency and awareness daily checklists include lube oil temperature checks 2. Maintenance procedures should ensure that lube oil cooling system failures are minimized 3. The level alarm on Lube oil tank should alert the operator to low level 4. Temperature alarm on MOL Pump bearings 5. Sight glass should allow verification of lube oil flow 6. Pressure indicators and alarms on the lube oil system should identify lube oil problems and allow corrective action to be taken 7. Low pressure should initiate the MOL engine trip and stop the pump before damage occurs	
		4. MOL Pump engine cooling water system failure (common cooling water supply to all) - Cooling water out of specification for example hardness	1. No significant additional consequences	S					
			2. No significant additional consequences	R					
			3. No significant additional consequences	E					
			4. Overheating of all MOL Pumps engine cylinder resulting in equipment damage.	F	F	4	6	1. Temperature alarm and trip on MOL Pumps engine cylinder (shared elements) 2. Preventative Maintenance (PM) on cooling water treatment package should ensure that water hardness is within specification	

	7. Low Temperature	1. The low temperature in dead leg lines	1. Wax deposition and associated water dropout leading to corrosion which would eventually cause a small leak with potential for spray leak. Ice formation could result in a piping crack and loss of containment with potential for a spray leak.	S	F	5	7	1. Some station equipment and piping are contained within heated pump and piping buildings. 2. Internal corrosion allowance on piping 3. Pump Station fire detection. Fixed fire protection. Fire Emergency Response team - may limit the extent of fire damage and escalation 4. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 5. Site standard PPE - FR-PPE obligable to use. 6. Oil spill kit (drum based) is available on site for mopping up of small leaks.	58. Corrosion in dead legs is a significant issue that could result in pipeline failure and loss of containment. Develop a dead leg management plan and register.
	8. Reaction	1. No reaction identified							
	9. Mixing	1. No reaction identified							
	10. Relief	1. Thermal Pressure Safety Valves (PSVs) are set at up	1. Overpressure of pipework but insufficient to cause loss of containment	S					59. Set point for Thermal Pressure Safety Valves (PSVs) on the suction side is higher than the design pressure for the pipework which they protect. This is not in keeping with good engineering practice and should necessitate revalidation of the pipework on each occasion that it exceeds its design pressure. Review the philosophy for thermal PSV settings and either reset the PSVS within the MAOP of the pipework protected or provide
			2. No significant additional consequences	R					
			3. No significant additional consequences	E					
			4. Overpressure of pipework above the maximum design pressure resulting in design expedience.	F	F	7	9	1. None	
		2. Downstream of MOL Pumps - Maintenance	1. Overstressing of the 150 class line between the Pressure Safety	S	G	6	5	1. Pressure Safety Valve (PSV) should reseat when the pressure reduces, thus limiting the release	

		valve closed on Pressure Safety Valve (PSV) discharge line	Valve (PSV) and the maintenance valve leading to probable line rupture and loss of containment. Estimated leak volume is in the order of liters where PSV seats. Possible small fire if ignited.					2. Maintenance valves downstream of Pressure Safety Valve (PSV) are Locked open 3. Locked Open – Locked Close (LOLC) register checks every 2 weeks 4. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 5. Pump Station fire detection. Fixed fire protection. Fire Emergency Response team - may limit the extent of fire damage and escalation 6. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Regular drills are conducted by the ERT. 7. Site standard PPE - FR-PPE obligable to use.	justification for not doing so together with details of actions to be taken when MAOP expedience arises.
			2. NSCI	R					
			3. Overstressing of the 150 class line between the Pressure Safety Valve (PSV) and the maintenance valve leading to probable line rupture and loss of containment.	E	G	4	5	1. As above	
			4. Overstressing of the 150 class line between the Pressure Safety Valve (PSV) and the maintenance valve leading to probable line	F	H	4	4	1. As above	

			rupture and loss of containment.						
	11. Equipment integrity	1. Corrosion under insulation	1. A potential large leak from insulated pipework. Potential form oil from small leak to soak into lagging causing an oil-soaked lagging fire	S	F	4	6	1. The site policy is to remove any oil soaked lagging as soon as it is identified. And replace 2. Pump Station fire detection. Fixed fire protection. Fire Emergency Response team - may limit the extent of fire damage and escalation 3. Site standard PPE - FR-PPE obligable to use.	60. There is the potential for fire spontaneously occurring should lagging become oil soaked. This is a recognized hazard for lagged oil pipe especially if it is warm or has heat tracing, Evaluate whether oil soaked lagging fires present a credible hazard to the pipeline If so, ensure adequate procedures and training are in place.
			2. NSCI	R					
			3. A potential large leak from insulated pipework	E	F	4	6	1. Corrosion allowance on pipework	
			4. NSCI	F					
		2. External corrosion on buried pipeline and pipework within site boundary	1. NSCI	S					
			2. NSCI	R					
			3. Underground leak on site which may be undetected for some time.	E	F	4	6	1. Cathodic protection for buried pipework should ensure that pipework is protected 2. Test post surveys are carried out which should confirm that the Cathodic Protection (CP) current is at the correct level 3. Buried pipework is coated (site applied at some locations so may be vulnerable to reduced adhesion) 4. Inspection is scheduled	
			4. The underground leak which may be undetected for some time. Leading to the cost of reinstating the ground, plus costs of pipeline	F				1. As above	

			repairs and corrosion inspection program.						
	12. Ignition	1. Fixed equipment - electrical - reciprocating engines - junction boxes, for example, heat tracing	1. Following the loss of containment, fire or explosion resulting in potential fatalities A credible explosion is only from fuel gas, not from crude oil	S	E	4	7	1. Hazardous area classification, and equipment rated appropriately. 2. Preventative maintenance on fixed equipment should ensure that it complies with its hazardous area rating 3. Site is a low occupancy area 4. Occupied Permanent and Portable Buildings Assessment carried out 5. Fire & Gas (F&G) system should detect fire and initiate station Emergency Shutdown (ESD) and alert operator. 6. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. 7. Site standard PPE - FR-PPE obligable to use. 8. Emergency Shutdown (ESD) 9. ISSOW (integrated safe system of work) for maintenance on fixed electrical equipment	61. For pump station, identified that several buildings as they were in the "Yellow Zone". There has to be a suitable protection for these buildings.
			2. NSCI	R					
			3. NSCI	E					
			4. Following the loss of containment, fire or explosion resulting equipment damage Credible explosion is only from fuel gas, not from crude oil	F	G	4	5	1. As above 2. Foam deluge at MOL Pumps	
		2. Electrostatic from Operator	1. Spark causing ignition should there be a leak. Potential fatality	S				1. Equipment and pipework is electrically bonded 2. Site standard footwear and gloves are	

								anti-static 3. Changing facilities are in a safe area.	
			2. NSCI	R					
			3. NSCI	E					
			4. Following the loss of containment, fire or explosion resulting equipment damage	F				1. As above	
	13. Maintenance	1. MOL Pumps engine maintenance	1. NSCI						
		2. Maintenance drain blocked (for example Inlet Strainers, MOL Pumps, pipework)	1. Strainers/pipework not drained prior to opening. Small spill when the unit first opened resulting in contamination of the operator.	S	H	4	4	1. Operator training competency and awareness - operator first visually checks flow by draining first to open drain tundish before opening the maintenance valve. 2. Strainer Closed Drain is 6" in order to reduce the likelihood of blockage (similar to the requirement for Pig Receiver) 3. Site and task specific Personal Protective Equipment (PPE) should minimize oil contact. 4. PTW - equipment be isolated and so any loss oil should be reduced.	
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					
	14. Safety	1. Insufficient fire detection within the Sleeping Facilities.	1. Potential for people to be trapped or injured in buildings	S	E	4	7	1. Fire Detection and Protection Review, has been carried out for buildings	
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					
		2. Process Safety Performance	1. Increased process safety	S	E	4	7	1. Number of process safety related Safety System cards recorded and tracked	62. A number of leading process safety performance

		Indicators (PSPIs) Recommendation	incident frequency. Potential unsafe conditions not known or highlighted such that corrective action can be taken prior to an incident.					2. A number of process safety related training hours completed per month.	indicators are being recorded. However, it was not clear which of these or how these are being reported to management and linked to risk control systems (RCS) with associated acceptance criteria. Additional KPI's that cover leading process safety indicators should be included. Implemented in a timely fashion. PSPIs must clearly be linked to the prevention of Major Accidents Hazard incidents and reported up to the executive level.
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					
	15. External Factors	1. External Environmental Factors Natural Factors - Extreme Weather (High winds, ice, snow) - Earthquake - Lightning - Subsidence Human Factors - Acts of War/War (bomb threat) - External sabotage - Intruders - Terrorism	1. Extreme weather (High winds, ice, snow) - May cause delay to shift change due to problems accessing the site. - Medical evacuation is difficult. - Outdoor working difficult - Delay to maintenance due to logistic problems. - Delay to food deliveries - Facial paralysis (6 months recovery time) due to exposure to cold winds (known incident)	S	F	5	7	1. The medical team at the site 2. Snow clearance team at the site 3. Critical spares in the warehouse 4. Cold weather Personal Protective Equipment (PPE) available at the site 5. Plan to minimize occupancy during forecast extreme weather based on site decision 6. Turkish Legal limitations on minimum temperature for working 7. Turkish legal limitations on wind speeds for lifting operations 8. Winter rescue team on site 9. Minimum food stocks for 1 week maintained 10. 4 x 4 vehicles used at the site and for access 11. Faraday cages (lightning protection on all buildings)	63. External factors as an initiating event that could result in a major oil leak at Station. Including: Natural Factors - Extreme Weather (High winds, ice, snow) - Earthquake - Lightning Human Factors - Acts of War/War (bomb threat) - External sabotage - Intruders - Terrorism - Internal sabotage - Industrial action - Computer Security A major oil leak could have a

		- Internal sabotage - Industrial action - Computer Security	2. Earthquakes leading to pipework and equipment damage. The potential loss of containment and fire if ignited.	S	E	3	6	1. Design codes take into account seismic zones according to "1984 ASCI guidelines for seismic design of oil and gas pipeline systems". 2. Incident management system manual	severe adverse safety and business impact on operations. Consequently, risk reduction measures that, pre Macondo, were deemed too costly may now be proportionate to the benefit gained in risk reduction. Additionally, some of the safety studies have not been updated since the commissioning of the pipeline. Example: studies to be confirmed For the pipeline, must be evaluated and reviewed Major Accident initiated by an External Factor is As Low As Is Reasonable Practicable (ALARP).
			3. Lightning damage causing physical damage to equipment causing a leak and igniting oil - large pool fire	S	F	3	5	1. Site station lightning protection 2. Faraday cages (lightning protection on all buildings) 3. Pump Station fire detection. Fixed fire protection. ERTAO 4. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Regular exercises and drills are conducted by the teams	
			4. Subsidence leading to loss of support for equipment and or pipework NSCI	S					
			5. Skeleton staff (untrained) on must be reduced. pipeline during industrial action leading to the potential for mal operation	S	E	2	5	1. Crisis Management Contingency Plan	
			6. NSCI.	R					
			7. Earthquakes leading to pipework and equipment damage. The potential loss of containment and fire if ignited.	E	F	3	5	1. Design codes take into account seismic zones according to "1984 ASCI guidelines for seismic design of oil and gas pipeline systems". 2. Incident management system manual	
			8. Lightning damage causing physical	F	G	5	6	1. As above 2. Site station Lightning protection to	

			damage to equipment Lightning damage causing interference with electrical protection and control systems.						
			9. Acts of war. Essential personnel may be called up for military service. - The pipeline may be shut down if there are acts of war in nearby countries that may impact the pipeline.	F	E			1 crisis Management Contingency Plan	
			10. Internal/External sabotage or intruders leading to loss of containment and plant shutdown.	F	E	4	7	1. Good industrial relations 2. Turkish Military Security 3. Site security (access control) and double fencing, Closed Circuit Television (CCTV) 4. Intruder detection system 5. External fence lighting 6. Watchtowers 7. Site perimeter patrols	
			11. Earthquakes leading to pipework and equipment damage.	F	G	3	4	1. Design codes take into account seismic zones according to "1984 ASCI guidelines for seismic design of oil and gas pipeline systems". 2. Incident management system manual	
	16. Controlled startup/shut down	1. Station shutdown too quickly within a controlled pipeline shutdown, for	Unable to risk rank.						

		example, human error.							
		2. Station starting too quickly within a controlled pipeline startup e.g. human error.	1. Low suction pressure leading to cavitation to online MOL pumps at this station. Reduced pipeline flow for 1 week while repairing damaged pumps. No additional consequences identified						
	17. Emergency shutdown ESD	1. Station Emergency Shutdown (ESD). Station Emergency Shutdown Valves (ESDV) should close quickly. This will result in surge overpressure at higher flowrates.	Unable to risk rank.						
5. Relief Tanks	1. No Flow	1. MOV- inlet Surge Relief Isolation valve closed during a surge event	1. Pipeline overpressure potentially causing pipeline rupture Leading to a large spill of oil and potential pool fire if ignition occurs See mainline node, shutdown deviation	S				1. MOV- is Locked Open (LO) 2. MOV- on Locked Open-Locked Closed (LOLC) register. LOLC register updated bi-weekly 3. MOV- can only be operated locally 4. Operator Competency Training and Awareness - Operators are aware of the importance of MOV-	64. In the event that a station is shutdown in an uncontrolled manner (including SSD and ESD), there is a high probability of surge overpressure at higher flowrates. The raw consequence analysis of this surge event (i.e. overpressure without surge protection) is not available. It
			2. Pipeline overpressure potentially causing pipeline rupture	R				1. As above	

			Leading to a large spill of oil - media attention						is therefore not possible to determine the likely consequences if surge protection is not available due to an abnormal situation. This study should at a minimum cover all the scenarios that were reported in the current study. Once the study has been completed, update the severities in the HAZOP and conduct the appropriate follow-on risk assessment (LOPA, QRA).
			3. Pipeline overpressure potentially causing pipeline rupture Leading to a large spill of oil	E				1. As above	
			4. Pipeline overpressure potentially causing pipeline rupture Leading to a large spill of oil	F				1. As above	
		2. Closure of all manual valves upstream SVs or spectacle blinds left closed after maintenance	1. Pipeline overpressure potentially causing pipeline rupture Leading to a large spill of oil and potential pool fire if ignition occurs See mainline node, shutdown deviation	S				1. MOV is Locked Open (LO) 2. MOV on Locked Open-Locked Closed (LOLC) register. LOLC register updated bi-weekly 3. MOV can only be operated locally 4. Operator Competency Training and Awareness - Operators are aware of the importance of MOV	
			2. Pipeline overpressure potentially causing pipeline rupture Leading to a large spill of oil - media attention	R				1. As above	
			3. Pipeline overpressure potentially causing pipeline rupture Leading to a large spill of oil	E				1. As above	
			4. Pipeline overpressure potentially causing pipeline rupture	F				1. As above	

			Leading to a large spill of oil						
		3. Closure of hand valves downstream of SVs or spectacle blinds left closed after maintenance	1. Potential for flanged joint rupture and release of oil inside the building. Leading to a large spill of oil and potential pool fire, if ignition occurs. Also, potential for rapid gas build up in the building (possible confined vapor explosion) Potential for operator fatality (Pipeline overpressure potentially causing pipeline rupture. This scenario is not scored here. See above)	S	E	3	6	1. The mechanical interlock system prevents closure of manual valves prior to closure of valves upstream valves HV. Interlock keys are released upon authorization of the chief engineer. 2. Valves are slowly opened before reinstatement to pressurize the system to normal line pressure to check for any leaks. 3. Isolation certificate and permit to work are required prior to closure of manual valves 4. 3 x 50% surge valves reduce the likelihood of simultaneous closure of all streams. 5. Startup checks prior to reinstatement after maintenance operations. 6. Fixed gas detectors in the gallery area 7. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 8. Site standard PPE - FR-PPE obligable to use. 9. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERTAO 10. Oil spill kit (drum based) is available on site for mopping up of small leaks. 11. Pump Station fire detection (including flame detectors). Fire Emergency Response team - may limit the extent of fire damage and escalation	

			2. NSCI	R					
			3. NSCI	E					
			4. Potential for flanged joint rupture and release of oil inside the building. Leading to a large spill of oil and potential pool fire; if ignition occurs, also a potential for rapid gas build up in the building (possible confined vapor explosion) and damage to more than one Surge valve SVx01. Extended pipeline shutdown while checks and valves repairs are performed (estimated one week)	F	D	3	7	1. As above	
		4. Surge valves SV- s fail to open on demand (e.g. nitrogen pressure high, or incorrect set point)	1. Potential for flanged joint rupture and release of oil inside the building. Leading to a large spill of oil and potential pool fire, if ignition occurs. Also, potential for rapid gas build up in the building (possible confined vapor explosion) Potential for operator fatality (Pipeline overpressure potentially causing pipeline rupture. This scenario is	S	E	4	7	1. The mechanical interlock system prevents closure of manual downstream valves prior to closure of upstream valves. Interlock keys are released upon authorization of the chief engineer. 2. Valves are slowly opened before reinstatement to pressurize the system to normal line pressure to check for any leaks. 3. Isolation certificate and permit to work are required prior to closure of manual valves 4. 3 x 50% surge valves reduce the likelihood of simultaneous closure of all streams. 5. Startup checks prior to reinstatement	

			not scored here. See above)					after maintenance operations. 6. Fixed gas detectors in the gallery area 7. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 8. Site standard PPE - FR-PPE obligable to use. 9. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERTAO 10. Oil spill kit (drum based) is available on site for mopping up of small leaks. 11. Pump Station fire detection (including flame detectors). Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. NSCI	R					
			3. NSCI	E					
			4. Potential for flanged joint rupture and release of oil inside the building. Leading to a large spill of oil and potential pool fire; if ignition occurs, also a potential for rapid gas build up in the building (possible confined vapor explosion) and damage to more than one Surge valve SVx01. Extended pipeline shutdown while checks and valves repairs are	F	D	4	8	1. As above	

			performed (estimated one week)						
		5. Closure of manual valves upstream pressure relief valves SVs or spectacle blinds left closed after maintenance (in case of blocked flow downstream MOL Pumps)	1. Potential to exceed the design pressure of mainline pipework, leading to potential pipe damage (most likely at a flanged joint) and release of oil in the pump house or pipe house. Leading to a large spill of oil and potential pool fire; also a potential for rapid gas build up in the building (possible confined vapor explosion if ignition occurs) Potential for operator fatality PSV on MOL Pumps may open (see more flow on Slop Tank node)	S	E	2	5	1. The mechanical interlock system prevents the closure of manual valves. Interlock keys are released upon authorization of the chief engineer. 2. Valves are slowly opened before reinstatement to pressurize the system to normal line pressure to check for any leaks. 3. Isolation certificate and permit to work are required prior to closure of manual valves 4. PAH high pressure alarm would alert operators in the control room. 5. PAHH tripping the MOL Pumps 6. 2 x 100% relief valves 7. Startup checks prior to reinstatement after maintenance operations. 8. Fixed gas detectors in the gallery area 9. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 10. Site standard PPE - FR-PPE obligable to use. 11. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Planned drill exercises are conducted by ER teams. ERTAO 12. Oil spill kit (drum based) is available on site for mopping up of small leaks. 13. Pump Station fire detection (including flame detectors). Fire Emergency	

								Response team - may limit the extent of fire damage and escalation	
			2. NSCI	R					
			3. NSCI	E					
			4. Potential to exceed the design pressure of mainline pipework, leading to potential pipe damage (most likely at a flanged joint) and release of oil in the pump house or pipe house. Leading to a large spill of oil and potential pool fire; also a potential for rapid gas build up in the building (possible confined vapor explosion if ignition occurs) Extended pipeline shutdown while checks and valves repairs are performed	F	D	2	6	1. As above	
		6. Locked Open (LO) valves on Relief Tank inlet closed or mechanical failure of valves leading to gate closing inside the valve	1. Surge pressure cannot be relieved to Relief Tanks. Pipework in the surge system between SVs and HV valves is class 150. Potential for overpressure and pipe or flange damage, leading to oil spill and fire, if ignited. Potential fatality	S	E	3	6	1. HV valves are Locked Open (LO) 2. HV valves are on Locked Open-Locked Closed (LOLC) register. LOLC register updated bi-weekly 3. HV valves valve position is shown in the control room 4. 2 x 100% Relief Tanks Maintenance of the relief tanks is carried on one tank at a time, while the other one is in service. 5. Limit switches on Locked Open (LO) valves HV on Relief Tank would cause Safety Shutdown (SSD) of the upstream	65. What the executive action is on position limit switches on Relief Tanks inlet/outlet valves HV. The P&ID shows an ESD interlock on position limit switches and the C&E shows an ESD of the upstream station. It is unclear whether this ESD/SSD is linked to the closure of the manual Relief Tanks inlet/outlet valves HV for one or both of the Relief

								pump station if valves HV are not in the open position 6. Operator Competency Training and Awareness - Safety Shutdown (SSD) of the upstream station would lead to a controlled shutdown of the station upon communication between operators	Tanks. It is also unclear whether this action results from loss of the open signal or full closure. However, currently, no shutdown action is presently functioning on position limit switches on Relief Tanks inlet/outlet valves HV. Clarify the intended actions taken from the position limit switches, update all the related documentation (C&E and P&IDs, philosophies) and ensure that the trip function is working.
			2. NSCI	R					
			3. Surge pressure cannot be relieved to Relief Tanks. Pipework in the surge system between SVs and HV valves is class 150. Potential for overpressure and pipe or flange damage, leading to an oil spill, lasting for about 20 min	E	G	4	5	1. As above 2. Above ground pipework either in Relief Tank bund or in the building (piping or reinjection pump building)	
			4. Surge pressure cannot be relieved to Relief Tanks. Pipework in the surge system between SV and HV valves is class 150. Potential for overpressure and pipe or flange damage, leading to an oil spill. Also, possible damage to mechanical seals of Reinjection Pumps Leading to pipeline shutdown, while repairs and reinstatement of	F	E	4	7	1. As above	

			pipework is carried out (expected 2 days)						
		7. LO valves HV on Relief Tank inlet closed or mechanical failure of valves leading to gate closing inside the valve (in case of blocked flow downstream MOL Pumps	1. Pressure from the discharge line cannot be relieved to Relief Tanks through relief valves. Pipework in the relief system between SV and HV valves is class 150. Potential for overpressure and pipe or flange damage, leading to oil spill and fire, if ignited. Potential fatality (For the relief valves, in case of line blockage downstream from the MOL Pumps the relief could go on for a long time)	S	E	2	5	1. HV valves are Locked Open (LO) 2. HV is on Locked Open- Locked Closed (LOLC) register. LOLC register updated bi-weekly 3. 2 x 100% Relief Tanks. Maintenance of the relief tanks is carried out on one tank at a time, while the other one is in service. 4. Operator Competency Training and Awareness - Safety Shutdown (SSD) of the upstream station would lead to a controlled shutdown of the station upon communication between operators	66. The inadvertent closure of the Relief Tanks inlet/outlet valves HV would potentially result in the rupture of the line between SVs and HV if the discharge relief valves SVs were to open. Investigate the feasibility of using the limit switch trip on Relief Tanks inlet/outlet valves HV to stop the MOL Pumps in a controlled manner, if the valves on the inlet of the Relief Tanks are not in a completely open position. If this can be done without making the situation worse by causing an additional surge event, then implement this trip.
			2. NSCI	R					
			3. Pressure from the discharge line cannot be relieved to Relief Tanks through relief valves. Pipework in the relief system between SV and HV valves is class 150. Potential for overpressure and pipe or flange damage, leading to an oil spill. (For the relief valves, in case of line blockage downstream from the	E	F	3	5	1. As above 2. Above ground pipework either in Relief Tank bund or in the building (piping or reinjection pump building)	

			MOL Pumps the relief could go on for a long time)						
			4. Pressure from the discharge line cannot be relieved to Relief Tanks through relief valves. Pipework in the relief system between SVs and HV valves is class 150. Potential for overpressure and pipe or flange damage, leading to oil spill and fire, if ignited. (For the relief valves, in case of line blockage downstream from the MOL Pumps the relief could go on for a long time) Leading to pipeline shutdown, while repairs and reinstatement of pipework is carried out (expected 2 days)	F	E	3	6	1. As above.	
	2. More Flow	1. Partial loss of nitrogen supply to surge (gauges) and relief valves (SV-s) leading to unintended relief	1. Possible vibration damage to small bore connections as surge valves chatter. Surge event leading to hammer effect and rupture of small bore pipework Leading to oil spray release and	S	E	4	7	1. From 2012, a nitrogen pressure indicator will be relayed to the control room. 2. Operator Competency Training and Awareness - Operator checks nitrogen pressure on the bottles and at the Surge Valves pressure gauges three times a day 3. Check valve in nitrogen system 4. Bracing at critical joints to reduce	

			potential jet fire/ flash fire, if ignited. Potential for fatality					vibrations on the relief streams 5. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 6. Site standard PPE - FR-PPE obligable to use. 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. - Booklet Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks. 9. Pump Station fire detection (including flame detectors). Fire Emergency Response team - may limit the extent	
			2. Possible vibration damage to small bore connections as surge valves chatter. Surge event leading to hammer effect and rupture of small bore pipework Leading to oil spray release and potential jet fire/ flash fire, if ignited. Potential for fatality (adverse media coverage)	R	G	4	5	1. As above	
			3. NSCI	E					
			4. Possible vibration damage to small bore connections as surge valves chatter. Surge	R	E	5	8	1. As above	

			event leading to hammer effect and rupture of small bore pipework Pipeline shutdown for investigation/corrective actions						
		2. Complete loss of nitrogen supply to surge or discharge pressure relief valves SVs leading to unintended relief.	1. Relief would cause an increase in level in Relief Tanks potentially leading to overfilling. See high level						
		3. Surge (SVs) or relief valves (SVs) not resetting after a surge/relief event	1. See high level						
		4. One Surge valve (one of SV- s1) or one relief valve	1. NSCI	S					
			2. NSCI	R					
			3. NSCI	E					
			4. One of the three Surge valve SVx01 (or one of the two relief valves) may operate more frequently than the others, due to opening at a lower set pressure. This may wear the valve and lead to a wrong calibration NSCI	F					
		5. Relief Tank drain line valve	1. Release of water first, then oil into bund	S				1. The control room operator would monitor the Relief Tank level through LT.	

		HV) left open or passing after Relief Tank maintenance	area. Spillage is likely to be limited because it would be noticed by the operator. Also, the 4" line would limit the release rate.					However, the filling rate would be higher than the leak rate from the drain and therefore leak might not be detected 2. Procedures for Relief Tank reinstatement after maintenance include valve positioning checklist and requirement to blank the drain line.	
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					
		6. Relief Tank drain line valve HV) stuck open during drainage of water from Relief Tank following a transfer of water from the Slop	1. Release of water first, then oil into bund area. A release can proceed for a long time. Release of oil, potential pool fire if ignited. Potential for injury to more than one person.	S	F	3	5	1. Operator Competency Training and Awareness - Operator would notice the release of crude oil. Reinjection pumps could be started to reduce the volume of crude oil 2. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated. 3. Site standard PPE - FR-PPE obligable to use. 4. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. - Oil Spill Containment Booklet Regular exercises and drills are conducted by the teams. ERTAO 5. Oil spill kit (drum based) is available on site for mopping up of small leaks. 6. Pump Station fire detection (including frame detectors). Fire Emergency Response team - may limit the extent of fire damage and escalation	67. The Relief Tank drain line valve HV can stick open during drainage of water from Relief Tank following a transfer of water from the Slop Tank. This would lead to the release of water first, then oil into the bund area with the release proceeding for a long time. This could lead to the pool fire, if ignited and potential for injury to more than one person. Install second drain valve in series to HV so that it can be closed if HV is stuck open
			2. NSCI	R					

			3. Release of water first, then oil into bund area, then to Oily Water Treatment Package system and then to the pond. A release can proceed for a long time.	E	F	4	6	1. As above 2. Relief tanks are sitting in a common bund, with 110% capacity of one tank. Bunds are connected to the Oily Water Treatment Package M55090 Assuming that the operator closes the bund drain valve to prevent further release.	
			4. NSCI	F					
		7. Rim seal leak on the floating roof of Relief Tanks	1. Oil collecting on the floating roof of the Relief Tanks, potentially sinking roof See high pressure for stuck floating roof scenario						
	3. Reverse Flow	1. Reinjection Pumps check valves HV stuck open and MOV downstream of Reinjection Pumps	1. Potential backflow from the station inlet strainers back into the Relief tanks (through reinjection pumps) Leading to over pressurization of class 150 pipework section between low pressure Reinjection pump and check valve Potential connection rupture leading to an oil spill in the Reinjection Pump house. Pool fire, if ignition occurs. Potential fatality	S	E	3	6	1. Preventative Maintenance (PM) on MOV- 2. Cross Interlock between MOV-0288 and MOV (prevents opening in error but not a safeguard against passing valve) and 3. Gas and flame detectors in the pump house 4. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 5. Site standard PPE - FR-PPE obligable to use. 6. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. - Planned drill exercises are conducted by ER teams. ERTAO 7. Oil spill kit (drum based) is available on site for mopping up of small leaks. 8. Gas and flame detectors in the pump	68. Several scenarios could result in potential backflow from the station inlet strainers towards the Low Pressure Reinjection Pump which has a section of class 150 pipe downstream. This could lead to over pressurization of class 150 pipework section between low pressure Reinjection pump and check valve, leading to potential connection rupture leading to an oil spill in the Reinjection Pump house. This could lead to a pool fire if ignition occurs and lead to a potential fatality. Consider changing PI downstream of the Low Pressure Reinjection Pump to have a pressure

								house. Fire Emergency Response team - may limit the extent of fire damage and escalation	indication downstream of the low pressure reinjection pump in the control room.
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					
		2. Possible backflow from Relief Tanks through discharge relief valves (SVs) into isolated discharge header of MOL Pumps during maintenance (MOL Pumps not running) Suspected occurrence at the pump station	1. Inability to drain MOL Pump discharge header during maintenance Potential hydrocarbon flow into the system during maintenance. Potential fire, if ignition occurs, leading to fatality	S	E	3	6	1. Discharge relief valves (SVs) isolation valves (HV) are closed during maintenance. 2. Maintenance procedures require complete drainage before breaking containment. If liquid continues to flow to equipment under maintenance, then this indicates that isolation is not effective. 3. Continuous gas monitoring during maintenance	
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					
	4. Part of Flow	1. No causes identified							
	5. Contamination/ Composition	1. No causes identified							
	6. High Pressure	1. Floating roof in Relief Tanks stuck and surge/relief event underway. (Leaking heating coil) may also	1. Potential over pressurization of Relief Tanks and roof tank damage, leading to oil above the floating roof. Possible rupture of Relief Tank if one of	S	F	3	5	1. Relief tanks are sitting in a common bund, with 110% capacity of one tank. Bunds are connected to the Oily Water Treatment Package 2. Seal of floating roof and Vent on the fixed roof of Relief Tanks should relieve pressure	69. There are PSVs on the floating roof of Relief Tanks intended to relieve pressure or vacuum from below the floating roof. However, these have not been taken as a safeguard because

		be a source of overpressure)	the tanks is not in service and the surge/relief pressure is directed into the tank in service. Release of oil, with potential pool fire, if ignition occurs Potential for injury to more than one person					3. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated. 4. Site standard PPE - FR-PPE obligable to use. 5. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 6. Oil spill kit (drum based) is available on site for mopping up of small leaks. 7. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation 8. The operator would perform a controlled shutdown in case of fire. That would limit the inventory of material available to fire.	they are not regularly maintained due to access difficulties. The manufacturer's literature for the valves in question states "proper function requires proper inspection and maintenance of devices...clean products, in general, need one check per year". The existing valves at Pump stations have not been inspected since commissioning. Review the maintenance procedure for these PSVs and introduce regular inspection and testing. If it is not feasible to maintain these valves, then an engineering modification to the design of the tank is required in order to prevent or protect against overpressure or vacuum.
			2. NSCI	R					
			3. Potential over pressurization of Relief Tanks and roof tank damage, leading to oil above the floating roof. Possible rupture of Relief Tank if one of the tanks is not in service and the surge/relief pressure is directed into the tank in service. Release of oil,	E	E	5	8	1. As above	

			the potential for oil to be released offsite						
			4. Potential over pressurization of Relief Tanks and roof tank damage, leading to oil above the floating roof. Possible rupture of Relief Tank if one of the tanks is not in service and the surge/relief pressure is directed into the tank in service. Release of oil, with potential pool fire, if ignition occurs. In case of fire, damage to both Relief tanks requiring pipeline shutdown, while repairs/replacement are being carried out. Possible to operate at low flowrate with neither relief tanks in service at	F	D	3	7	1. As above	
		2. Relief Tank vents on external roof blocked (e.g. snow) or Apex vent blocked on relief tanks	1. NSCI. Due to the number and size of relief vents and that vents lines are extended beyond the maximum anticipated snow level.						

		3. Line blockage - Surge line - Relief line	1. See no flow						
		4. Thermal expansion: - at locked in section downstream of Reinjection Pumps - between manual valves on relief skid bypass line - Between MOV and surge valves SVs	1. Potential flange/gasket damage leading to limited oil spill NSCI						
	7. Low Pressure	1. PSVs blocked and Relief Tank floating roof stuck (Roof grounded - see low level)	1. Potentially leading to vacuum below the stuck floating roof. Potential Relief Tank damage/rupture resulting in the release of oil. Pool fire, if ignited Potential for fatalities	S	E	2	5	1. Operator Competency Training and Awareness - Operator may note the difference in level between the Relief Tanks which would arise if one tank was under reduced pressure (when both are in service) 2. Relief tanks are sitting in a common bund, with 110% capacity of one tank. Bunds are connected to the Oily Water Treatment Package 3. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated. 4. Site standard PPE - FR-PPE obligable to use. 5. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. - Containment Booklet	70. A stuck floating roof inside the Relief Tanks could lead to vacuum generation below the stuck floating roof when Reinjection Pumps are operating. This may lead to potential Relief Tank damage/rupture resulting in the release of oil and pool fire if ignited. There is the potential for fatalities. In case of the stuck roof in one Relief Tank, the operator may note the difference in level between the Relief Tanks (when both are in service). If practicable, install a level differential indicator/alarm showing any difference in level between the two Relief Tanks.

								Planned drill exercises are conducted by ER teams. ERTAO 6. Oil spill kit (drum based) is available on site for mopping up of small leaks. 7. Pump Station fire detection (including flame detectors). Fire Emergency Response team - may limit the extent of fire damage and escalation	This will give an indication of a stuck floating roof in one of the Relief Tanks. In considering this, bear in mind that there may be a difference of water contents, and hence level between the two tanks, which may cause different level readings.
			2. Potentially leading to vacuum below the stuck floating roof. Potential Relief Tank damage/rupture resulting in the release of oil. Pool fire, if ignited Media coverage	R	E	3	6	1. As above 2. Incident Management Team has personnel trained and authorized to provide accurate information to the media and the public.	
			3. Potentially leading to vacuum below the stuck floating roof. Potential Relief Tank damage/rupture resulting in the release of oil.	E	F	3	5	1. As above	
			4. Potentially leading to vacuum below the stuck floating roof. Potential Relief Tank damage/rupture resulting in the release of oil. Pool fire, if ignited, leading to possible damage of both Relief Tanks. Potential cavitation of Reinjection pumps and pump damage.	F	D	3	7	1. As above	

			Extended pipeline shutdown while repair/replacement is being carried out.						
		2. Reinjection Pump low discharge pressure	1. See low flow NSCI						
	8. High Temperature	1. External fire	1. Escalation to - power and control cable damage - transformer fire - generator fire - pump house building fire - possible leak of oil from the failed flange - the natural gas fire within the pump house - loss of Emergency Shutdown Valve (ESDV) function (fail safe) Fire in the reinjection pumps building. Fire around the Relief Tanks leading to relief tanks failure with large increase of oil inventory to fire. Fire in the discharge side of the pump station would lead to relief of hot oil into the relief tanks, with the potential to exceed the tank	S	F	4	6	1. Relief tanks are equipped with a fixed deluge system to cool them in case of fire. 2. Vents on Relief Tanks designed for fire relief according to API 2000 3. Trained firefighters on site 4. Fire & Gas (F&G) detection and alarm 5. Fixed and portable firefighting equipment is on site and if employed may control or extinguish the fire. 6. Manual alarm call points 7. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 8. Emergency Shutdown Valve (ESDV) is fail safe closed on loss of control or power 9. Weekly emergency equipment tests 10. Foam is effective at temperatures down to -10oC	71. In case of fire in the Relief Tank area, an Emergency Shutdown (ESD) of the station should not be initiated as this would exacerbate the problem by discharging more oil into the tanks due to a surge event. Ensure that the requirement of having a normal station shutdown, as opposed to an ESD, is included in station operating procedures and training, in case of fire or imminent overflow of the Relief Tanks.

			design temperature. Potential for boil over if the oil temperature is above water boiling temperature (water is present at the bottom of relief tanks) Potential injury							
			2. NSCI	R						72. The bund sizing calculations for relief tanks are made available. The bund sizing and calculation should include not only containment of tank contents, but also provide volume for firewater. Calculations should conform to accepted international standards (e.g. IP19 - Fire precautions at petroleum refineries and bulk storage installations).
			3. Contaminated foam and firewater released to the environment.	E	E	4	7	1. Relief tanks are sitting in a common bund, with 110% capacity of one tank. Bunds are connected to the Oily Water Treatment Package 2. Possibility of diverting bund contents to the pond should limit the likelihood of bund overtopping	
			4. Escalation to - power and control cable damage - transformer fire - generator fire - pump house building fire - possible leak of oil from the failed flange - the natural gas fire within the pump house - loss of Emergency Shutdown Valve (ESDV) function (fail safe) Potential damage to essential equipment (including both Relief Tanks T) for example electrical switch rooms resulting delays of	F	D	4	8	1. As above	

			weeks to restart of the pipeline.						
		2. Fire around: - Surge valves skid or - Relief valves skid	1. If two flame detectors are activated by a fire around Relief valves SV skid, which has been caused by an oil leak, an emergency shutdown (ESD) is activated. This will cause a surge event, which in turn would increase the leak rate into the affected area (as the surge and relief pipework is interconnected). Fire escalation leading to extended equipment damage on site.	F	D	4	8	1. Routine and frequent checks around the area should identify leaks prior to ignition. 2. Fire and gas detection 3. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 4. Site standard PPE - FR-PPE obligable to use. 5. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 6. Oil spill kit (drum based) is available on site for mopping up of small leaks. 7. Pump Station fire detection (including flame detectors). Fire Emergency Response team - may limit the extent of fire damage and escalation	73. In the case of fire around Relief valves SV skid inside the building, the activation of two flame detectors would cause an emergency shutdown (ESD). If the fire had been caused by an oil leak, the surge event following the activation of the ESD would, in turn, increase the leak rate into the affected area (as the surge and relief pipework is interconnected). Investigate and implement solutions to prevent exacerbating leaks around the relief valve skid, following the detection of fire in the area.
		3. Hot oil relieved into Relief Tanks in case of fire on pump station discharge side	1. See above for escalation of fire scenario Fire in the discharge side of the pump station would lead to relief of hot oil into the relief tanks, with potential to exceed the Relief Tanks design temperature. Potential for boil over if the oil temperature is	S	E	2	5	1. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 2. Site standard PPE - FR-PPE obligable to use. 3. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Oil Spill Containment Booklet Planned drill exercises are conducted by	

			above water boiling temperature (water is present at the bottom of relief tanks). This might lead to the rupture of the relief tanks and the release of tank contents. Potential fatality					ER teams. ERTAO 4. Oil spill kit (drum based) is available on site for mopping up of small leaks. 5. Pump Station fire detection (including flame detectors). Fire Emergency Response team - may limit the extent of fire damage and escalation 6. Water in Relief Tank is drained once per year. This should limit the amount of water present. 7. Relief tanks are sitting in a common bund, with 110% capacity of one tank. Bunds are connected to the oily Water Treatment Package separator.	
			2. NSCI	R					
			3. NSCI	E					
			4. NSCI	F					
		4. Solar gain on Relief Tanks	1. NSCI						
	9. Low Temperatur e	1. Low ambient temperature	1. NSCI	S					
			2. NSCI	R					
			3. NSCI	E					
			4. Potential for freezing of water in the Relief Tanks. Potential to damage of the tank's base or shell. This may lead to the release of oil after the ice has melted. The tank has to be taken out of service for repair Potential inability to pump out the relief tanks.	F	F	2	4	1. Heating coil and insulation at bottom of the Relief Tanks 2. TIC might warn operators of low temperatures and potential for freezing in Relief Tanks 3. Pressure and temperature indicators in the heating water system 4. 2 x 100% Relief Tanks 5. Water in Relief Tanks is drained once per year. This should limit the amount of water present.	

			5. Potential freezing of Relief Tanks vents (at insect meshes). Not previously observed.					1. Visual inspection of insect meshes should detect condensation and freezing	
			6. Waxing/Gelling of oil leading to blocked lines (see no flow)					1. Winterization and Heat tracing on pipework 2. Most pipework is inside buildings, which are heated	
			7. Check valves sticking open/close (see no/reverse flow)					1. Winterization and Heat tracing on valves 2. Most pipework (and valves) is inside buildings, which are heated	
		2. Failure of TIT or Heating Coil failure, or Electric Heater	1. Potential for freezing of water in the Relief Tanks. Potential to damage of tanks base or shell. This may lead to the release of oil after the ice has melted. The tank has to be taken out of service for repair Potential inability to pump out the relief tanks.	F	F	2	4	1. Insulation at bottom of the Relief Tanks 2. Pressure and temperature indicators in the heating water system 3. 2 x 100% Relief Tanks 4. Separate heating systems for each Relief Tank 5. Water in Relief Tanks is drained once per year. This should limit the amount of water present.	
	10. High Level	1. Complete loss of nitrogen supply to surge valves gauges leading to unintended relief.	1. The surge would cause a rapid increase in level in Relief Tanks potentially leading to overfilling and relief tank damage. If only one relief tank is in service, the relief tank expected to be filled in 10 min. However, the design basis is that one Relief	S	F	2	4	1. FS with high flow alarm would alert the operator of a flowrate through surge line. The operator will possibly isolate the manual isolation valves upstream of SV, or close MOV on the inlet to surge valves. 2. Low pressure alarm on the nitrogen system would alert operators of the failure of the nitrogen system. The operator will possibly isolate the manual isolation valves upstream of SV, or close MOV on the inlet to surge valves. The	74. Complete loss of nitrogen supply to surge valves SVs could lead to unintended relief resulting in rapid filling of Relief Tanks. The relief tank could fill in a few tens of minutes with potential for an overflow of oil if immediate actions are not taken. This could lead to a pool fire if ignited and injury to more than one person. Include this

			Tank would reach the maximum level in approximately 40 min. Release of oil, potential pool fire if ignited. Potential for injury to more than one person. Pump station suction pressure will fall, potentially leading to cavitation and damage to the MOL Pumps.					operator can do several things to try and reinstate the nitrogen system (see nitrogen system HAZOP) 3. Check valves on the nitrogen supply system might maintain pressure on the Surge valve SVx01 body for some time. 4. LI with LAH would provide an indication of the level at the control room and alert operators. 5. LS on Relief Tank with high Level alarm High would cause an SSD of the upstream station. (Used if only one tank is in service). This alone does not stop the event, as there is still a sufficient volume of oil in the section of the pipeline upstream of the pump station.	scenario (complete loss of nitrogen supply to surge valves gauges) into the regular drills performed at pump stations to improve response time following detection of relief events and alarms.
								6. LS on Relief Tank with high Level alarm High would cause an SSD of the upstream station. (Used if both relief tanks are in service). This alone does not stop the event, as there is still a sufficient volume of oil in the section of the pipeline upstream of the pump station. 7. The operator could close upstream block valve after the controlled shutdown of the upstream station to limit the volume of oil draining into Relief Tanks. 8. After the shutdown of the upstream station, the operator would keep MOL Pumps running for some time to decrease volume from the upstream section. 9. Operating philosophy requires to operate Relief Tanks at a minimum level. Relief Tank Procedure 10. PALL would trip MOL Pumps in case of low pressure on the suction side (this is	75. What the executive action is on high high level switches LS on Relief Tanks. The P&ID shows an ESD interlock on high high level switches LS and the C&E shows overall ESD of the pipeline. However, the SCADA screen shows an SSD of the upstream station. Clarify and implement the intended actions taken from the high high level switches LS and update all the related documentation (C&E and P&IDs, philosophies). 76. Complete loss of nitrogen supply to surge valves gauges could lead to unintended relief resulting in rapid filling of Relief Tanks. The relief tank

								only a protection against MOL pump damage) 11. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated. 12. Site standard PPE - FR-PPE obligable to use.	could fill in a few tens of minutes with potential for an overflow of oil if immediate actions are not taken. This could lead to a pool fire if ignited and injury to more than one person. Identify whether a more automatic response to the surge valves failing open can be implemented to prevent overfilling of the Relief Tanks
								13. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Emergency Response Procedure - , Oil Spill Response Plan and Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 14. Oil spill kit (drum based) is available on site for mopping up of small leaks. 15. Pump Station fire detection (including flame detectors). Fire Emergency Response team - may limit the extent of fire damage and escalation	77. Complete loss of nitrogen supply to surge valves gauges could lead to unintended relief resulting in rapid filling of Relief Tanks. The relief tank could fill in a few tens of minutes with potential for an overflow of oil, if immediate actions are not taken. This could lead to a pool fire if ignited and injury to more than one person. A number of different documents were checked to identify the time to fill the Relief Tank in this scenario (complete loss of nitrogen supply to surge valves gauges), but no consistent value was found. Review all relevant documentation, establish the actual likely time to fill the Relief Tanks, confirm time available for emergency action before relief tanks are

									overfilled and update all documents, including emergency procedures, to reflect this value.
			2. The surge would cause a rapid increase in level in Relief Tanks potentially leading to overfilling and relief tank damage. If only one relief tank is in service, the relief tank expected to be filled in 10 min. However, the design basis is that one Relief Tank would reach the maximum level in approximately 40 mins. Pump station suction pressure will fall, potentially leading to cavitation and damage to the MOL Pumps. Release of oil, the potential for oil to be released offsite Media coverage	R	E	4	7	1. As above 2. Relief tanks are sitting in a common bund, with 110% capacity of one tank. Bunds are connected to the Oily Water Treatment Package separator. 3. Incident Management Team has personnel trained and authorized to provide accurate information to the media and the public.	77. Complete loss of nitrogen supply to surge valves gauges could lead to unintended relief resulting in rapid filling of Relief Tanks. The relief tank could fill in a few tens of minutes with potential for an overflow of oil, if immediate actions are not taken. This could lead to a pool fire if ignited and injury to more than one person. Develop or add to existing written emergency procedures a requirement to evacuate people from the relief tank bund as soon as this scenario is detected (complete loss of nitrogen supply to surge valves gauges, SV failed open or not reclosing). Also, include this action in regular drills.
			3. The surge would cause a rapid increase in level in Relief Tanks potentially leading to overfilling and relief tank damage. If only one relief tank is in service, the relief tank expected to be filled in	E	E	4	7	1. As above 2. Relief Tanks are sitting in a common bund, with 110% capacity of one tank. Bunds are connected to the Oily Water Treatment Package separator.	

			10 mi. However, the design basis is that one Relief Tank would reach the maximum level in approximately 40 mins. Pump station suction pressure will fall, potential damage to the MOL Pumps by leading cavitation. Release of oil, the potential for oil to be released offsite						
			4. The surge would cause a rapid increase in level in Relief Tanks potentially leading to overfilling and relief tank damage. If only one relief tank is in service, the relief tank expected to be filled in 10 min. However, the design basis is that one Relief Tank would reach the maximum level in approximately 40 mins. Pump station suction pressure will fall, potential damage to the MOL Pumps by leading cavitation. Release of oil with potential pool fire, if ignition occurs. In case of fire, damage to both	F	D	3	7	1. As above	

			Relief tanks requiring pipeline shutdown, while repairs/replacement are being carried out. Possible to operate at low flowrate with neither relief tanks in service at						
		2. Fire around: - Surge valves SVs skid or - Relief valves SVs skid	1. Damage to the nitrogen supply pipework surge valves SVs or relief valves SVs leading to the opening of SVs and potential high level in Relief Tanks. See above consequences	S	F	2	4	1. FS with high flow alarm would alert the operator of a flowrate through surge line. The operator will possibly close MOV on the inlet to surge valves. 2. Low pressure alarm on the nitrogen system would alert operators of the failure of the nitrogen system. The operator will possibly close MOV on the inlet to surge valves. 3. LI with LAH would provide an indication of the level at the control room and alert operators. 4. LS on Relief Tank with high Level alarm High would cause an SSD of the upstream station. (Used if only one tank is in service). This alone does not stop the event, as there is still a sufficient volume of oil in the section of the pipeline upstream of the pump station. 5. LS on the other Relief Tank with high Level alarm High would cause an SSD of the upstream station. (Used if both relief tanks are in service). This alone does not stop the event, as there is still a sufficient volume of oil in the section of the pipeline upstream of the pump station. 6. The operator could close upstream	78. It was noted that the operating level at which the Relief tanks should be maintained is "within normal operating range". This level range is given as 2000-8000mm. It is not clear from the operating instructions that the level should be maintained at a minimum within the operating range. Amend the operating instruction to require that the Relief Tank level is maintained at a minimum within the operating range, in line with the operating philosophy.

								block valve after the controlled shutdown of the upstream station to limit the volume of oil draining into Relief Tanks. 7. After the shutdown of the upstream station, the operator would keep MOL Pumps running for some time to decrease volume from the upstream section.	
								8. Operating philosophy requires to operate Relief Tanks at minimum level Relief Tank Procedure 9. PALL would trip MOL Pumps in case of low pressure on the suction side (this is only a protection against MOL pump damage) 10. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated. 11. Site standard PPE - FR-PPE obligable to use. 12. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 13. Oil spill kit (drum based) is available on site for mopping up of small leaks. 14. Pump Station fire detection (including flame detectors). Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. Damage to the nitrogen supply pipework surge valves SVs or relief valves	R				1. As above	

			SVs leading to the opening of SVs and potential high level in Relief Tanks. See above consequences						
			3. Damage to the nitrogen supply pipework surge valves SVs or relief valves SVs leading to the opening of SVs and potential high level in Relief Tanks. See above consequences	E				1. As above	
			4. Damage to the nitrogen supply pipework surge valves SVs or relief valves SVs leading to the opening of SVs and potential high level in Relief Tanks. See above consequences	F				1. As above	
		3. Higher flow into Relief Tanks than running capacity of Reinjection Pumps	1. No additional consequences identified						
		4. High Temperature, leading to tank content expansion when Relief Tanks	1. NSCI						

		already at a high level								
	11. Low Level/No Level	1. Reinjection Pumps fail to stop at a low low level (e.g. LS failure)	1. A level decrease in Relief Tank, the potential for floating roof legs to touch the bottom of the Relief Tank, potentially leading to vacuum below the grounded floating roof caused by the pump suction. Note that roof grounding could lead to damage to the tank bottom, leading to accelerated corrosion and potential leak. If vacuum breaker valves work (PSVs), a flammable atmosphere may be created in the space below the floating roof. Potential for internal tank explosion, if ignition occurs. One possible ignition source could electrostatic discharge during the refilling of the Relief Tanks. Potential for fatalities	S	E	2	5	1. Operator Competency Training and Awareness - operator is monitoring Relief Tank level on LT and is expecting Reinjection Pumps to stop at a low level 2. LAL would alert the operator of low level in Relief Tanks 3. Operator Competency Training and Awareness - Operating practice is to stop the Reinjection Pump at a 15-20% level rather than waiting for a LALL because LT is known to be not very accurate below this level. 4. Preventative Maintenance (PM) on Level switches should reduce the likelihood of failure 5. LALL on second Relief Tank may give an alarm if the second tank is not out of service for maintenance and alert operator. 6. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated. 7. Site standard PPE - FR-PPE obligable to use.	
								8. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 9. Oil spill kit (drum based) is available on site for mopping up of small leaks. 10. Pump Station fire detection (including	

								flame detectors). Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. The level decrease in Relief Tank, the potential for floating roof legs to touch the bottom of the Relief Tank, potentially leading to vacuum below the grounded floating roof caused by the pump suction. Note that roof grounding could lead to damage to the tank bottom, leading to accelerated corrosion and potential leak. If vacuum breaker valves work a flammable atmosphere may be created in the space below the floating roof. Potential for internal tank explosion, if ignition occurs. One possible ignition source could electrostatic discharge during the refilling of the Relief Tanks. Potential for fatalities Media coverage	R	E	2	5	1. As above 2. Incident Management Team has personnel trained and authorized to provide accurate information to the media and the public.	
			3. A level decrease in Relief Tank, the potential for floating	R	G	3	4	1. As above 2. Drains from beneath the tank should	

			roof legs to touch the bottom of the Relief Tank, potentially leading to vacuum below the grounded floating roof caused by the pump suction. Note that roof grounding could lead to damage to the tank bottom, leading to accelerated corrosion and potential leak into the ground below the tank, causing soil contamination.					enable the identification of leaks from the bottoms of the tanks	
			4. A level decrease in Relief Tank, the potential for floating roof legs to touch the bottom of the Relief Tank, potentially leading to vacuum below the grounded floating roof leading to possible tank walls or floating roof buckling at both Relief tanks. (This consequence is used to score business severity) Potential cavitation of Reinjection pumps and pump damage. Extended pipeline shutdown while repair/replacement is being carried out.	F	D	3	7	1. Operator Competency Training and Awareness - operator is monitoring Relief Tank level on LT and is expecting Reinjection Pumps to stop at a low level 2. LAL would alert the operator of low level in Relief Tanks 3. Operator Competency Training and Awareness - Operating practice is to stop the Reinjection Pump at a 15-20% level rather than waiting for a LALL because LT is not very accurate below this level. 4. Preventative Maintenance (PM) on Level switches should reduce the likelihood of failure 5. LALL on second Relief Tank may give an alarm if the second tank is not out of service for maintenance and alert operator.	

	12. Reaction	1. No causes identified							
	13. Mixing	1. No causes identified							
	14. Relief	1. Maintenance valve downstream of relief valve skid if closed in error could result in high pressure on Class150 piping	1. See No Flow						
	15. Rupture/Leak	1. Large bore, Pipe rupture within Relief Tanks	1. Flow from rupture/leak of oil from Relief Tanks or from surge relief valves and pressure relief valves. There is the potential for the content of the Relief Tanks to be released Potential for spill offsite. It could lead to potential pool fire if ignition occurs. Potential for injury to operators	S	F	3	5	1. See safeguards for specific causes of rupture (e.g. vehicle impact, etc.), in mainline node 2. Bund (if the leak occurs in pipework within it) 3. Operator Competency Training and Awareness - Operators may notice decreasing level in Relief Tanks 4. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated. 5. Site standard PPE - FR-PPE obligable to use. 6. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 7. Oil spill kit (drum based) is available on site for mopping up of small leaks. 8. Pump Station fire detection. Fixed fire protection including mobile foam pourers.	

								Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. Flow from rupture/leak of oil from Relief Tanks or from surge relief valves and pressure relief valves. There is the potential for the content of the Relief Tanks to be released Potential for spill offsite. Media coverage	R	E	4	7	1. As above 2. Incident Management Team has personnel trained and authorized to provide accurate information to the media and the public.	
			2. Flow from rupture/leak of oil from Relief Tanks or from surge relief valves and pressure relief valves. There is the potential for the content of the Relief Tanks to be released. Potential for spill offsite. Media coverage	E	E	4	7	1. As above	
			4. Flow from rupture/leak of oil from Relief Tanks or from surge relief valves and pressure relief valves. There is the potential for the content of the Relief Tanks to be released. Potential for spill offsite Value of lost product,	F	E	4	7	1. As above	

			remediation costs, and extended pipeline operation at reduced flowrate.						
		2. Damage or crack at instrument tee for example - freezing (an incident where firefighting pumps started caused by instrument error) - a vibration of small bore piping - failure at hydrostatic vents used for commissioning but still in place	1. See Mainline node for consequence and safeguards						
	16. Equipment integrity	1. During maintenance involving welding on pipework or MOL Pumps equipment may be water filled. This water is drained to the Slop Tank and subsequently transferred to Relief Tank and main oil line	1. NSCI	S					
			2. NSCI	R					
			3. Increased corrosion in Relief Tanks bottom. This may lead to leaks from the tank bottom resulting in soil contamination beneath the Relief Tanks.	E	G	4	5	1. Tank base is coated internally (metal filled epoxy) and externally 2. Asphalt layer isolating tank exterior from the ground should prevent electrochemical corrosion of tank exterior, as long as there are no gaps between asphalt and steel surfaces. 3. Annual process safety audits should identify the potential for external corrosion at an early stage 4. Regular corrosion inspections are performed 5. Drain channels underneath the tank	

								base should allow early identification of the leak 6. Relief tanks are sitting in a common bund, with 110% capacity of one tank. Bunds are connected to the Oily Water Treatment Package	
			4. Increased corrosion in Relief Tanks bottom. This may lead to leaks from the tank bottom resulting in soil contamination. Tank off service for a long period to inspect and repair. The cost associated with draining, and performing intrusive maintenance. NSCI	F					
		2. Corrosion Under Insulation (CUI) on tank wall insulation (on the lower part of tanks)	1. Corrosion Under Insulation (CUI) on Relief Tank wall insulation could lead to a sudden larger leak. Potential for pool fire, if ignited and injury to operators.	S	F	2	4	1. Relief tanks are sitting in a common bund, with 110% capacity of one tank. Bunds are connected to the oily Water Treatment Package 2. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated. 3. Site standard PPE - FR-PPE obligable to use. 4. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 5. Oil spill kit (drum based) is available	

								on site for mopping up of small leaks. 6. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation 7. The operator would perform a controlled shutdown in case of fire. That would limit the inventory of material available to fire.	
			2. NSCI						
			3. Corrosion Under Insulation (CUI) on Relief Tank wall insulation could lead to a sudden larger leak and release of full tank inventory	E	F	4	6	1. As above	
			4. Corrosion Under Insulation (CUI) on Relief Tank wall insulation could lead to a sudden larger leak. Potential for pool fire, leading to damage to both Relief Tanks and prolonged pipeline shutdown	F	D	2	6	1. As above 2. Relief tanks are fitted with firewater deluge sprays which are available for cooling Relief Tanks in case of fire	
	17. Ignition	1. The flammable atmosphere above the floating roof of Relief Tanks due to oil leaking above the roof.	1. The flammable atmosphere could be ignited by lightning or other ignition sources. Could lead to tank internal explosion with possible fatality Non-safety						79. The flammable atmosphere may exist above the floating roof of Relief Tanks due to oil leaking above the floating roof or vapor coming through the pressure vacuum relief valves on refilling following complete emptying of the

		Not certain if this is credible as tank basis of design is that ventilation via fixed roof vents is sufficient to prevent flammable atmosphere.	consequences and likelihood could not be identified in detail. See Recommendation						Relief Tanks, with the floating roofs landing on their legs. It is not certain if this is credible as the tank basis of design is that ventilation via the fixed roof vents is sufficient to prevent a flammable atmosphere. Investigate by means of period gas testing whether the flammable atmosphere is present for a significant portion of time above the floating roof of the Relief Tanks and determine the requirement for flame arrestors at fixed roof vents.
	18. Abnormal Operation	1. Activation of inhibit on LS	1. In order to avoid a shutdown of the upstream pump station, station supervisor might decide to operate the pipeline with inhibit on LS. The automatic ESD action on the high level would therefore not work and might lead to Relief Tank overfill See high level					1. Possibility of using the second Relief Tank as the lead tank, with functioning ESD action on LS 2. Operating philosophy requires to operate Relief Tanks at a minimum level. Relief Tank Procedure	
	19. Human Factors	1. Activation of Emergency Shutdown (ESD) by ESD button onsite in case of problems related with Relief							

		Tanks (e.g. fire, or high level restriction)							
		2. Manual setting of the pressure of nitrogen supply to surge (gauges) and relief valves	1. Too great a pressure set will lead to no flow through the surge valves when the flow is required. Too little nitrogen pressure could lead to the inadvertent opening of the surge valves below their normal set pressure. These deviations are considered under more/no flow					1. Pressure set point clearly marked on gauge dials 2. Operator Competency Training and Awareness - Operators check nitrogen pressure three times a day,	
6. Slop Tank	1. No Flow	1. Into Slop Tank - Failure to de-isolate Slop Tank (spectacle blinds left online downstream of HVs left closed)	1. NSCI for the Slop Tank						
		2. Into Slop Tank - Blocked line (e.g. wax or foreign object)	1. NSCI for the Slop Tank	S					
			2. NSCI	R					
			3. NSCI	E					
			4. The blocked line would lead to the unavailability of the Slop Tank system and the decision to shut down the pump station until the problem rectified. Expected	F					

			shutdown time less than one day. NSCI						
		3. Into Slop Tank - A leak or ruptured pipe - Tundish valves closed in error - strainers draining valves closed in error -pump suction/discharge draining valves closed in error -mainline draining valves closed in error - s draining valves closed in error	1. NSCI for the Slop Tank						
		4. Out of Slop Tank - Slop Tank Pump stopped in error or faulty - Local manual selector switch faulty - Local power outage - Failure of flow switch causing the Slop Tank Pump to trip - Failure of flow switches on surge relief line sending a signal	1. Inability to empty the Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the Slop Tank vent. The pool of oil and potential pool fire ignition occurs. Potential for injury to operators.	S	F	3	5	1. Operator Competency Training and Awareness - Operators control local level indicator and would notice that level is not decreasing when expected. Also, operators in the LCR would monitor level indication. 2. Power supply failure at Slop Tank Pump indicated on SCADA 3. Level alarm High will initiate alarm at the control room (level switch) 4. Level alarm High will initiate alarm at the control room (level transmitter) 5. The level switch will initiate Pump station Emergency shutdown (ESD) on high high level and gives the warning to the control room and control room	

		in error indicating that there is a relief event - Interlock on Slop Tank Pump start if relief flow is detected by (normal function, when relief is actually taking place) - Failure of interlock with Reinjection Pumps (reinjection pumps are not running but failure of interlock prevents Slop Tank Pump from starting)						operator. 6. Standard procedure would be to stop draining activities if Slop Tank Pump is not working/tripped and there is no flow out. 7. Portable pump available on site to empty the Slop Tank into temporary containers. 8. Low occupancy around Slop Tank 9. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated. 10. Site standard PPE - FR-PPE obligable to use.	
								11. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Planned drill exercises are conducted by ER teams. ERTAO 12. Oil spill kit (drum based) is available on site for mopping up of small leaks. 13. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation.	
			2. NSCI	R					
			3. Inability to empty the Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the Slop Tank vent. The pool of	E	H	4	4	1. Operator Competency Training and Awareness - Operators control local level indicator and would notice that level is not decreasing when expected. Also, operators in the LCR would monitor level indication. 2. Level alarm High will initiate alarm at the control room (level switch)	

			oil contaminating the ground around					3. Level alarm High will initiate alarm at the control room (level transmitter) 4. Power supply failure at Slop Tank Pump indicated on SCADA 5. The level switch will initiate Pump station Emergency shutdown (ESD) on high high level and gives the warning to the control room and control room operator. 6. Standard procedure would be to stop draining activities if the pump is not working/tripped and there is no flow out. 7. Portable pump available on site to empty the Slop Tank into temporary containers. 8. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 9. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. Inability to empty the Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the Slop Tank vent. The pool of oil and potential pool fire ignition occurs. Estimated shutdown 2 days following a fire	F	E	3	6	1. Operator Competency Training and Awareness - Operators control local level indicator and would notice that level is not decreasing when expected. Also, operators in the LCR would monitor level indication. 2. Level alarm High will initiate alarm at the control room (level switch) 3. Level alarm High will initiate alarm at the control room (level transmitter) 4. Power supply failure at Slop Tank Pump indicated on SCADA 5. The level switch will initiate Pump	

								station Emergency shutdown (ESD) on high high level and gives the warning to the control room and control room operator. 6. Standard procedure would be to stop draining activities if the pump is not working/tripped and there is no flow out. 7. Portable pump available on site to empty the Slop Tank into temporary containers. 8. Low occupancy around Slop Tank 9. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated.	
								10. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 11. Oil spill kit (drum based) is available on site for mopping up of small leaks. 12. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
			5. High high level in the Slop Tank cause an Emergency Shutdown (ESD) of the pumping station, potentially leading to a surge in the pipeline upstream. Estimated shutdown	F					

			period of less than one day. NSCI						
		5. Out of Slop Tank - Slop Tank Pump Strainer blocked	1. Inability to empty the Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the Slop Tank vent. The pool of oil and potential pool fire ignition occurs. Potential for injury to operators.	S	F	2	4	1. Operator Competency Training and Awareness - Operators control local level indicator and would notice that level is not decreasing when expected. Also, operators in the LCR would monitor level indication. 2. Tank cleaning performed following review of Slop Tank Pump performance (time to empty the Slop Tank 3. Level alarm High will initiate alarm at the control room (level switch) 4. Level alarm High will initiate alarm at the control room (level transmitter) 5. Flow switch would detect no flow out of the Slop Tank Pump and stop the Slop Tank Pump. This would alert operators of process upset 6. The level switch will initiate Pump station Emergency Shutdown (ESD) on a high high level and gives the warning to the control room and control room operator. 7. Standard procedure would be to stop draining activities if the pump is not working/tripped and there is no flow out. 8. Portable pump available on site to empty the Slop Tank into temporary containers. 9. Low occupancy around Slop Tank 10. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated.	

									11. Site standard PPE - FR-PPE obligable to use. 12. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 13. Oil spill kit (drum based) is available on site for mopping up of small leaks. 14. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. NSCI	R					
			3. Inability to empty the Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the Slop Tank vent. The pool of oil contaminating the ground around	E	H	3	3	1. Operator Competency Training and Awareness - Operators control local level indicator and would notice that level is not decreasing when expected. Also, operators in the LCR would monitor level indication. 2. Level alarm High will initiate alarm at the control room (level switch) 3. Level alarm High will initiate alarm at the control room (level transmitter) 4. Tank cleaning performed following review of Slop Tank Pump performance (time to empty the Slop Tank) 5. Flow switch would detect no flow out of the Slop Tank Pump and stop the Slop Tank Pump. This would alert operators of process upset 6. The level switch will initiate Pump station ESD on a high high level and gives the warning to the control room and	

								control room operator. 7. Standard procedure would be to stop draining activities if the pump is not working/tripped and there is no flow out. 8. Flow switch would detect no flow out of the pump and stop the Slop Tank Pump 9. Portable pump available on site to empty the Slop Tank into temporary containers. 10. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Emergency Response Procedure and Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 11. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. Inability to empty the Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the Slop Tank vent. The pool of oil and potential pool fire ignition occurs. Estimated shutdown 2 days following a fire	F	E	2	5	1. Operator Competency Training and Awareness - Operators control local level indicator and would notice that level is not decreasing when expected. Also, operators in the LCR would monitor level indication. 2. Level alarm High will initiate alarm at the control room (level switch) 3. Level alarm High will initiate alarm at the control room (level transmitter) 4. Tank cleaning performed following review of Slop Tank Pump performance (time to empty the Slop Tank) 5. The level switch will initiate Pump station Emergency Shutdown (ESD) on a high high level and gives the warning to the control room and control room operator.	

								6. Flow switch would detect no flow out of the Slop Tank Pump and stop the Slop Tank Pump 7. Standard procedure would be to stop draining activities if the pump is not working/tripped and there is no flow out. 8. Portable pump available on site to empty the Slop Tank into temporary containers. 9. Low occupancy around Slop Tank 10. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated.	
								11. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Emergency Response Procedure for Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 12. Oil spill kit (drum based) is available on site for mopping up of small leaks. 13. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
			5. Potential damage to the pump (cavitation)	F	H	3	3	1. Flow switch will stop the Slop Tank Pump if no flow is detected 2. Slop Tank Pump can be removed and strainer cleaned. The operation can be performed in less than one day 3. Spare pump available in the warehouse. Can be replaced in less than one day	

								4. Portable pump available on site to empty the Slop Tank into temporary containers.	
		6. Out of Slop Tank - Discharge line blockage (e.g. wax or debris) - Check valve blocked - Spectacle blind downstream of Check valve left closed	1. Inability to empty the Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the Slop Tank vent. The pool of oil and potential pool fire ignition occurs. Potential for injury to operators.	S	F	3	5	1. Operator Competency Training and Awareness - Operators control local level indicator and would notice that the level is not decreasing when expected. Also, operators in the LCR would monitor level indication.	80. The closure of the manual valve would prevent emptying the Slop Tank leading to a high level and possible overfill of the Slop Tank, which in turn could lead to gas release and then liquid release from the Slop Tank vent. A pool of oil could form, followed by a pool fire if ignition occurs. Potential for injury to operators. We has not been able to understand the purpose of the manual valve on a drawing. Evaluate whether the manual valve can be removed
								2. In case of wax blockage, the line is electrically traced and insulated where above ground 3. Level alarm High will initiate alarm at the control room (level switch) 4. Level alarm High will initiate alarm at the control room (level transmitter) 5. The level switch will initiate Pump station emergency Shutdown (ESD) on high high level and gives the warning to the control room and control room operator. 6. Standard procedure would be to stop draining activities if the pump is not working/tripped and there is no flow out. 7. Portable pump available on site to empty the Slop Tank into temporary	81. The closure of the manual valve would prevent emptying the Slop Tank leading to a high level and possible overfill of the Slop Tank, which in turn could lead to gas release and then liquid release from the Slop Tank) vent. A pool of oil could form, followed by a pool fire if ignition occurs. Potential for injury to operators Change the valve to Locked Open (LO) position.

								containers. 8. Low occupancy around Slop Tank 9. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated. 10. Site standard PPE - FR-PPE obligable to use. 11. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 12. Oil spill kit (drum based) is available on site for mopping up of small leaks. 13. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. NSCI						
			3. Inability to empty the Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the Slop Tank vent. The pool of oil contaminating the ground around	E	H	4	4	1. Level alarm High will initiate alarm at the control room (level switch) 2. Level alarm High will initiate alarm at the control room (level transmitter) 3. The level switch will initiate Pump station Emergency Shutdown (ESD) on a high high level and gives the warning to the control room and control room operator. 4. Standard procedure would be to stop draining activities if the pump is not working/tripped and there is no flow out. 5. Portable pump available on site to empty the Slop Tank into temporary	

								containers. 6. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Emergency Response Procedure - , Oil Spill Response Plan and Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 7. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. Inability to empty the Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the Slop Tank vent. The pool of oil and potential pool fire ignition occurs. Estimated shutdown 2 days following a fire	F	E	3	6	1. Level alarm High will initiate alarm at the control room (level switch) 2. Level alarm High will initiate alarm at the control room (level transmitter) 3. The level switch will initiate Pump station Emergency Shutdown (ESD) on a high high level and gives the warning to the control room and control room operator. 4. Standard procedure would be to stop draining activities if the pump is not working/tripped and there is no flow out. 5. Portable pump available on site to empty the Slop Tank into temporary containers. 6. Low occupancy around Slop Tank 7. Site ignition controls - equipment in hazardous areas is ATEX rated and where required work is evaluated for ignition potential 8. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Emergency Response	

								Procedure - , Oil Spill Response Plan and Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 9. Oil spill kit (drum based) is available on site for mopping up of small leaks. 10. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
			5. Potential damage to Slop Tank Pump motor (pump deadheaded)	F	H	4	4	1. Flow switch will stop the Slop Tank Pump if no flow is detected 2. Slop Tank Pump can be removed and strainer cleaned. The operation can be performed in less than one day 3. Spare pump available in the warehouse. Can be replaced in less than one day 4. Portable pump available on site to empty the Slop Tank into temporary containers.	
		7. Out of Slop Tank - Faulty level alarm on may fail to start the Slop Tank Pump when a high level is reached	1. Inability to empty the Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the Slop Tank vent. The pool of oil and potential pool fire ignition occurs. Potential for injury to operators.	S	F	3	5	1. Preventative Maintenance (PM) routines on level instruments should ensure reliable readings 2. Level alarm High will initiate alarm at the control room (level switch). The slop tank pump can be started in the manual by operators. 3. The level switch will initiate Pump station Emergency shutdown (ESD) on high high level and gives the warning to the control room and operator. 4. Low occupancy around Slop Tank	

								5. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated. 6. Site standard PPE - FR-PPE obligable to use. 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Emergency Response Procedure - , Oil Spill Response Plan and Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks. 9. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of the fire damage and escalation	
			2. NSCI						
			3. Inability to empty the Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the Slop Tank vent. The pool of oil contaminating the ground around	E	H	4	4	1. As above	
			4. Inability to empty the Slop Tank leading to a high level and possible overfill.	F	E	3	6	1. As above	

			Leading to gas release and then liquid release from the Slop Tank vent. The pool of oil and potential pool fire ignition occurs. Estimated shutdown 2 days following a fire						
	2. Less Flow	1. Into Slop Tank - Partial blockage of lines upstream - Partly closed drain valve	1. No additional consequences. See No flow						
		2. Out of Slop Tank - Partial blockage of lines downstream - Partly closed manual valves	1. No additional consequences. See No flow						
	3. More Flow	1. From Pump Discharge - - Mainline PSVs failed open/passing, From Wax handling system PSV failed open/passing	1. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. The pool of oil and potential pool fire ignition occurs. Potential for injury to operators.	S	F	3	5	1. Operator daily checks to include Pressure Safety Valves (PSVs) should detect abnormal conditions. 2. Preventative Maintenance (PM) on Pressure Safety Valves (PSVs) to include bench testing 3. Level alarm High will initiate alarm at the control room (level switch) 4. Level alarm High will initiate alarm at the control room (level transmitter) 5. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 6. The level switch will initiate Pump station ESD on a high high level and gives the warning to the control room and	

									control room operator. 7. Low occupancy around Slop Tank 8. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous areas and where work having ignition potential evaluated. 9. Site standard PPE - FR-PPE obligable to use. 10. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 11. Oil spill kit (drum based) is available on site for mopping up of small leaks. 12. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. NSCI	R					
			3. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. The pool of oil contaminating the ground around	E	H	4	4	1. Level alarm High will initiate alarm at the control room (level switch) 2. Level alarm High will initiate alarm at the control room (level transmitter) 3. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 4. The level switch will initiate Pump station ESD on a high high level and gives the warning to the control room and control room operator. 5. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill	

									and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 6. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
				4. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. Fire ignition occurs. Estimated shutdown 2 days following a fire	F	E	3	6	1. Level alarm High will initiate alarm at the control room (level switch) 2. Level alarm High will initiate alarm at the control room (level transmitter) 3. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 4. The level switch will initiate Pump station ESD on a high high level and gives the warning to the control room and control room operator. 5. Low occupancy around Slop Tank 6. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 7. Site standard PPE - FR-PPE obligable to use. PPE Procedure 8. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 9. Oil spill kit (drum based) is available on site for mopping up of small leaks. 10. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	

		2. Normally closed drain valves open in error or passing	1. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. The pool of oil and potential pool fire ignition occurs. Potential for injury to operators.	S	F	4	6	1. Operation and maintenance procedures require to close drain valves after draining/maintenance activity. 2. Operator Competency Training and Awareness - Operators would notice rising levels in Slop Tank and would investigate potential causes. 3. Level alarm High will initiate alarm at the control room (level switch) 4. Level alarm High will initiate alarm at the control room (level transmitter) 5. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 6. The level switch will initiate Pump station Emergency shutdown (ESD) on high high level and gives the warning to the control room and operator. 7. Low occupancy around Slop Tank 8. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 9. Site standard PPE - FR-PPE obligable to use. 10. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 11. Oil spill kit (drum based) is available on site for mopping up of small leaks. 12. Pump Station fire detection. Fixed fire protection including mobile foam pourers.	

								Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. NSCI	R					
			3. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. The pool of oil contaminating the ground around	E	H	5	5	1. Operation and maintenance procedures required to close drain valves after draining/maintenance activity. 2. Operator Competency Training and Awareness - Operator would notice a rising level in Slop Tank and would investigate potential causes. 3. Level alarm High will initiate alarm at the control room (level switch) 4. Level alarm High will initiate alarm at the control room (level transmitter) 5. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 6. The level switch will initiate Pump station Emergency shutdown (ESD) on high high level and gives the warning to the control room and operator. 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release	F	E	4	7	1. Level alarm High will initiate alarm at the control room (level switch) 2. Level alarm High will initiate alarm at the control room (level transmitter) 3. Slop Tank Pump to start if this is set into remote automatic mode upon high	

			from the slop tank vent. The pool of oil and potential pool fire ignition occurs. Estimated shutdown 2 days following a fire					level from LT. 4. The level switch will initiate Pump station ESD on a high high level and gives the warning to the control room and control room operator. 5. Low occupancy around Slop Tank 6. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks. 9. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
		3. Thermal relief and PSVs close afterward From Pump Discharge passing	1. NSCI						
		4. Multiple draining operations	1. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. The pool of oil and	S	F	3	5	2. Operator Competency Training and Awareness - Operator would notice a rising level in Slop Tank and would investigate potential causes. 3. Level alarm High will initiate alarm at the control room (level switch) 4. Level alarm High will initiate alarm at the control room (level transmitter)	

			potential pool fire ignition occurs. Potential for injury to operators.					5. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 6. The level switch will initiate Pump station Emergency shutdown (ESD) on high high level and gives the warning to the control room and operator. 7. Low occupancy around Slop Tank 8. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 9. Site standard PPE - FR-PPE obligable to use. 10. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 11. Oil spill kit (drum based) is available on site for mopping up of small leaks. 12. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. NSCI	R					
			3. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent.	E	H	4	4	2. Operator Competency Training and Awareness - Operator would notice a rising level in Slop Tank and would investigate potential causes. 3. Level alarm High will initiate alarm at the control room (level switch) 4. Level alarm High will initiate alarm at	

			The pool of oil contaminating the ground around					the control room (level transmitter) 5. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 6. The level switch will initiate Pump station Emergency shutdown (ESD) on high high level and gives the warning to the control room and operator. 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. Pool of oil and potential pool fire ignition occurs. Estimated shutdown 2 days following a fire	F	E	3	6	1. Operator Competency Training and Awareness - Before draining operators inform control room. No multiple draining are normally performed 1. Level alarm High will initiate alarm at the control room (level switch) 2. Level alarm High will initiate alarm at the control room (level transmitter) 3. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 4. The level switch will initiate Pump station ESD on a high high level and gives the warning to the control room and control room operator. 5. Low occupancy around Slop Tank 6. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated.	

								7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks. 9. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
		5. Draining from vacuum road tanker into the slop tank	1. No additional consequences identified						
		6. During maintenance, draining of water or oil into open drain header	1. No additional consequences identified						
		7. Multiple simultaneous thermal reliefs	1. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. Pool of oil and potential pool fire ignition occurs. Potential for injury to operators.	S	F	3	5	1. Operator daily checks to include Pressure Safety Valves (PSVs) should detect abnormal conditions. 2. Preventative Maintenance (PM) on Pressure Safety Valves (PSVs) to include bench testing 3. Level alarm High will initiate alarm at the control room (level switch) 4. Level alarm High will initiate alarm at the control room (level transmitter) 5. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 6. The level switch will initiate Pump	

								station ESD on a high high level and gives the warning to the control room and control room operator. 7. Low occupancy around Slop Tank 8. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 9. Site standard PPE - FR-PPE obligable to use. 10. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 11. Oil spill kit (drum based) is available on site for mopping up of small leaks. 12. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. NSCI	R					
			3. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. The pool of oil contaminating the ground around	E	H	4	4	1. Level alarm High will initiate alarm at the control room (level switch) 2. Level alarm High will initiate alarm at the control room (level transmitter) 3. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 4. The level switch will initiate Pump station ESD on a high high level and gives the warning to the control room and control room operator. 5. Oil spill emergency response plan for	

								pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Emergency Response Procedure - , Oil Spill Response Plan and Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 6. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. Fire ignition occurs. Estimated shutdown 2 days following a fire	F	E	3	6	1. Level alarm High will initiate alarm at the control room (level switch) 2. Level alarm High will initiate alarm at the control room (level transmitter) 3. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 4. The level switch will initiate Pump station ESD on a high high level and gives the warning to the control room and control room operator. 5. Low occupancy around Slop Tank 6. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 7. Site standard PPE - FR-PPE obligable to use. 8. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 9. Oil spill kit (drum based) is available on site for mopping up of small leaks.	

								10. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
	4. Part of Flow	1. No causes identified							
	5. Other than Flow	1. Contamination via open tundishes, for example, absorbent pads	1. See no / less flow						
		2. Foam into drain lines as part of maintenance (injected to avoid potential gas breakthrough)	1. Potential for increased internal corrosion of Slop Tank. NSCI 2. Potential for causing misreading of level instruments on slop tank. NSCI						
	6. Contamination/Composition	During maintenance, draining of water or oil into open drain header	1. No additional consequences identified						
		2. Foam into drain lines as part of maintenance (injected to avoid potential gas breakthrough)	1. See Other than flow						
		3. Foreign objects left in lines or in the Slop Tank	1. See no flow						

	7. High Pressure	1. Discharge valves on station discharge open in error or passing	1. NSCI	S					
			2. NSCI	R					
			3. Potential for closed drain line rupture (Class 150) if exposed to full upstream line pressure through a fully open valve, for example where there is a restriction in the drains, leading to loss of containment on site.	E	G	4	5	1. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Emergency Response Procedure - , Oil Spill Response Plan Planned drill exercises are conducted by ER teams. - Oil Spill response plan Oil Spill Response Procedure 2. Operator training competency and awareness procedures require that drain valves are closed prior to restart 3. Manual valves HVs are Locked Open (LO) and on Locked Open/Locked Close (LOLC) register. LOLC is reviewed bi-weekly	
			4. NSCI	F					
		2. Overfilling of Slop Tank resulting in a high level in the vent line would cause Slop Tank to exceed the design pressure	1. NSCI	S					82. There is the potential for over pressurizing the Slop Tank due to hydrostatic head of the oil column in the vent line, in the event of an overfill. Review the design of the Sop Tank and confirm whether its ability to withstand pressure exceeds the stated design pressure on the P&IDs. If so, up rate the tank to a higher pressure.
			2. NSCI	R					
			3. Potential for Slop Tank to crack/rupture leading to oil contaminating the surrounding ground	E	G	4	5	1. Level alarm High will initiate alarm at the control room (level switch) 2. Level alarm High will initiate alarm at the control room (level transmitter) 3. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 4. The level switch will initiate Pump station Emergency Shutdown (ESD) on a high high level and gives the warning to	

								the control room and control room operator.	
			4. Potential for Slop Tank to crack/rupture leading to pipeline shutdown while repairs are performed Slop Tank has to be taken out service for repairs. This could lead to an extended shutdown period for the pipeline (up to 5 days)	F	E	4	7	1. As above	
		3. Breather vent blocked (e.g. Bird activity), Preventing draining into the Slop Tank. Static head in closed drains would cause Slop Tank to exceed design pressure.	1. NSCI	S					
			2. NSCI	R					
			3. Potential for Slop Tank to crack/rupture leading to oil contaminating the surrounding ground	E	G	4	5	1. Wire mesh around the vent should prevent the ingress of insects and debris within the vent line. 2. Daily operator walk around to include a visual check of breather vent 3. Preventative Maintenance (PM) on breather vent	
			4. Potential for Slop Tank to crack/rupture leading to pipeline shutdown while repairs are performed Slop Tank has to be taken out service for repairs. This could lead to an extended shutdown period for the pipeline (up to 5 days)	F	E	4	7	1. As above	

	8. Low Pressure	1. Breather vent blocked (e.g. bird activity). If pumping out from Slop Tank, or using the vacuum truck from the vacuum truck connection, a vacuum can be generated into the Slop Tank or Blocked Vent and rapid condensation occurring inside the Slop Tank (e.g. due to temperature drop)	1. NSCI	S					
			2. NSCI	R					
			3. Potential for Slop Tank to crack/rupture leading to oil contaminating the surrounding ground	E	G	4	5	1. Wire mesh around the vent should prevent the ingress of insects and debris within the vent line. 2. Daily operator walk around to include a visual check of breather vent 3. Preventative Maintenance (PM) on breather vent	
			4. Potential for Slop Tank to crack/rupture leading to pipeline shutdown while repairs are performed Slop Tank has to be taken out service for repairs. This could lead to an extended shutdown period for the pipeline (up to 5 days)	F	E	4	7	1. As above	
	9. High Temperatur e	1. External fire on site leading to relief of hot oil into the Slop Tank	1. The amount of oil relieved expected to be small and some cooling is expected on piping. NSCI						
	10. Low Temperatur e	1. Low ambient temperature can cause check valves to stick in place.	1. See reverse flow (for stick open) and no flow						
		2. Cold oil in Slop Tank	1. Gel formation. See less/no flow NSCI						

	11. High Level	1. See causes of more flow into the Slop Tank Or causes of no/less flow out the Slop Tank							
		2. Slop Tank Pump is left in manual mode mistakenly when it should be put back into automatic mode	1. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. Pool of oil and potential pool fire ignition occurs. Potential for injury to operators.	S	F	3	5	1. Operator Competency Training and Awareness - an interface between the field operator and control room operator should prevent the wrong setting of the Slop Tank Pump operating mode. 2. Level alarm High will initiate alarm at the control room (level switch) 3. Level alarm High will initiate alarm at the control room (level transmitter) 4. The level switch will initiate Pump station Emergency shutdown (ESD) on high high level and gives the warning to the control room and operator. 5. Low occupancy around Slop Tank 8. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 6. Site standard PPE - FR-PPE obligable to use. 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks. 9. Pump Station fire detection. Fixed fire	

								protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. NSCI	R					
			3. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. The pool of oil contaminating the ground around	E	H	4	4	1. Operator Competency Training and Awareness - the interface between the field operator and control room operator should prevent the wrong setting of the pump operating mode. 3. Level alarm High will initiate alarm at the control room (level switch) 4. Level alarm High will initiate alarm at the control room (level transmitter) 6. The level switch will initiate Pump station Emergency shutdown (ESD) on high high level and gives the warning to the control room and operator. 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. Pool of oil and potential pool fire ignition occurs. Estimated	F	E	3	6	1. Operator Competency Training and Awareness - the interface between the field operator and control room operator should prevent the wrong setting of the pump operating mode. 1. Level alarm High will initiate alarm at the control room (level switch) 2. Level alarm High will initiate alarm at the control room (level transmitter) 4. The level switch will initiate Pump	

			shutdown 2 days following a fire					station ESD on a high high level and gives the warning to the control room and control room operator. 5. Low occupancy around Slop Tank 6. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks. 9. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
		3. Failure of the level transmitter. Failing to start Slop Tank Pump	1. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. Pool of oil and potential pool fire ignition occurs. Potential for injury to operators.	S	F	3	5	2. Level alarm High will initiate alarm at the control room (level switch) 4. The level switch will initiate Pump station Emergency shutdown (ESD) on high high level and gives warning to control room and operator. 5. Low occupancy around Slop Tank 8. Control of Site for ignition - ATEX/IECEx rated equipment used in hazardous area and where work having ignition potential evaluated. 6. Site standard PPE - FR-PPE obligable to use. . 7. Oil spill emergency response plan for pump stations and pipeline should locate	83. Failure of level transmitter LT may fail to start Slop Tank Pump. The same level transmitter provides a signal to the local level indicator LI-0178 and the SCADA screen reading at LCR. This is the only indication of level in the Slop Tank without dipping. This fault may lead to confusion of the operator about the level in the Slop Tank and inability to empty the Slop Tank, with potential high level and

								the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks.. 9. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	possible overfill leading to gas release and then liquid release from the slop tank vent. Pool of oil and potential pool fire ignition occurs. Potential for injury to operators. Investigate improvements to reduce the likelihood of this scenario, such as improved reliability of level transmitter, or having to also start the Slop Tank Pump or providing an independent local level indicator. Following the investigation, implement one or a combination of identified solutions.
			2. NSCI	R					
			3. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release from the slop tank vent. The pool of oil contaminating the ground around	E	H	4	4	3. Level alarm High will initiate alarm at the control room (level switch) 6. The level switch will initiate Pump station Emergency shutdown (ESD) on high high level and gives the warning to the control room and operator. 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Emergency Response Procedure - , Oil Spill Response Plan and Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks.	
			4. A high flow of oil into Slop Tank leading to a high level and possible overfill. Leading to gas release and then liquid release	F	E	3	6	1. Level alarm High will initiate alarm at the control room (level switch) 4. The level switch will initiate Pump station ESD on a high high level and gives the warning to the control room and control room operator.	

			from the slop tank vent. The pool of oil and potential pool fire ignition occurs. Estimated shutdown 2 days following a fire					5. Low occupancy around Slop Tank 6. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks. 9. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
	12. Low Level/No Level	1. Failure of the level transmitter. Failing to turn off Slop Tank Pump or Slop Tank Pump fails to stop	1. NSCI	S					
			2. NSCI	R					
			3. NSCI	E					
			4. Slop Tank Pump continues running leading to cavitation and potential pump damage	F	H	4	4	1. FS would stop the Slop Tank Pump 2. Spare pump available at the warehouse. Can be replaced in less than one day	
		2. A leak from Slop Tank oil to the environment (e.g. due to corrosion)	1. NSCI	S					
			2. NSCI	R					
			3. The tank may leak into the ground for a long time before a leak is detected, leading to ground contamination.	E	G	2	3	1. Slop Tank is double shelled 2. Slop Tank inspection should allow detection of a leak 3. Space between the inner and outer shell of Slop Tank is filled with glycol, with level switch and alarm (LS) 4. The coating on the exterior surface of Slop Tank should reduce corrosion issues	

								of Slop Tank 5. Cathodic Protection (CP) on the tank exterior should reduce corrosion issues of Slop Tank	
			4. NSCI	F					
		3. A leak from Slop Tank either in the inner or outer shell resulting in low level in the space between inner and outer shells of Slop Tank	1. NSCI	S					
			2. NSCI	R					
			3. NSCI	E					
			4. Slop Tank has to be taken out of service for repairs. Leak on inner shell occurred, leading to repairs taking 2 days This could lead to an extended shutdown period for the pipeline (up to 5 days).	F	E	5	8	1. Slop Tank inspection 2. The coating on the exterior surface of Slop Tank should reduce corrosion issues of Slop Tank 3. The coating on the exterior surface of Slop Tank should reduce corrosion issues of Slop Tank 4. Space between the inner and outer shell of Slop Tank is filled with glycol, with level indicator and alarm (LS). It would allow detecting the leak and plan for tank inspection and replacement in advance.	
	13. Reaction	1. No causes identified							
	14. Mixing	1. No causes identified							
	15. Relief	1. No causes identified (see more flow)							
	16. Rupture/Leak	1. Rupture upstream of Slop Tank	1. NSCI						
		2. The rupture between Slop Tank and check valve on the outlet line	1. NSCI						

		3. Rupture downstream check valve	1. Could drain out all content of Relief Tank						
		4. Large leak at site pipework - external impact - dropped object - loss of support - sabotage	1. See Mainline node for consequence and safeguards						
		5. Damage or crack at instrument tee for example - freezing (an incident where firefighting pumps started caused by instrument error) - vibration of small bore piping	1. See Mainline node for consequence and safeguards						
	17. Instrumentation	1. During maintenance involving welding on pipework or MOL Pumps equipment may be water filled. This water is drained to the Slop Tank and subsequently transferred to Relief Tank and main oil line	1. The flow of water into Slop Tank Note that different fluid density may cause misreading of the level transmitter LT. This could lead to a high level and possible overfill when the Slop Tank is filled again afterward. Leading to gas release and then liquid release (oil first, then water) from the slop tank vent. Pool of	S	F	3	5	1. Level alarm High will initiate alarm at the control room (level switch) 2. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 3. The level switch will initiate Pump station Emergency shutdown (ESD) on high high level and gives the warning to the control room and operator. However, ESD will not prevent water from flowing into the slop tank 4. Low occupancy around Slop Tank 5. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work	

			oil and potential pool fire ignition occurs. Potential for injury to operators.					having ignition potential evaluated. 6. Site standard PPE - FR-PPE obligable to use. PPE Procedure 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. Emergency Response Procedure for Oil Spill Response Plan and Oil Spill Containment Booklet Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks. 9. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. NSCI						
			3. The flow of water into Slop Tank - Note that different fluid density may cause misreading of the level transmitter LT. This could lead to a high level and possible overfill when the Slop Tank is filled again afterward. Leading to gas release and then liquid release (oil first, then water) from the slop tank vent. The pool of oil contaminating the	E	H	4	4	1. As above	

			ground around the Slop Tank						
			4. The flow of water into Slop Tank - Note that different fluid density may cause misreading of the level transmitter LT. This could lead to a high level and possible overfill when the Slop Tank is filled again afterward. Leading to gas release and then liquid release (oil first, then water) from the slop tank vent. Pool of oil and potential pool fire ignition occurs. Potential for injury to operators. Estimated shutdown 2 days following a fire					1. Level alarm High will initiate alarm at the control room (level switch) 2. Level alarm High will initiate alarm at the control room (level transmitter) 3. Slop Tank Pump to start if this is set into remote automatic mode upon high level from LT. 4. The level switch will initiate Pump station ESD on a high high level and gives the warning to control room and Control room operator. 5. Low occupancy around Slop Tank 6. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 7. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB Planned drill exercises are conducted by ER teams. ERTAO 8. Oil spill kit (drum based) is available on site for mopping up of small leaks. 9. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
		2. Failure of LS giving a high reading and causing a Station Emergency	1. NSCI	S					
			2. NSCI	R					
			3. NSCI	E					
			4. Emergency Shutdown potentially	F					

		Shutdown (ESD).	leads to a surge in the pipeline upstream. Estimated shutdown period of less than one day. NSCI						
	18. Equipment integrity	1. During maintenance involving welding on pipework or MOL Pumps equipment may be water filled. This water is drained to the Slop Tank and subsequent transferred to Relief Tank and main oil line	1. NSCI	S					
			2. NSCI	R					
			3. Increased corrosion in Slop Tank or Relief Tanks See low level	E					
			4. Increased corrosion in Slop Tank or Relief Tanks See low level	F					
		2. Sulfate Reducing Bacteria (SRB), Microbially Induced Corrosion (MIC) Static fluid in deadlegs resulting in accumulation of water and internal MIC	1. No deadlegs on this node NSCI						
		3. External corrosion of buried sections of	1. NSCI	S					
			2. NSCI	R					
			3. Leak over an extended period as it	E	G	4	5	1. Cathodic Protection (CP) should prevent external corrosion. CP checked	

		pipework/equipment within the station boundary	cannot easily be detected resulting in ground contamination onsite					by transformer-rectifier checks and test post surveys. 2. Pipework/equipment is coated 3. Pipework is wrapped at the soil air interface 4. Pipework/equipment is surrounded by sand or similar to prevent damage to the coating 5. Onsite environmental analysis carried out on site at well points	
			4. Corrosion penetration of pipework leading to large leak which would then need to be repaired. An enlarged inspection program would then be required. The possible shutdown of the pipeline while repairs/replacement are carried out.	F	E	4	7	1. As above	
		4. Corrosion Under Insulation (CUI) - can be for extended periods as unseen - can be more severe than typical corrosion if lagging is wet	1. A leak can be more severe than typical corrosion if lagging is wet. Potential for fire, if ignition occurs, leading to injury to operators (pool fire)	S	F	2	4	1. Corrosion Under Insulation (CUI) survey and asset integrity managing plan by integrity contractor are under way at Pump stations. 2. Low occupancy around Slop Tank 3. Control of Site for ignition - ATEX/IECEx rated equipment used in the hazardous area and where work having ignition potential evaluated. 4. Site standard PPE - FR-PPE obligable to use. 5. Oil spill emergency response plan for pump stations and pipeline should locate the spill, mitigate the effects of the spill and clean up. ERP for OSRP and OSCB	

								Planned drill exercises are conducted by ER teams. ERTAO 6. Oil spill kit (drum based) is available on site for mopping up of small leaks. 7. Pump Station fire detection. Fixed fire protection including mobile foam pourers. Fire Emergency Response team - may limit the extent of fire damage and escalation	
			2. NSCI	R					
			3. A leak can be more severe than typical corrosion if lagging is wet. This will result in ground contamination onsite	E	G	4	5	1. Corrosion Under Insulation (CUI) survey and asset integrity managing plan by integrity contractor are under way at Pump stations.	
			4. Corrosion penetration of pipework leading to large leak which would then need to be repaired. An enlarged inspection program would then be required. The possible shutdown of the pipeline while repairs/replacement are carried out.	F	E	4	7	1. As above	
		5. Slop Tank is not available	1. The worst case would be a major failure of Slop Tank leading to pipeline shutdown while repairs are performed. Slop Tank has to be taken out of service for repairs. This could lead to an						

			extended shutdown period for the pipeline (up to 5 days) See high pressure						
	19. Abnormal Operation	1. No causes identified							
	20. Maintenance	1. Difficult access to equipment in the Slop Tank	1. Occupational hazards to operators when working into the pit (slip, trips falls) Difficult rescuing operations from confined space	S	H	6	6		84. Access to the Slop Tank pit is difficult. This creates occupational hazards to operators when working into the pit (e.g. slip, trips falls). In addition, rescuing operations from confined space is difficult. This could lead to fatality if a person cannot escape from confined space if there is an imminent danger. Improve access for entry into Slop Tank pit and rescue operations.
			2. Occupational hazards to operators when working into the pit (slip, trips falls) Difficult rescuing operations from confined space could lead to fatality if a person cannot escape from confined space.	S	E	3	6		
			3. NSCI	R					
			4. NSCI	E					
			5. NSCI	F					
	21. Human Factors	1. No causes identified							

Curriculum Vitae

Mehmet Orhan KILINÇ

Place & Date of Birth : Istanbul - 09.01.1978

Marital Status : Married

Adress : Graan voor Visch 15709 Hoofddorp Netherland

I have 17 years of experience in the oil & gas and chemical industry. Between April 2005 and September 2019, I worked in Botas International, starting as Ceyhan Marine Terminal Operation Supervisor for 5 years and I worked as an Operations Chief for Pump Station and Block valve operations as well as Area Authority (AA) in BP Permit to Work system. At the same time, I worked at SOMA KIMYA A.Ş. from February 2006 to September 2015 as a Research and Development and Production consultant. Now I am working as Engineer in Commissioning Department at South Stream Transport Company B.V in Amsterdam.

Education

BS Middle East Technical University Chemistry

Work Experience

South Stream Transport B.V., Commissioning Engineer (Operation)

Botas International, Competency Expert

Botas International, PT4 Operation Chief

Botas International, CCR Supervisor

Botas International, CCR Senior Operator

Soma Kimya A.S., Production and R&D consultant

Hayat Kimya A.S., Production Engineer

Odul Ilac A.S., R&D Manager

Odul Ilac A.S., Research Expert