ENGG404 TEAM PROJECT FINAL TECHNICAL REPORT:

Submitted by Team #: 314

Case Study: Humber Refinery Fire and Explosion, UK, 2001

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On April 16, 2001, a massive explosion that resulted in a fire occurred at the ConocoPhillips Humber Refinery. A failure of a section of piping occurred at an elbow just downstream of a water-into-gas injection point on the refinery's Saturated Gas Plant. This failure caused the release and ignition of highly flammable gas containing 90% ethane/propane/butane which resulted in the explosion and fire. There were no fatalities from the incident, but two serious injuries were reported. There were damages sustained by the site adjacent to the Saturated Gas Plant, as well as on houses and businesses that are within one-kilometre radius of the refinery. In terms of assets, the Humber refinery sustained significant damage and ConocoPhillips Ltd. was charged and fined for multiple offences amounting to over £1,000,000. The refinery was temporarily shut down, halting its production for several weeks.

Context and Purpose

This report is completed by our team for ABC Conglomerate Company, an oil refinery in Edmonton, Alberta. Like the Humber refinery, the ABC facility includes an alkylation plant and rotary kilns for petroleum coke manufacturing. Crude oil arrives by tanker and is stored at an oil terminal before being pumped into the plant for refining. Approximately 130,000 barrels of petrol are being produced in the plant everyday and the products are shipped out to locations across Alberta. Due to this similarity in production system, an incident investigation is done to prevent the same incident from happening to ABC Conglomerate's Refinery. This report details the findings of our investigation on the explosion and fire incident in ConocoPhillips Humber Refinery on April 16, 2001. The main objective is to logically break down and analyze the basic causes, immediate causes, and latent causes that led to the incident by using the Root Cause Analysis method and Cause and Effect model. This report would be beneficial not only to ABC Conglomerate Company, but also to the entire oil refinery industry, in preventing such an incident from happening again.

Root Cause Analysis

The scope of this Root Cause Analysis focuses on the direct causes, particularly the latent causes, that led to the fire and explosion incident in Humber refinery. The emergency response handled the fire effectively, so the duration of the fire did not have much impact on the losses as the initial explosions. Therefore, the factors that contributed to the preservation of the fire in the plant were not explored for this analysis. Failures, oversights and incidents that occurred previously in the plant but did not directly affect the failure of the elbow were also not considered. The first key latent cause determined from this analysis is that the company had no process in place to ensure that an impact study is completed before a process change is created. The additional water injection point was installed as a quick fix and no evaluation was made on its impact on the pipe's corrosion potential. The water injection eroded the protective

coating leaving the pipe open to attack by corrosive agents causing the failure of the elbow and the release of highly flammable gases. The lack of process in place to safely manage changes to the system led to the incident. The second key latent cause determined is that the company perpetuated a culture of valuing production over following process to ensure safety. The erosion and corrosion in the elbow were not detected because it was never inspected. This is because the installation of the additional water injection point was never documented, thus, it is not in the plant's database nor did anywhere say it was in operation. The process to record changes in the piping system was not followed as the company lacked the culture of following processes. Management wanted little to no downtime for the modifications, to not affect the production so the installation of the water injection point was performed without following the process. The culture of prioritizing production over the safety in the company ultimately led to the failure of the elbow causing the incident.

List of Latent Causes

RMS Element #1: Management Leadership, Commitment and Accountability

- Management preferred production
- Management prioritized project completion over quality
- Company value to put production in front of safety
- Management did not value routine inspections
- Lack of guidelines for the corporate team
- Management did not see the importance of the Corrosion engineer
- Management valued profit over safety

RMS Element #2: Risk Assessment and Management of Risks

- Lack of risk identification process to confirm adequacy of design standard
- No impact study on effect of erosion of protective coating
- Inadequate Risk Assessment and Management process
- The risk evaluation program was not evaluated

RMS Element #4: Management of Change

- No processes in place to require an impact study on quick modifications
- Inadequate Management of Change process
- No process to record piping changes

RMS Element #5: Incident Reporting, Investigation, Analysis and Actions

- No process in place to implement corporate recommendations based on incidents at other plants

RMS Element #6: Program Evaluation and Continuous Improvement

- Lack of auditing to ensure and reinforce compliance

RMS Element #7: Design, Construction and Start-up

- Inadequate evaluation of Deliverable during Design Phase

RMS Element #8: Operations and Maintenance

- Operation and maintenance crews did not regularly communicate about the changes being done

RMS Element #9: Employee Competency and Training

- Employees were not taught why paperwork is so essential
- Document management and review process was not followed
- Design Engineer was not trained or given orientation about the project
- Training program did not exist
- Inadequate training on risk evaluation for inspectors
- Lack of training for risk-based inspection coordinators

RMS Element #10: Contractor Competency and Integration

- Design Engineer was not able to manage his time and handle pressure when working in multiple projects

RMS Element #11: Operations and Facilities Information and Documentation

- No processes in place to require documentations on quick modifications
- No system in place requiring employees to do paper work
- Document management and review process was inadequate
- Inadequate Document Management Control System for records on changes
- No system for recording discoveries from and follow up on inspections
- Inadequate Document Management Control system

Key Recommendations and Alignment to Elements

After careful review of the root causes of the incident at the Humber Refinery and the associated Risk Management Elements, the following four key recommendations were developed such that, when implemented, they will immediately mitigate numerous potential risks stemming from 8 of the 11 Risk Management Elements. After application of the Gain and Effort Indices Criteria, all four recommendations were classified as low-hangin fruit. It is imperative that these recommendations be implemented in full to prevent future losses at ABC.

The first recommendation is to implement a policy requiring adherence to a Management of change Assessment and Tracking procedure when implementing any process or pipework modifications. This policy will prevent quick-fixes from going unevaluated and undocumented. It will ensure that the risks are assessed competently and completely. Application of this recommendation will help synthesize alignment with the following Risk Management Elements:

- RME #1 - Management Leadership, Commitment and Accountability
- RME #2 - Risk Assessment and Management of Risks
- RME #4 - Management of Change
- RME #8 - Operations and Maintenance
- RME #11 - Operations and Facilities Information and Documentation

The second recommendation is to improve the Employee Competency and Training program to ensure employees are properly trained and qualified to perform their roles. The incident at Humber could have easily been prevented at multiple different occasions if the personnel involved had received proper training in the management of change, risk assessment, and project scope. Ensuring that all employees are trained in these areas will result in a safer workplace. Improving the training program will align with the following Risk Management Elements:

- RME #1 - Management Leadership, Commitment and Accountability
- RME #2 - Risk Assessment and Management of Risks
- RME #9 - Employee Competency and Training
- RME #10 - Contractor Competency and Integration

The third recommendation is to review ABC's routine maintenance inspection process of the plant's pipework and make recommendations for improvement as needed to ensure it allows the identification of hazards before failure. The Humber Refinery missed multiple opportunities to identify the damage to the elbow long before it ruptured do to ineffective inspections. This review of ABC's inspection program will ensure that inspections are comprehensive and no erosion, corrosion, or other fatigue is occuring undetected in the refinery. This review will bring to light any existing issues in order to align with the following Risk Management Elements:

- RME #1 - Management Leadership, Commitment and Accountability
- RME #8 - Operations and Maintenance
- RME #11 - Operations and Facilities Information and Documentation

The fourth and final key recommendation is to implement an improved Document Management and Storage System that notifies appropriate employees of any documentation that could affect their work. This web-based platform will ensure that all processes, piping, and components of the refinery are recorded and that the documents are easily accessible to all necessary personnel. This will ensure no details of the plant are forgotten and will aid in the application of the other three recommendations. Implementing this recommendation will achieve alignment in the following Risk Management Elements:

- RME #1 - Management Leadership, Commitment and Accountability
- RME #4 - Management of change
- RME #7 - Design Construction and Start-up
- RME #11 - Operations and Facilities Information and Documentation

A table summarizing the recommendations can be found on page 24.

Business Case Analysis

The cost of this incident to ConocoPhilips included almost $2.5 million in fines, almost $10 million in production losses and about $100 million in loss of assets. Ignoring all other costs, ConocoPhillips paid over $112 million for this incident. It is expected that if no remediation efforts are taken, this scale of incident would occur again in 30 years, resulting in an annual risk exposure of $3.7 million.

Implementation of the top two recommendations would cost approximately $760,000 up front with an additional yearly improvement cost of $37,500. The total implementation cost over 30 years of life is $1,885,000. With these implementations the likelihood of this scale of incident occurring again is reduced to 1 in 100 years, reducing the annual risk exposure to $1.1 million. The gross benefit per year becomes $2,616,510 and over 30 years of life the gross benefit is $78,495,270. With the minor implementation cost of $1,885,000, the net gain of implementing the top two recommendations is $76,610,270 over 30 years.

Issues with Implementation and Next Steps

The recommendation with the greatest potential implementation challenges is the recommendation to implement an improved document management and storage system. The first possible challenge stems from stakeholder buy-in. The system will involve new technologies foreign to the workers, will require changes to current habits and may initially reduce production. These obstacles may impede supervisors from accepting and promoting the system. With stakeholder engagements to hear concerns and properly convey the benefits of the program this challenge can be avoided. The second challenge comes with the size of the scope of the implementation. The system will bear a large up-front cost and take many years to implement fully. It is critical that no documentation is lost or neglected in the transition years. Have a temporary system in place will facilitate the transition, prevent loss of information, and ease inter-employee relationships.

This report recommends that, in order to prevent incidents at any of ABC’s facilities, all of the recommendations presented be implemented at the earliest possibility. These improvements will prevent future losses of people, environment, assets, and production, which will not only will result in net financial gains but will uphold ABC’s commitment to zero loss incidents.

Chapter 1: Incident Description and Losses

Incident Description

On April 16, 2001 an explosion and resulting fire occurred on the ConocoPhillips Humber refinery. In the morning everything was operating normally with no alarms in the saturate gas plant. The staff were preparing for a shift handover which was to occur at 3:00pm. At about 2:20pm a section of pipework on the saturate gas plant failed at an elbow downstream of a water into gas injection point. This resulted in a cloud of 90% ethane/propane/butane filling the air for 20 to 30 seconds until it ignited. The first explosion followed and a fireball of over 30 meters resulted.

From a bird's eye view, an eyewitness described the event as a very bright flash by one of the saturated gas plant columns. This was followed by a much larger flash accompanied by a loud bang. The second flash travelled from the mid point to the top of the de-ethaniser tower. Then the first explosion occurred. After the first explosion a fire started between the de-ethaniser and stabiliser columns in the vicinity of the surge/feed drum. The fire was described to be a clean yellow flame. Around 15 minutes after the initial explosion there was another release of the 90% ethane/propane/butane mixture. This resulted in another fireball and the fire extending to the stabiliser and the propane/butane columns. As the fire continued, there were multiple other failures of pipework from the increase in temperature resulting in a loss of strength. As a result, more fuel was being poured into the fire. This resulted in more smaller fireballs following and the fire increasing in size.

Three workers in a building 175m away from the explosion were knocked down by the blast. There were also some contractors working on scaffolding platforms nearby that were blown over. Additional effects to the workers included coughing and choking from the resulting exhaust on the explosion. All the workers made a full recovery.

The emergency response was swift, as moments after the initial explosion members of the ConocoPhillips Emergency Response Team made their way to the fire. The refinery’s general alarm was sounded and as the Emergency Response Team made their way to the fire, they set up turrets, monitors, and hoses to pour water onto the flames. 20 minutes after the explosion the plant leader called the Production Superintendent to shut down the refinery as the fire was out of control. The team worked to close isolation valves and limit the supply to the refinery as now the smoke was turning darker indicating the burning of heavy oils. Just before 70 minutes after the first explosion the White Oils Field Leader under considerable fire protection approached the damaged pipework and found out that the fire was being fed from the Cryogenic unit. As a result, three isolation valves were shut off and the fire quickly died down and was put under control. The initial fireball occurred at 2:21pm and by 5:10pm it was mostly extinguished before it was finally put out as 9:01pm.

Losses

The personal losses on this incident were minimal. Many workers report being blown over by the explosion. Two people were seriously injured. There were no deaths as a result of the explosion. The environmental damage was substantial. Damage was recorded on the adjacent Lindsey Oil Refinery and houses/business within 1km radius of the ConocoPhillips Humber refinery. Specifically, the village of North and South Killingholme and the town of Immingham.

In terms of assets the ConocoPhillips Humber refinery was badly damaged. ConocoPhillips Limited was charged with multiple offences and fined £895,000 as well as ordered to pay £218,854 in damages. The explosion impacted production as the incident temporarily shut down the refinery for several weeks.

Chapter 2: Context and Purpose

Context

This report is written for ABC Conglomerate Company, who runs several similar oil refinery plants across Canada. The goal of this report is to logically break down and analyze the incident that took place at the Humber Refinery in 2001 in order to prevent similar incidents from occurring at any refinery owned by ABC Conglomerate Company. This report will uncover the basic causes, immediate causes and latent causes of the incident at Humber. This report will also highlight the potential issues present at the Humber Refinery and within Conoco Ltd. and make recommendations to ABC to ensure similar issues are not present in their plants.

The Humber Refinery was first built for Continental Oil (UK) Ltd which was a major US brand of oil and is currently owned by Phillips 66 since the split of ConocoPhillips. It is in South Killingholme, North Lincolnshire in the United Kingdom. It is situated south of the railway next to the road A160 [1].

The production facilities include an alkylation plant and rotary kilns for petroleum coke manufacturing. Crude oil arrives by tanker at Tetney in East Lindsey and is stored at the Tetney oil terminal before being pumped into the plant for refining. 130,000 barrels (21,000 m^3) of petrol are being produced in the plant everyday and 700,000 tonnes of petrol are produced each year as of 2014 [1]. The products are shipped out to locations across the UK and around the world. 70% of the products are for the market in the UK and the rest are for international markets. The inherent risks of the operation in this facility is that this is a facility with a high density of explosive materials and surrounded by numerous ignition points.

In 2001, after the accident, the company pleaded guilty and was fined £895,000. Since ABC Conglomerate Company is running a similar production system, this report will help them to prevent similar incidents from happening, avoid fines, and improve their risk assessment system, inspection system, and system of management of changes. Applying the recommendations in this report will not only increase the safety of ABC’s employees, but will protect the public image of the company, maintain the confidence of investors, and protect the price of ABC’s stocks.

Purpose

The purpose of this report is to identify and learn from the causes of the Humber Refinery Explosion on April 16, 2001. Recommendations will be made based on an investigation into the incident as recorded in this report. The Canadian Energy Pipeline Association (CEPA), which represents most of all pipelines in the country, released a report stating that corrosion is one of the main causes of pipeline incidents in Canada [2]. As piping systems make up a major part of ABC Conglomerate Company’s infrastructure, there is a lot of opportunity for corrosion. Therefore, this incident is a very representative case and thus it is essential for ABC to review and implement the recommendations found in this report. In addition, as this incident and the

hazards it exposed are not atypical in the oil and gas industry in Canada, the recommendations from this report should be implemented by anyone in the industry.

Chapter 3: Root Cause Analysis – Discussion

Scope and Boundaries

In order to determine the underlying causes of the Humber Refinery explosion, a Root Cause Analysis (RCA) was conducted. In preparation for the study, the scope was defined to focus the investigation on relevant factors in order to arrive at relevant latent causes. The breadth of the study was defined with the incident description: “Fire and Explosion at Humber Refinery Saturate Gas Plant”. As stated in the description, the scope involves the causes of the fire and explosion at the Humber Refinery Saturate Gas Plant (SGP). The immediate factors causing the fire, namely air, fuel, and ignition, are explored in this analysis, particularly how the fuel vapour cloud was formed by a ruptured elbow in a high-pressure gas line containing a mix of highly flammable gasses. The factors that affected the perpetuation of the fire were not considered as the emergency response team handled the fire effectively, and the duration of the fire did not have as much impact on the losses as the initial explosions. Failures, oversights, and incidents at other parts of the plant over its history, that did not directly affect the failure of the elbow, were not considered. The depth of the study was such that the latent causes behind the breached elbow and the resultant fire were determined. Two latent causes and the paths to them are discussed here as examples.

Key Latent Cause #1

To arrive at the first latent cause, the cause and effect model was used starting at the incident description. The incident was described as a “Fire and Explosion at Humber Refinery Saturate Gas Plant”. All fires require air, fuel, and an ignition source. This latent cause stems from the immediate cause of there being fuel present, which is a substandard condition. The fuel for this explosion and subsequent fire came from a vapour cloud of 90% Butane, Ethane, and Propane, which was released due to a failed elbow on the P4363 line just downstream of an ad-hoc water injection point. The elbow failed due to unidentified erosion at the elbow. This leads to another immediate cause: The Black Iron Sulfide protective coating, which was in place to protect the elbow from corrosion, had been eroded. This cause can be attributed as a substandard condition. This erosion was a direct result of the water injection point just 670 mm upstream of the failed elbow. The immediate cause here is the substandard condition of the water injected at the injection point eroding the protective coating. The erosion was permitted to occur because the impact of installing the additional water injection point so close to the elbow was not evaluated as the injection point was installed hastily as a quick-fix to mitigate fouling in the heat exchangers. The quick fix was not evaluated as there was no process in place to ensure an impact study was completed when a process change was created. This is the latent cause, connected with the Risk Management Element number 4 of Management of Change as there was no process in place to safely manage changes to the system.

Key Latent Cause #2

The second latent cause was found by starting at the incident description and following the cause and effect model. The incident descriptions states that there was a fire and an explosion at the SGP at the Humber refinery. The first immediate cause of the fire was the substandard condition of the presence of a fuel source, in this case a vapour cloud of 90% butane, ethane, and propane. The vapour cloud was present due to a failed elbow on the P4363 line downstream of a water injection point. The elbow failed due to undetected corrosion in the elbow. The second immediate cause is that the corrosion was undetected because the elbow was never inspected. This is a substandard practice. In 1992 the refinery received a safety bulletin from corporate warning of the downstream impacts of water injection points. The refinery inspected the pipework downstream of the water injection points in the refinery. The third immediate cause is another substandard practice: the 1992 inspection of downstream piping did not include the pipework of P4363 and the failed elbow. The elbow and its pipework were not inspected because the water injection point was not in the refinery's database. The basic cause for the injection point not existing in the database is that the workers in the refinery did not believe that the water injection point was in operation. This leads to a second basic cause that there was no documentation of the operating condition of the water injection point on P4363. A third basic cause indicates that there was no documentation of the operation of P4363 because there was no documentation of the installation of the water injection point. This was due to a failure to follow processes requiring documenting changes in the piping system. This failure is the result of another basic cause of a lack of culture of following processes. Ultimately, the second latent cause is that the company perpetuated a culture of valuing production over following process to ensure safety. This is connected to the first Risk Management Element: Management Leadership, Commitment and Accountability.

Chapter 4: Application of the Cause and Effect Model

Immediate Causes

Substandard Conditions:

- Improperly prepared equipment - pipe protective coating eroded due to improper installation of water injection
- Defective equipment - corrosion of pipe elbow after loss of protective coating
- Inadequate warning systems - no warning of pipe rupture until vapor cloud ignition
- Inadequate isolation of process or equipment - vapor cloud was ignited by a nearby open ignition source
- Exposure to fire and explosion - due to pipe rupture creating flammable vapor cloud

Substandard Work Practices:

- Lack of knowledge of hazards - pipe elbow never inspected despite hazard evidence
- Lack of knowledge of hazards - water injection installation and operation not well documented
- Using equipment improperly - Water injection point was an existing vent valve, not designed as an injection point
- Improper placement - water injection point was placed too close to elbow that ruptured
- Not following safety standards or guidelines - inspections ignored elbow
- Not following safety standards or guidelines - software to predict risk did not consider injection point due to lack of input or documentation
- Not following proper operating procedures or methods - injection point size was changed and injection style (constant flow or intermittent) was not documented

Basic Causes

Engineering Design Factors:

- Inadequate technical design - drawings not reviewed
- Inadequate monitoring of initial operation - pipe impact on erosion/corrosion ignored
- Inadequate documentation of change - design not processed through MOC procedures
- Inadequate design criteria - pipe protection coating was thought to be enough

Job Factors:

- Error-inducing conditions - Design and implementation time was rushed
- Inadequate communication - Water injection point was thought not to be in operation, no documentation on operation or installation
- Inadequate training - no training or culture for recording process

- Inadequate maintenance - pipe inspections did not include inspection downstream of water injection point
- Inadequate communication - Operations did not inform inspectors of water injection pipe size and operational changes
- Inadequate job procedures - management did not establish level of unacceptable risk

Personal Factors:

- Improper motivation - employees did not want to do paper work
- Perceived mental stress - engineer prioritized design for other bigger projects
- Lack of knowledge or skill - Inexperienced inspectors did not know water injection points were a risk
- Lack of knowledge or skill - Misunderstood RBI coordinators thought water feed line was permanently isolated
- Lack of knowledge or skill - Inspectors not trained or experienced

Latent Causes (weaknesses in Management System Elements)

- Management preferred profit, production, and project completion over adequate design time to ensure quality and safety (Management Leadership, Commitment and Accountability)
- Management did not value routine inspections (Management Leadership, Commitment and Accountability)
- Lack of corporate guidelines for documentation of change to refinery systems (Management Leadership, Commitment and Accountability)
- Management did not see the importance of a corrosion engineer (Management Leadership, Commitment and Accountability)
- No impact study on erosion of protective coating (Risk Assessment and Management of Risks)
- Inadequate review process/program for submitted design drawings (Design, Construction and Start-up)
- Operations and Maintenance did not regularly communicate (Operations and Maintenance)
- No training programs or risk evaluation for inspectors or employees (Employee Competency and Training)
- Employees completing the water injection installation did not consider the impact of water injection downstream of the input (Employee Competency and Training)
- Design engineer was not able to manage time and pressure of multiple projects, so the quality of design suffered (Contractor Competency and Integration)
- No process to implement corporate recommendations based on incidents at other plants (Incident Reporting, Investigation, Analysis and Actions)
- No system for recording discoveries and to follow up on inspections (Operations and Facilities Information and Documentation)

- No process to require impact study or documentation on quick modifications or piping changes (Management of Change, Operations and Facilities Information and Documentation)
- Lack of auditing to ensure and reinforce compliance to existing plant documentation and inspection standards (Program Evaluation and Continuous Improvement)

Chapter 5: Key Recommendations

The following Gain and Effort Indices Criteria were adapted from the ESRM Handbook, Chapter 4.6:

Gain Index Criteria:

Gain Index	Gain Index Criteria (any one of or combination of
4	➢ Addresses latent causes. ➢ Eliminates hazards or has the greatest reduction in risk levels. ➢ Eliminates initiating events.
3	➢ Addresses basic causes. ➢ Reduces risk levels to a lesser extent than “4”. ➢ Prevents incident by eliminating subsequent condition splits. ➢ Eliminates impact in overall PEAP despite having an event.
2	➢ Addresses immediate causes. ➢ Reduces risk levels to a lesser extent than “3”. ➢ Minimizes impact significantly in overall PEAP (i.e., mitigates the consequences of an incident)
1	➢ Minimizes impact slightly in overall PEAP (i.e., mitigates the consequence of an incident). ➢ Does not address any cause ➢ Reduces risk levels to a lesser extent than “2” or not at all.

Effort Index Criteria:

	1 (high effort)	2	3	4 (low effort)
Practicability	difficult / challenging / develop new technology	apply complex technology	apply simple technology	the solution is not technology
Initial Cost	> $2M	$1M - $2M	$0.1M - $1M	< $100,000
On-going Costs	> $100,000 per year	$100K > cost per year > $10K	< $10,000 per year	no additional on-going cost
Timeline (the time before the action can be implemented)	implemented more than one year	can be implemented within 1 year	can be implemented within 3 months	can be implemented immediately
Duration (the time it takes before the action addresses the relevant latent cause)	requires more than 3 months	requires less than 3 months	requires less than one month	requires less than one week
Frequency (how often does the action needs to be repeated)	once per month or more often	once per quarter	once per year	one-time

Key Recommendations:

1. Implement a policy requiring adherence to a Management of change (MoC) Assessment and Tracking procedure when implementing any process or pipework modifications

- The installation of the second water injection in Humber was a quick fix and was never assessed. There were no technical and risk reviews done to assess the impacts of this installation on the corrosion potential of the pipe. This ultimately caused the failure of the elbow causing the incident. Having this MoC procedure will allow easy management of changes in ABC. The procedure will include the assessment of the proposed changes, approvals from appropriate levels of subject-matter experts (SMEs) and management before implementation, documentation and tracking of changes made within the plant.
    - Technical and risk evaluations will be done for any proposed change in process or pipework within the plant
    - Appropriate SMEs and management representatives will review the evaluations and will provide feedback or request more information if needed
    - Written approval from the SMEs and the management must be provided before implementing the change
    - Once the change is implemented, it will be documented in accordance to ABC's Document Management system to inform other departments on site of the changes affecting their work
    - The change will also be evaluated and tracked regularly to ensure the change is still doing its purpose. If not, this must be reported and dealt with accordingly

- Gain Index = 4
    - It addresses the latent cause of inadequate Management of Change process. Having a MoC process that will manage and track all proposed and completed changes will reduce the risk of such an incident from happening in ABC.
- Effort Index = 21
    - Practicability = 4
        - The solution does not require technology
    - Initial Cost = 4
        - The initial cost is estimated to be less than $10,000 for the training workshop resources of existing employees of this new process, as well as the inclusion of this new process to new employee orientation training
    - On-going Cost = 4
        - There is no on-going cost as this policy will only be implemented once
    - Timeline = 2
        - The policy will be implemented within 3 months once the procedure is tested and approved at ABC
    - Duration = 3
        - The policy will require less than one month to work and prevent undesirable incidents due to unreported changes
    - Frequency = 4
        - The policy will be implemented once, for the lifetime of the plant and will be updated as needed.
- Total Score = 84 - Low Hanging Fruit
- Nature of Fix: The policy will be implemented one time and will be permanent for the lifetime of the plant. This solution does not require technology.
- Latent causes addressed
    - No impact study on effect of erosion of protective coating
    - No processes in place to require an impact study on quick modifications
    - Inadequate Management of Change process
    - No process to record piping changes
    - No processes in place to require documentations on quick modifications
    - Operation and maintenance crews did not regularly communicate about the changes being done
- Alignment to RM Element(s):
    - RME #1 - Management Leadership, Commitment and Accountability
    - RME #2 - Risk Assessment and Management of Risks
    - RME #4 - Management of Change
    - RME #8 - Operations and Maintenance
    - RME #11 - Operations and Facilities Information and Documentation

2. Improve the Employee Competency and Training program to ensure employees are properly trained and qualified to perform their roles

- One of the root causes identified from this investigation that led to the Humber incident is the inadequate competency and training for the employees. The employees did not follow processes required for managing changes, lacked the knowledge on the project's scope and risk evaluation and identification. The improved Competency and Training program

will ensure that the employees will be trained to know their responsibilities, the processes, hazards and risks associated with their work as well as how to manage and control these risks. The program will also test and confirm the competency of the employees in their specific roles and authorization will be provided for the employees to perform their roles.
    - New employees will undergo the Competency and Training program prior to working on site. A certificate of completion and an authorization from appropriate management must be provided confirming the employee is ready to work on site
    - Employees will undergo refresher competency and training programs yearly. This Includes performance evaluations to test competency of the employees
    - Management will ensure every employee working on site are completing the annual program
- Gain Index = 4
    - The program will address the latent cause of inadequate employee competency and training program. Employees will better understand their responsibilities and will be able to identify manage and risk on site as needed. This will prevent such an incident from happening in ABC.
- Effort Index = 16
    - Practicability = 3
        - This solution will require simple technology to assist in relaying information to employees during training sessions such as visual presentations, animations and computer simulations etc.
    - Initial Cost =3
        - The initial cost is estimated to be around $500,000 - $1M to implement the improved competency and training program. This is to gather all the resources that would be enough for the training of the employees working on site, as well as for new employees. The cost was calculated based on the assumption that the plant will have 650-750 workers on site.
    - On-going Cost = 2
        - The on-going cost is estimated to be around $25,000 - $50,000 a year. This is the cost for yearly refresher competency and training programs and evaluations for all employees on site.
    - Timeline = 2
        - The improved program will be implemented within 1 year once all resources and materials are gathered and ready to be shared with the employees. The refresher training programs for the employees will need to be scheduled and organized accordingly to not affect the work being done in the plant.
    - Duration = 3
        - With regular competency and training programs, this solution will only require less than one month to ensure employees are aware of their responsibilities
    - Frequency = 3
        - New employees will undergo the improved Competency and Training program before commencement and then mandatory refresher competency and training program must be done annually for existing employees
- Total Score = 64 - Low hanging fruit

- Nature of Fix: Employees will undergo the improved refresher training program annually. The improvement of the Competency and Training program only requires simple technology.
- Latent causes addressed
    - Employees did not consider the impact it would have
    - Document management and review process was not followed
    - Design Engineer was not trained or given orientation about the project
    - Training program did not exist
    - Inadequate training on risk evaluation for inspectors
    - Lack of training for risk-based inspection coordinators
    - Design Engineer was not able to manage his time and handle pressure when working in multiple projects
- Alignment to RM Element(s):
    - RME #1 - Management Leadership, Commitment and Accountability
    - RME #2 - Risk Assessment and Management of Risks
    - RME #9 - Employee Competency and Training
    - RME #10 - Contractor Competency and Integration

3. Review ABC's routine maintenance inspection process of the plant's pipework and make recommendations for improvement as needed to ensure it allows the identification of hazards before failure

- The elbow failure that caused the Humber incident was due to corrosion that was not detected from the maintenance inspections done in the plant. ABC's routine maintenance inspection process will be reviewed to ensure it include the scheduling and tracking of inspection reports, initiation and tracking of repair work, as well as the communication and documentation of the inspection findings and recommendations to appropriate departments on site. This will allow the identification of potential hazards within the plant's pipework, preventing their failure,
    - A team of appropriate inspection experts and management representatives will be formed for reviewing ABC's existing maintenance inspection process
    - The team is responsible for doing surveys and evaluations on the inspection process and discuss through a series of workshop meetings
    - The team will also propose improvements to the process, if any, to appropriate management
- Gain Index = 3
    - It addresses the immediate and basic causes concerning inspection not being done and not communicating inspection findings and recommendations
- Effort Index = 21
    - Practicability = 4
        - This solution will not require technology as review can be done by appropriate ABC's inspection experts/management team through a series of workshop meetings
    - Initial Cost = 4

        - The initial cost is expected to be low as the review will be done by existing ABC employees and will not require a lot of new resources
    - On-going Cost = 4
        - There is no additional on-going cost expected for this solution as the review will only be done once
    - Timeline = 4
        - It can be done immediately as the team performing the review are already employees of ABC and are aware of the existing inspection process
    - Duration = 1
        - The review is estimated to take 3-6 months to complete and propose and recommend new process to the management, if any. Assuming the review team meets bi-weekly
    - Frequency = 4
        - The review will be done one-time as a response from this investigation
- Total Score = 63 - Low hanging fruit
- Nature of Fix: The review will be done one-time and does not require technology. It will be done through a series of workshop meetings involving ABC's inspection experts/management team
- Latent cause addressed
    - Management did not value routine inspections
    - Management did not see the importance of the Corrosion Engineer
    - Operation and maintenance crews did not regularly communicate about the changes being done
    - No system for recording discoveries from and follow up on inspections
- Alignment to RM Element(s):
    - RME #1 - Management Leadership, Commitment and Accountability
    - RME #8 - Operations and Maintenance
    - RME #11 - Operations and Facilities Information and Documentation

4. Implement an improved Document Management and Storage System that notifies appropriate employees of any documentation that could affect their work

- The installation of the second water injection point in Humber was never documented. Inspections were never done for the elbow that failed because no documentation informed the maintenance and inspection crew that it was in operation. Implementing a document management and storage system that will contain all necessary documentation and can be accessed by the employees will prevent the Humber incident from happening in ABC. The system will be a web-based platform specifically developed for ABC. It will be used to store and manage all documentation within the plant including design drawings, inspection and technical reports/recommendations, record of pipework/process changes etc. Employees can access the system and their profiles will be personalized so they can receive notifications on any new documents that could affect the work they are doing.
    - All design drawings for the plant will be stored in the system. Tracking reviews, revisions and approvals of different document deliverables will be done by appropriate management through the system to ensure they meet ABC's requirements

    - Record of process/pipework changes proposed and implemented within the plant, as well as Inspection reports and recommendations will be stored in this system
    - Employees will have personalized profiles so they can receive notifications if new documentations are uploaded that concerns their work
    - Appropriate management will ensure documents are always uploaded in the system
- Gain Index = 4
    - This solution addresses the latent causes concerning inadequate document management control system
- Effort Index = 14
    - Practicability = 3
        - The Document management system will be a web-based platform specific for ABC plant that will require the application of a complex technology
    - Initial Cost = 3
        - The estimated initial cost will be less than $500,000 which includes that cost of the developer who will create a platform specific for ABC's document management system needs
    - On-going Cost = 2
        - The on-going cost is estimated to $50,000 a year for the cost of developer who will be responsible for maintaining and upgrading the platform
    - Timeline = 1
        - The system will be implemented in less than 4 years once all information and resources has been gathered. This period will also include the transfer or existing documents to the new system and the dry run tests on certain departments of ABC
    - Duration = 1
        - The system is expected to take effect after a year and address document management and storage system concerns
    - Frequency = 4
        - This Document management and storage system will be implemented once
- Total Score = 56 - Low hanging fruit
- Nature of Fix: The improved document management and storage system will be implemented only once and will require the application of complex technology
- Latent causes addressed
    - Inadequate evaluation of deliverable during design phase
    - No processes in place to require documentations on quick modifications
    - Document management and review process was inadequate
    - Inadequate Document Management Control System for records on changes
    - No process in place to implement corporate recommendations in the long term
    - No process in place to implement corporate recommendations based on incidents at other plants
    - Inadequate Document Management Control system
- Alignment to RM Element(s):
    - RME #1 - Management Leadership, Commitment and Accountability
    - RME #4 - Management of change
    - RME #7 - Design Construction and Start-up
    - RME #11 - Operations and Facilities Information and Documentation

Summary of Key Recommendations

Rank	Recommendation	Gain Index	Effort Index	Total Score	Nature of Fix	Latent Cause Addressed	Applicable RME
1	Implement a policy requiring adherence to a Management of change (MoC) Assessment and Tracking procedure when implementing any process or pipework modifications	4	21	84	The policy will be implemented one time and will be permanent for the lifetime of the plant. This solution does not require technology.	● No impact study on effect of erosion of protective coating ● No processes in place to require an impact study on quick modifications ● Inadequate Management of Change process ● No process to record piping changes ● No processes in place to require documentations on quick modifications ● Operation and maintenance crews did not regularly communicate about the changes being done	1, 2, 4, 8, 11
2	Improve the Employee Competency and Training program to ensure employees are properly trained and qualified to perform their roles	4	16	64	Employees will undergo the improved refresher training program annually. The improvement of the Competency and Training program only requires simple technology.	● Employees did not consider the impact it would have ● Document management and review process was not followed ● Design Engineer was not trained or given orientation about the project ● Training program did not exist ● Inadequate training on risk evaluation for inspectors ● Lack of training for risk-based inspection coordinators ● Design Engineer was not able to manage his time and handle pressure when working in multiple projects	1,2,9,10
3	Review ABC's routine maintenance inspection process of the plant's pipework and make recommendations for improvement as needed to ensure it allows the identification of hazards before failure	3	21	63	The review will be done one-time by appropriate ABC inspection experts/management and does not require technology.	● Management did not value routine inspections ● Management did not see the importance of the Corrosion engineer ● Operation and maintenance crews did not regularly communicate about the changes being done ● No system for recording discoveries from and follow up on inspections	1, 8, 11
4	Implement an improved Document Management and Storage System that notifies employees of any documentation that could affect their work	4	14	56	The improved document management and storage system will be implemented only once and will require the application of complex technology	● Inadequate evaluation of Deliverable during Design Phase ● No processes in place to require documentations on quick modifications ● Document management and review process was inadequate ● Inadequate Document Management Control System for records on changes ● No process in place to implement corporate recommendations in the long term ● No process in place to implement corporate recommendations based on incidents at other plants ● Inadequate Document Management Control system	1, 4, 7, 11

Chapter 6: Business Case Analysis

The net value of implementing the top two recommendations combined is a positive value strictly from a monetary point of view looking at the losses in assets and production. Taking other factors into consideration such as people and environment we can quickly see how implementing the top two recommendations will bring great benefit to ABC Conglomerate.

The cost of avoiding a loss incident was calculated by adding together the fines, the loss in production and the loss of assets. The fines totaled 1,113,854 pounds. Exchanged at the April 2001 exchange rate ($2.223 CAD to Pound) to CAD we have a total of $2,476,100 CAD in fines. There are also 71 claims for injury that were pursued by both workers and private citizens. Next, we look at the loss in production. The plant was shut down for an estimated 5 weeks. At an average of 12,000 US barrels of oil a day being produced at the plant at a cost of $23 per barrel puts the total revenue loss at $9,660,000. The total investment on the refinery has been in excess of $750,000,000. It is estimated that the repairs to the refinery cost $100,000,000, putting the total cost avoidance of a loss incident at $112,136,100.

The annual risk exposure with these two new recommendations was estimated to now be at 1 in every 100 years instead of 1 in every 30 years. This is due to the inherent risk in operating flammable and explosive materials around many ignition points found in a refinery.

	Top Two Recommendations
Cost Avoidance of a Loss Incident	$112,136,100
Initial Costs of Improvements	$10,000 + $750,000 = $760,000
On-going Costs of Improvements per Year	$37,500
Life of Project	30 years
Total Cost of Improvements	$1,885,000
Annual Risk Exposure without Improvements	$3,737,870
Annual Risk Exposure with Improvements	$1,121,360
Annual Gross Benefit	$2,616,510
Total Gross Benefit	$78,495,270
Net Benefit	**$76,610,270**

1) Referring to the Complex Effort v Gain Tool, in which quadrant does this case fall? Explain.

The case falls under the low hanging fruit. Both recommendations score a 4 on the gain index meaning they both address latent causes, eliminate hazards or has the greatest reduction in risk levels, and eliminates initiating events. The effort is relatively low as well with the first key recommendation scoring a 21 and the second scoring a 16, this places both under the low hanging fruit category.

2) *What conclusion do you draw about this Business Case Analysis? Explain.*

From a business point of view, both recommendations are worth implementing because of the estimated savings from avoiding another event. We can see how the recommendations greatly reduce the risk of another event occurring. As they both have a low cost to implement and maintain, considering the scale of the business, it makes implementing them simple and easy.

3) *What other factors must you consider as it pertains to the application of this business case analysis? Hint: Recall that this approach is a preliminary assessment of the loss incident under study and is definitely not a sound basis on which to make a final decision.*

The business case analysis takes into account loss of assets, production, and fines that were taken on by ConocoPhillips. As this is a business case analysis, an abundance of other losses were not taken into account. These include injuries to the workers, damage to the nearby towns, company reputation when hiring new employees, company reputation when retaining current employees and so on. When all the losses are taken into account, we can further see the continued importance on implementing the key recommendations.

Chapter 7: Issues with Implementation

Selected recommendation:

Our top recommendation is implementing an improved document management and storage system that notifies employees of any documentation that could affect their work. The lack of a documentation system is one of the latent causes of this incident. The installation of the second water injection point was never documented, which led to the lack of inspection, causing corrosion of the pipe elbow to go undetected and eventually the pipe rupture.

Culture and working environment:

Implementation of an improved documentation system will have a great benefit on building the safety culture with minimal issues and negative impact. This improved documentation system will help build a safe working environment while keeping work as productive as possible. An improved documentation system can make sure everything is kept in record including safety documents, inspection reports, design drawing and so on. It makes sure that the employee will follow the safety procedures, like filling out PTW (Permit to Work), which can remind employees of the value of safety. In the meantime, all the changes made to the process and pipework are documented, which could be a great asset for future inspection and plant improvement. Employees can make an inspection list instead of doing inspection based on experience and vague memory, which is exactly what led to the Humber explosion. This system, along with the data collected during production, can also help the employee analyze how to improve production in future renovations. Therefore, this documentation system might reduce production in the short term, but it will benefit production in the long term.

First Challenges:

One of the main concerns is that this system might not be welcomed, and these measures might not function as designed. Even though the documentation system is strengthened, the function of the system might be against some of the workers' working habits and some of the supervisors might think this is affecting the production rate. This may lead to negative impacts on the working environment and noncooperation of employees, which is against the intention of the recommendation. The company should not forget that a system only works when the employees comply with the system. Therefore, it is recommended that before the documentation system is put into practice the company should consider providing a trial of the new improved system and also engaging the employee stakeholders to listen to their advice on the system, while advocating the benefits of the new system.

Second Challenges:

The other major concern is that the cost of the implementation might be too big. The estimated initial cost will be around $500,000 and with more investment in the coming years. Also, it will take almost four years for the system to be fully functioning. During the initial years, working without a documentation system or with the old outdated system is unacceptable and unsafe. A lot of important information might go missing during these years, and the slow building of the system might also challenge the patience of the employer. This might affect employee-employer relations. Therefore, it will be a good idea to build a temporary template to collect information during preliminary system setup. Meanwhile, during the process of improving the system, constant progress reports from the safety department to the owner is also recommended. Showing the progress and outcome can help owners understand the work better and earn the department more support from the employer.

Chapter 8: Next Steps

Water injection is a necessary portion of the gas refinery process to ensure that fowling does not accumulate in the heat exchangers, threatening process efficiency. However, the Humber Refinery incident shows that water injection points must be examined beyond their production purpose to determine safety flaws in the system. Furthermore, the management systems that allow lack of documentation and oversight on changes to the refinery process must be evaluated. As a result of the Humber Refinery case analysis, ABC Conglomerate has recommendations regarding the management, training and documentation of refinery systems.

The first and primary recommendation is that all changes and inspections of the production process, not just piping, should be documented, stored and tracked such that safety standards are maintained, and employees are notified of any documentation that could affect their work. This will facilitate the management of change for implementation of process or pipework modifications, so that system changes can be analyzed in the context of historical data, so risks can be managed before causing a safety incident.

The second major recommendation as a direct result of the elbow failure downstream of the water injection point that caused the incident, is that the maintenance inspection process for all water injection points must be extended to piping and elbows downstream of the injection point. Piping must be inspected to ensure erosion-corrosion has not impacted pipe or internal anti-corrosive coating integrity. This will ensure that future incidents will not cause catastrophic pipe failure as a result of erosion-corrosion as in the Humber Refinery incident.

The third recommendation is that employee and contractor training procedure should be reviewed and reworked regarding the documentation of changes to pipework or any part of the production process. This will ensure any piping changes done by workers are properly documented so that changes can be analyzed for potential safety risks.

The primary benefit of the above changes is an increase in plant safety, which will also prevent loss of assets or production capacity. This comes as a result of reducing current issues regarding lack of communication and understanding of risk in the current management system. Furthermore, a better inspection process will prevent future incidents of the Humber Refinery type and may expose other safety concerns that can be solved by the risk management and documentation process recommended above. Failure to implement the above processes will only provide an environment where future catastrophic incidents resulting in loss of life, assets, production, or reputation are not only likely, but to be expected. As representatives of ABC Conglomerate, we strongly support the inclusion of the above recommendations to ensure no future disasters occur.

References:

[1] Health and Safety Executive. (2005, December 1). Public Report of The Fire and Explosion at the ConocoPhillips Humber Refinery on 16 April 2001. Retrieved from http://www.hse.gov.uk/comah/conocophillips.pdf.

[2] Bakx, K. (2016, June 27). Pipelines and why they fail in Canada. In CBC. Retrieved from https://www.cbc.ca/news/business/cepa-2016-safety-report-1.3654640

Appendix A: Root Cause Analysis – Chart:

Appendix A: Root Cause Analysis - Chart:

Legend:

AND

OR

WIP: Water Injection Point

WSE: Written Schedule of Examination

RBI: Risk Based Inspection

Immediate Causes

Intermediate Causes

Basic Causes

Latent Causes

Risk Management Element

ENGG 404 TEAM Project – RCA CHART
Submitted by Team # 314
Case Study: Humber Refinery Fire and Explosion, UK, 2001
Date Submitted: December 5, 2019

Team Members	Student #s	Signatures
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Summary Rubric for the RCS Chart in the Final Report:

- *Incident Description* ___ / 2
- *The correct use of AND & OR gates* ___ / 3
- *The rationale and logic for any 3 roots should be clearly evident. (3 roots x 2 = 6 marks)* ___ / 6
- *Sufficient breadth and depth to identify at least 18 latent causes specific to the loss incident. Latent causes should be clearly identified.* ___ / 5
- *The latent causes (at least 18) must be explicitly and specifically stated in terms relevant to the loss incident under study. Latent causes expressed in broad terms are not acceptable. RMS Elements coded as latent causes are not acceptable.* ___ / 5

___ / 20

Fire and Explosion at Humber Refinery Saturate Gas Plant, UK, 2001

P: 2 people seriously injured, E: Damage was on adjacent refinery and houses/business within 1 km radius of Humber refinery, A: Humber refinery sustained significant damage and ConocoPhillips Ltd. was charged and fined for multiple offences amounting to over £895,000, P: Humber refinery was temporarily shutdown, halting production for several weeks

Ignition **(IC: SC)**

Gas fired heater adjacent to unit - Cause of Ignition

EOL

Fuel Source **(IC: SC)**

Release of hydrocarbons: 90% ethane/propane/ butane as vapour cloud

Pipe P4363 failed at elbow downstream of adhoc WIP

Erosion/Corrosion in P4363 elbow

Oxygen

EOL **(IC: SC)**

Pipe protective coating eroded (Black Iron Sulfide) **(IC: SC)**

2nd water injection installed at existing vent

Water injection point washed away protective coating **(IC: SC)**

Impact of installing water Injection was not evaluated

Installation of 2nd water injection was a 'quick fix' and not documented

Management wanted little to no downtime for modification **(BC: Job Factors)**

Management preferred production **(LC)**

RME #1: Management Leadership, Commitment and Accountability

Employees who installed the quick fix did not follow process for reporting and documenting changes **(IC: SP)**

Employees did not want to do paper work **(BC: Personal Factors)**

No system in place requiring employees to do paper work **(LC)**

RME #11: Operations and Facilities Information and Documentation

Lack of auditing to ensure and reinforce compliance **(LC)**

RME #6: Program Evaluation and Continuous Improvement

Employees were not taught why paper work is so essential **(LC)**

RME #9: Employee Competency and Training

No processes in place to require an impact study on quick modifications **(LC)**

RME #4: Management of change

No processes in place to require documentations on quick modifications **(LC)**

RME #11: Operations and Facilities Information and Documentation

Lack of in stream water in initial design **(IC: SC)**

Corrosive agents accumulated in the feed stream of P4363

Water flow reduced in pipe in P4363

Pipe size of the water feed line to the P4363 injection point was increased **(IC: SP)**

Confusion about the original pipe size in the original design drawings

Design drawings showed different pipe sizes for the water feed line

Design Drawings were not reviewed **(BC: Engineering & Design Factors)**

Document management and review process was inadequate **(LC)**

RME #11: Operations and Facilities Information and Documentation

Document management and review process was not followed **(LC)**

RME #9: Employee Competency and Training

Inadequate evaluation of deliverable during Design Phase **(LC)**

RME #7: Design, Construction, and Start-up

Hired Design Engineer rushed the design drawings

Management rushed Design Engineer to meet project schedule **(BC: Job Factors)**

Management prioritized project completion over quality **(LC)**

RME #1: Management Leadership, Commitment and Accountability

Design Engineer prioritized design drawings he is working on for other bigger projects **(BC: Personal Factors)**

Design Engineer was not able to manage his time and handle pressure when working in multiple projects **(LC)**

RME 10: Contractor Competency and Integration

Hired Design Engineer did not have enough knowledge about the project **(BC: Personal Factors)**

Design Engineer was not trained or given orientation about the project (LC)

RME #9: Employee Competency and Training

Use of 2nd Water injection installed after commissioning was changed to intermittent **(IC: SP)**

No evaluation made on the effect this would have on the corrosion potential of pipe

Change was not progressed through a Management of Change Procedure **(BC: Engineering & Design Factors)**

Inadequate Management of Change process **(LC)**

RME #4: Management of change

P4363 Elbow Corroded **(IC: SC)**

Carbon steel elbow was selected

Carbon steel was the current standard

Standard thought to be adequate **(BC: Engineering & Design Factors)**

Lack of risk identification process to confirm adequacy of design standard **(LC)**

RME #2: Risk Assessment and Management of Risks

No pipe steel corrosion inhibitor added to gas pipe

Pipe protection coating was thought to be enough **(BC: Engineering & Design Factors)**

Inadequate backup plan for loss of protective coating

No impact study on effect of erosion of protective coating **(LC)**

RME #2: Risk Assessment and Management of Risks

P4363 Elbow was never Inspected **(IC: SP)**

1992 Inspection of piping networks near WIPs did not include P4364 **(IC: SP)**

WIP near P4363 not in database

P4363 WIP believed to be not in operation **(BC: Job Factors)**

No documentation showing P4363 WIP was in operation **(BC: Job Factors)**

No documentation on installation of P4363 WIP **(BC: Job Factors)**

Inadequate Document Management Control System for records on changes **(LC)**

RME #11: Operations and Facilities Information and Documentation

No process to record piping changes **(LC)**

RME #4: Management of Change

Process to record piping changes not followed

Lack of training on recording changes **(BC: Job Factors)**

Training program did not exist **(LC)**

RME #9: Employee Competency and Training

Lack of culture of following process **(BC: Job Factors)**

Company value put production in front of safety **(LC)**

RME #1: Management Leadership, Commitment and Accountability

1994 WIP Inspection found pitting at the WIP but did not include P4363 elbow in the scope **(IC: SP)**

Fail to implement and incorporate bulletin from 1992 recommending inspection of all pipes downstream of WIP **(BC: Job Factors)**

No process in place to implement corporate recommendations based on incidents at other plants **(LC)**

RME #5: Incident Reporting, Investigation, Analysis and Actions

No system for recording discoveries from and follow up on inspections **(LC)**

RME #11: Operations and Facilities Information and Documentation

1996 Pipework Inspection - elbow thickness measurements not taken **(IC: SP)**

Operations department thought it was blinded off **(BC: Job Factors)**

1997 WSE created without specific inspection requirements for WIP or downstream pipework **(IC: SP)**

Inspectors didn't know WIPs were a risk **(BC: Personal Factors)**

Failed to appropriately evaluate risk

Inadequate training on risk evaluation for inspectors **(LC)**

RME #9: Employee Competency and Training

In Nov 2000, as part of a RBI initiative, a software program was run for line P4363 to predict risk but injection point was not considered **(IC: SP)**

The RBI coordinators believed that feed line was permanently isolated and would prevent routine operations of the water wash **(BC: Personal Factors)**

Operation side did not inform inspection side of the change **(BC: Job Factors)**

Operation and maintenance crews did not regularly communicate about the changes being done **(LC)**

RME #8: Operations and Maintenace

RBI coordinators were not familiar with the plant **(BC: Personal Factors)**

RBI study was done 19 years after installation

Refinery did not have a document strategy for inspection until Oct 2000

Documentation not kept/ cannot be found

Inadequate Document Management Control system (LC)

RME #11: Operations and Facilities Information and Documentation

Management did not properly evaluate safety risks of refinery

Inadequate Risk Assessment and Management process **(LC)**

RME #2: Risk Assessment and Management of Risks

Management did not value routine inspections **(LC)**

RME #1: Management Leadership, Commitment and Accountability

RBI coordinators were not competent **(BC: Personal Factors)**

Lack of training for risk based inspection coordinators **(LC)**

RME #9: Employee Competency and Training

Output of the program put P4363 as high risks

Inspection booked too late

Management did not establish criteria to indicate at what level of risks it is unacceptable to justify potential operation of the SGP **(BC: Job Factors)**

Risk evaluation program was incomplete

Lack of guidelines for the corporate team **(LC)**

RME #1: Management Leadership, Commitment and Accountability

The risk evaluation program was not evaluated **(LC)**

RME #2: Risk Assessment and Management of Risks

Corrosion Engineer spent 75% of time on other projects **(BC: Personal Factors)**

Management did not see the importance of the corrosion engineer **(LC)**

RME #1: Management Leadership, Commitment and Accountability

The plant was under staffed

Management valued profit over safety **(LC)**

RME #1: Management Leadership, Commitment and Accountability