

CONOCOPHILLIPS RESPONSE TO THE SATURATE GAS PLANT FIRE AND EXPLOSION INCIDENT

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The ConocoPhillips Humber Refinery was first commissioned in 1969. Over subsequent years it has been expanded and its efficiency enhanced. One project was the addition of a Saturate Gas Plant (SGP), designed to improve the recovery of Liquefied Petroleum Gas (propane and butane) and gasolene (petrol components).

The SGP was commissioned in 1980. The design included facilities to water wash the feed streams in order to remove inorganic salts which could ultimately cause corrosion and contamination of the products. Soon after commissioning additional water wash was installed in the overhead system, downstream of two main fractionator water draw streams. The additional water wash was designed to flush out soluble deposits which were causing a blockage in the overhead system, these deposits being mainly hydrates. It was not intended to reduce corrosion. These deposits were not totally unexpected.

In April 2001 the 6" pipe between the de-ethaniser and the overhead condensers X452/3 failed downstream of the additional overhead system water wash, releasing highly flammable materials which ignited causing significant plant damage.

Following the incident ConocoPhillips carried out a Root cause Analysis. The HSE investigation resulted in an Improvement Notice. These are described in the paper and focused on Piping Inspection (Root Based Inspection), Corrosion Management and Management of Change (MOC).

ConocoPhillips believed that these actions were the start point. Additional longer term actions are also described in the paper.

The Saturate Gas Plant was rebuilt to current design standards and the overheads system water injection was relocated between the two overheads heat exchangers. The paper describes the monitoring that was initiated and proposed long term plans.

These additional steps are an essential part of the requirements to comply with Regulation 4 of COMAH. This being achieved by the implementation of a comprehensive Risk Based Inspection process that includes input from inspection, corrosion engineers and operating staff. This process starts at the initial review developing inspection plans, inspection results and a re-evaluation of the original review conclusions.

INTRODUCTION

The ConocoPhillips Saturate Gas Plant (SGP) was commissioned (1980) as part of an ongoing commitment to enlarge and improve refinery operations.

In April 2001 a 6″ pipe carrying highly flammable gases failed. The gases ignited after a 20 second delay and the resultant explosion and fire caused extensive damage to the SGP. Onsite and offsite buildings were also damaged.

The fire from this failed pipe and other piping failures were extinguished by ConocoPhillips staff isolating the sources of the hydrocarbons. The incident also required resources from the local emergency services as well as mutual aid from the neighbouring refinery.

There were no significant injuries as a result of the incident. This to some extent was due to the incident occurring on Easter Monday and at shift change time when there were few people in the operating units.

The Saturate Gas Plant was rebuilt to current design standards. The overheads water wash system was reinstalled, but in a different location.

DISCUSSION

This paper is divided into two sections:

A. The Company Investigation into the fire and explosion on the Saturate Gas Plant on April 16th 2001.
B. Changes to further improve Process Safety at the Humber Refinery.

A. COMPANY INVESTIGATION INTO THE FIRE AND EXPLOSION ON THE SATURATE GAS PLANT APRIL 2001

Following the incident, the company commissioned a Root Cause Analysis Team comprising employees of various disciplines, and led by an experienced Chemical Engineer with 34 years experience in Refinery Operations and Technical Management. The team was supplemented by external expertise as required.

The team completed its investigation and reported the findings to the Refinery Management by June 2001. It produced a total of 12 recommendations. These are outlined later in this paper.

BACKGROUND

In 1980 the light ends recovery units at the refinery were becoming too small to handle the gases produced by the coking processes. It was decided that the optimum solution was to remove the "saturated" liquids from the existing light ends handling plant and process them separately in a new "Saturate Gas Plant". The feedstocks coming from the two catalytic reformers and desulphurisation units. These Saturate Gas Plant (SGP) feed streams therefore contained high levels of ammonium chloride and hydrogen sulphide. In order to reduce the possibility of corrosion and product contamination in the downstream equipment, the design included a feed water wash system. This wet, cleaner product was firstly fractionated in the de-ethaniser to remove methane, ethane and hydrogen sulphide.

A simulation of the de-ethaniser showed that water would be trapped in the upper section of the tower. To facilitate the removal of this water, two water draws were included in the design and these drained into the vertical section of the de-ethaniser overhead line, prior to the point where the additional water injection point was subsequently installed.

The possibility of fouling in the overhead system was recognised in the design. The temperatures in the final exchanger were in the range where hydrates could form. The gas product line from the reflux drum upstream and downstream of the flow measurement was steam jacketed.

Plugging in the overhead exchangers was therefore not totally unexpected. An investigation in November 1981 recommended that as well as the additional water wash, the problem could be ameliorated to some extent by reducing the raw water (tube-side) flow in order to raise vapour side temperatures above the anticipated temperature of formation of hydrates (approximately 27–30°C). The deposits would primarily be in the lower exchanger.

The two water draws from the de-ethaniser were later redesigned to improve operator accessibility and safety. Instead of being routed to the overhead line, they were connected to an existing nozzle on the reflux drum. This bypassed the overhead heat exchangers.

The concept of having a water injection point in the overhead was therefore not new and included in the original design. These two points had no injection quill to disperse the flow in the vapour stream.

The relocation of the two water draw systems had been through the refinery management of change system, the additional water injection point had not been through a formal review.

The overhead exchangers had their tube bundles replaced due to tube side corrosion and were replaced in an alloy material. Owing to material availability, the original carbon steel tube sheets were reused, but later replaced with alloy.

The de-ethaniser tower, overhead exchangers and reflux drum had received extensive inspection, both for corrosion but also for the Refinery initiative to detect and eliminate wet hydrogen sulphide cracking. Routine inspections being carried out every two years.

The inspection of the exchangers post the shell replacement, revealed very little corrosion in the shell. The heat exchanger inlet nozzle thickness results were variable, but no definite consistent trend could be determined.

There had been regular corrosion reviews carried out on all the refinery processes and the next steps were allocated and followed up. The water injection point was not included. The operations group believed that the injection point was to remove plugging. The inspection and corrosion inspection staff believed that from 1994 the point was not in use, based on their advice they had considered that they had received.

The focus of corrosion control on the SGP was on the feed system water wash, as it was believed that removal of more of the inorganic materials likely to be potential corrodants in the de-ethaniser overhead system, would be beneficial. The feed water wash system was therefore enhanced, by raising the injection rate and mixing efficiency.

The water analysis from the reflux drum showed little iron, and localised corrosion was not suspected. The rest of the Saturate Gas Plant had no corrosion problems.

There was little documented data on the piping thickness in the overhead system. Other injection points in refinery processes, where for example ammonium bisulphide corrosion was a probable outcome, had detailed pipe thickness data. This was consistent with National Association of Corrosion Engineers (NACE) and API guidelines. The refinery corrosion engineer was a member of NACE, with back up from ConocoPhillips central expertise.

The philosophy had been to focus on inspection of equipment (vessels, exchangers and towers). This philosophy followed from the Factories Act statutory inspection of steam raising equipment. Process System and Transportable Gas Regulations and the Pressure System Safety Regulations, all tend to promulgate this focus. While equipment is included for relevant fluids, piping is only included if it is likely to cause danger. One piece of learned guidance actually states that pinhole leaks in piping do not “cause danger” from a stored energy perspective. Interestingly this view of piping was seen to be widespread, if you read the HSE Report, commissioned in 2002 and reported in 2004 entitled Plant Integrity Initiative for pipework systems at UK Refineries . . . ”. This is available on the HSE web site.

In 1997 ConocoPhillips recognised, along with the USA refining industry that a more structured risk based approach was required to the inspection of piping and equipment. This resulted in the API guidance on Risk Based Inspection (RBI) published in 2000. As ConocoPhillips were part of the development process, the concept was included in the Humber Refinery plans, firstly for equipment and then for piping. The Saturate Gas Plant was the first plant to have its piping subject to review. The process had already been tested on equipment in other units.

The RBI system is based on a comprehensive piece of software where processing condition, metallurgy etc. are entered and a risk factor determined. This uses data from known corrosion mechanisms found in the refining industry in order to predict among other issues, the level of risk associated with the pipe.

Since the SGP had little thickness data for piping, and the plant contained flammable materials, the piping print out showed “high risk”. This can only be reduced by the entering of actual plant inspection data, frequency etc into the computer.

The RBI analysis of the Saturate Gas Plant piping was complete in November 2000. The output was then turned into detailed inspection plans for the plant using existing inspection department isometrics, which showed the points for inspection e.g. bends, elbows, off takes and any dead ends. The inspection plans for the SGP were converted into work packs and planned for July 2001. Unfortunately the pipe failed in April 2001.

Since the injection point was not believed to be in service the RBI analysis was in error. Had the injection point been entered into the software as being in service then it would have indicated a much higher risk factor.

The operating manuals did not include clear, unequivocable guidance on when to use the overhead water injection system, or when or where to record the information.

ROOT CAUSE ANALYSIS FINDINGS

There were a total of 12 findings; these have been aggregated into two headings.

INSPECTION OF REFINERY WATER WASHES

A comprehensive list was made of all process mixing points, these included liquid into liquid points as well as liquid into gas points. These were inspected in accordance with a new refinery procedure, which was based on API 570 guidance. A documented scheme was developed and implemented for the continued routine inspection, the frequency being based on risk, consequence and inspection findings.

These two steps were complete by 3rd August 2001 and the findings reviewed with the HSE, prior to the start up of each refinery unit.

DEVELOPMENT AND MAINTENANCE OF INSPECTION PROCESSES

The RBI process was to be extended to the remaining units on the refinery. To achieve this in a timely manner more resources were allocated to the RBI team. These resources, and the process to ensure that the RBI was reviewed by a multi discipline team from Inspection, Operations and Process and Mechanical Engineering were developed and instigated.

The output from the RBI process and the subsequent on plant inspection findings were also to be reviewed by the Multidiscipline team. This process was called revalidation, and the frequency formally set down in a rewritten RBI procedure.

In addition, any mix points were assumed to be in use, even if they were thought to be out of service, used intermittently or continuously.

In order to ensure that the inspection, RBI and corrosion groups were included in all plant modifications, they were made mandatory reviewers in the management of change process.

Since all the above were developments of the fledgling RBI system, clarification of the Roles and Responsibilities of all people involved in the RBI process were produced and rolled out to those affected.

COMPLETION DATES

With the exception of the RBI review of the entire refinery, the RCA action items were completed by mid 2001.

HSE IMPROVEMENT NOTICE

In July 2001 the HSE served an Improvement Notice on ConocoPhillips. The notice required ConocoPhillips to develop action plans for implementing the provisions of a suitable industry standard for pipework inspection. The suitable industry standard quoted as an example was the American Petroleum Institute's "Piping Inspection Code" known as API 570. The plan was to include a timetable for implementing the following 7 criteria:

(a) *Establishment of a multidisciplinary approach to the management of corrosion degredation mechanisms in pipework.*
Compliance with these criteria was achieved using the RBI process already in existence. It would continue on a unit by unit basis. The expert review would be firstly carried out on all high consequence lines. This to be complete by the end of 2002.

(b) *A system for setting the scope, intervals and techniques for pipework inspection.*
This was to be achieved by loading all Written Schemes examination for all piping inspections in the Company standard planning software SAP.

(c) *A system for scheduling and planning pipework inspections.*
This was to be achieved by utilising SAP.
With both b) and c) to be complete in early 2002.

(d) *Data storage and retrieval system for pipework inspection data, that in particular provides ready access to historical data.*
Credo was to be fully utilised for all piping inspections and would be complete by mid 2002.

(e) *A programme for inspecting corrosion under insulation (CUI).*
To comply with these criteria, a policy procedure and refinery programme was developed.
With inspection of high consequence piping to be complete by mid 2002.

(f) *A risk control system to control and monitor process stream analysis for the purpose of corrosion management, to enable decisions on remedial action/inspection to be taken in a timely fashion.*
Compliance to be achieved by assigning formal responsibilities for the laboratory, corrosion management and operations functions. Training to be an essential element of these criteria.

(g) *A system for capturing changes in usage patterns of injection points which triggers a review of inspection intervals.*
This was to be achieved by extending the existing Management of Change system, with enhanced training. This to be completed by the end of the first quarter of 2002.

COMPLIANCE WITH THE IMPROVEMENT NOTICE

Naturally, the HSE monitored progress and compliance with the plan. This included auditing the standard of policy, procedures and data where appropriate.

The only area where the original plan was not practical was in the area of developing the RBI reviews preferentially, on high consequence piping.

The problem area was in organising the relevant expertise from the operating divisions on a piece meal basis just focusing on part of a process unit. It was a more efficient use of resources to carry out a review on a single processing unit at a time. There are approximately 30 processing units at the refinery. The scheduling of the unit reviews would however be based on a process unit risk and consequences, as set out in the COMAH safety report.

This meant that the whole refinery would not have been through a RBI review until the end of 2003 with the offsite facilities to be completed in 2004. The change was agreed with the Health and Safety Executive.

B. CHANGES TO FURTHER IMPROVE PROCESS SAFETY AT THE HUMBER REFINERY

Piping inspections at the refinery had historically been focused on areas where there has been industry or company "alerts". For example areas with high potential for ammonium bisulphide corrosion, especially in Reactor Effluent Air Cooler systems. Typically above 4% ammonium bisulphide. Other areas of the refinery had not had the same level of surveillance.

RBI, to be effective requires historical data to enable trends to be established in order to set realistic inspection plan intervals.

Expert review of piping systems, in some cases, showed that existing inspection locations might not be optimal for predicting corrosion rates. In 2002 the refinery therefore started two major piping inspection initiatives.

A. HAWKEYE

This entailed carrying out a "quick hit" review of all the refinery units, utilising corrosion expertise from within ConocoPhillips worldwide and also where appropriate external expertise. The object being to mark up unit Process and Instrument Diagrams with high consequence piping, and then to develop inspection plans and then to inspect these locations. This covered about 15% of the refinery pipework. To achieve this, the refinery was shutdown until the unit piping checks were carried out. The cost of the manpower for this exercise was approximately £10.6 million and was completed in about 10 weeks.

B. PROJECT 570

With the refinery back in operation, all piping deemed not to be high consequence was inspected using the principles of API 570 utilising inspectors trained in the principles from the USA. This was achieved at a cost of £3.0 million and completed by early 2003. The combination of Hawkeye and Project 570 resulted in a higher confidence level of the predictions emanating from the RBI, API 581 software.

This however resulted in a delay to the completion of the main RBI reviews, but it was believed to be an acceptable risk, as the RBI output would be based on more up to date information. The refinery was now to be complete by the end of 2004 with the offsite in 2005.

REORGANISATION AND RESPONSIBILITIES

As part of the company Root Cause Analysis, Roles and Responsibilities were better defined. In order to provide more focus on the technical aspects of Mechanical Integrity, not just piping inspection, a new division covering Asset Integrity and Reliability was formed, this included Inspection, Corrosion Management, RBI and "Fit for Purpose" who had the responsibility for independent review of the vessel and piping thickness data. It also included a Process Safety Management function to promote the concepts of the USA Process Safety Management systems 14 elements including Mechanical Integrity. These concepts being integrated with the requirements of the Control of Major Accident Hazard Regulations.

CORPORATE RESPONSE

In addition to the Refinery response, the corporation initiated a worldwide review of all its processing location, both in upstream (oil and gas production) but also in down stream (refining and chemical) facilities. This was carried out by an independent consultancy, with annual updates of progress required by corporate senior management.

REBUILDING THE SATURATE GAS PLANT

The continued efficiency and environment management of the refinery required the rebuilding of the Saturate Gas Plant. It was recommissioned in April 2003. The replacement was essentially like for like except that modern design standards were followed rather than those pertaining in 1980. Also the feed water wash system was enhanced in order to provide improved removal of inorganic contaminants. This was a continuation of the policy on the old Saturate Gas Plant to reduce the level of potential corrosion activity on the overhead system.

Also the overhead water wash design was improved with the provision of an injection device. However instead of installing it ahead of the first heat exchanger, it was installed on the outlet of the first exchanger where there is a two phase flow regieme, but ahead of the second heat exchanger. This was practical because the point of deposition of solids would be in the second heat exchanger, where conditions were coldest and hydrates would form.

There was far too little ammonium bisulphide to produce corrosion similar to that experienced in hydroprocessing reactor effluent systems. Typical levels were 0.03%.

Never the less as a precaution a Field Signature Monitor (FSM) was installed on the first elbow downstream of the injection point, prior to the second heat exchanger. This device measures on line corrosion at many finite locations on a pipe or elbow. This showed localised corrosion, where you would expect the fluid trajectory to follow the contour of the bend.

A plan was established to determine the optimum conditions to minimise the overhead corrosion.

Various experimental runs were carried out, with and without the feed water wash in operation. Significant reduction in the corrosion rate was experienced with the feed water wash out of commission.

This was believed to be due to the buffering effect of the ammonia in the overhead system, which was previously removed in the feed water wash system. Confirmation of this was achieved by injecting a neutraliser in the overhead system, with the feed water wash back in commission the corrosion rate was reduced.

The pipe between the two overhead exchangers was replaced at the 2005 unit shutdown, with the FSM reinstalled.

Long-term plans therefore include a study of the optimum method of removing the acidic elements of the feed, which are believed to be the main cause of the corrosion in the SGP overhead system.

SUMMARY

Piping inspection to an appropriate standard is an essential requirement for ensuring compliance with Regulation 4 of COMAH. This inspection is not limited to the actual measurement of the thickness of the pipe. It includes the whole RBI study. The study comprises the initial assessment by a multidiscipline team, its output based on risk and consequence, the subsequent inspection plan, the measurement and the final revalidation of the original assessment also by a multidiscipline team.

However, this can only be achieved by having an organisation that has clearly defined Roles and Responsibilities and the process routinely audited for both standards and compliance.