Health and Safety Executive

PUBLIC REPORT OF

THE FIRE AND EXPLOSION AT

THE CONOCOPHILLIPS

HUMBER REFINERY

ON 16 APRIL 2001

Prepared by the Health and Safety Executive

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FOREWORD

A message from Kevin Allars, Head of Hazardous Installations Directorate Chemical Industries, Health and Safety Executive:

The fire and explosion at the Humber Refinery on 16 April 2001 was a very serious event and should serve to illustrate the potential for harm that arises from major hazard plant. As confirmed by Judge Reddihough, when passing sentence on ConocoPhillips Ltd for breaches of health and safety legislation, this incident had the potential to be catastrophic. The immediate area of the refinery was devastated, many other buildings on site were badly damaged and there was widespread damage to surrounding properties, particularly in the village of South Killingholme. Fatalities and serious injuries were avoided only because the incident occurred on a Bank Holiday and at shift changeover time when there were very few people out on site.

The investigation revealed a systematic failure to understand the conditions that pipework was operating under, and to appropriately inspect pipework in the Saturate Gas Plant of the refinery. This confirms the vital requirement for companies who operate high-hazard sites, such as oil refineries and chemical plants, to ensure that they have in place rigid, robust and appropriate systems for inspecting pipework to detect corrosion and other defects.

The investigation also revealed failings in ConocoPhillips management of change arrangements in that it had not correctly analysed the effects of an operating mode change, and had not recorded it, leading to operators, inspection staff and monitoring staff not being as one to the actual operating arrangements on the plant.

ConocoPhillips have co-operated with the Health and Safety Executive in the preparation of this report and so I commend it to a wide audience. In particular people living and working in the vicinity of the refinery will be able to see why the incident occurred and how the company has responded both on the day and with measures to prevent a re-occurrence. There are also lessons in the report for people who manage high-hazard activities, especially those in the oil refinery and chemical industries.

In response in particular to questions raised by local Members of Parliament and by professionals working in the petrochemical industry it was agreed that a report of the incident be prepared.

This public report into the incident is designed to summarise the events and the investigations carried out by the Competent Authority and by ConocoPhillips. A full description of all the detailed investigative work and legal work are not presented in this report.

The report seeks to reassure the public that a thorough and detailed investigation into the cause of the incident has been carried out by all parties concerned. In addition the report is intended to demonstrate that a number of lessons have been learned, both by ConocoPhillips and by the regulators, and actions have been taken in order to improve safety performance at the Refinery Complex.

The report is also intended to be viewed by a wider audience of companies, safety professionals and Trade Union representatives involved in the major accident hazard industries and to serve as a reminder of many of the issues that need to be addressed by safety reports for major hazard installations. Operators of COMAH sites are expected to carefully consider the contents of this report and the HSE will use Trade Association contacts plus site inspection plans and other means to publicise the incident and to ensure the lessons are widely learned.

EXECUTIVE SUMMARY

The ConocoPhillips Humber Refinery is a Major Accident Hazard site as defined under the Control of Major Accident Hazard Regulations (COMAH) 1999, which implements the Seveso II Directive in Great Britain (GB). It is one of approximately 1000 COMAH sites in GB. At the time of the incident in 2001 the operator was Conoco Ltd, but this changed in August 2002 following a merger with Phillips Petroleum.

Companies operating "top tier" COMAH sites are required to prepare safety reports which identify the systems used to ensure that their processes are operated safely at all times, and that all necessary measures have been implemented to prevent major accidents, or in the event of such accidents, to limit the effects to people and the environment.

Under the COMAH Regulations, companies are also required to provide information on safety measures at their establishments to anyone likely to be affected by a major accident occurring at their establishment. On and off-site emergency planning is also a key component. ConocoPhillips had provided such information to the local authorities for inclusion in an off-site emergency plan and prepared an on-site plan.

The joint inspection and enforcement body, known as the Competent Authority, consisting of the Health and Safety Executive (HSE) and the Environment Agency (EA) in England and Wales, is required by the Directive to carry out significant regulatory activity including inspections in order to ensure that the operations are being conducted in accordance with both legislative requirements and company claims as evidenced in the COMAH safety reports.

On 16 April 2001 a fire and explosion incident occurred at the ConocoPhillips Humber Refinery following the catastrophic failure of an overhead gas pipe. The incident was subsequently investigated, as required under COMAH Regulation 19, by the Competent Authority and by ConocoPhillips in order to determine the underlying root causes of the incident.

The incident had the potential to cause fatal injury and environmental impact although no serious injury occurred, and there was only short-term impact on the environment. There was however significant damage to the Refinery and to properties nearby, the incident caused concern to residents in the vicinity and received national and local press coverage.

ConocoPhillips were prosecuted on indictment at Grimsby Crown Court on 16th December 2004 and pleaded guilty to breaches of Section 2 & 3 of the Health and Safety at Work etc. Act 1974 relating to the incident. At the sentencing hearing on 29th June 2005 they were fined £800,000, plus £95,000 for other offences.

This report details the findings of the investigations carried out by the Competent Authority and ConocoPhillips. There are a number of key lessons, detailed in Section 9 that commend operators of high hazard processes in the chemical and downstream oil industry to ensure, where appropriate, they have the following crucial measures in place:

- Effective pipework inspection systems that meet or exceed current industry practice and are based upon full knowledge of past history and current operating conditions.
- Management of Change systems that accommodate both plant and process modifications.
- Systematic arrangements for the management of corrosion including identification of possible corrosion mechanisms and the use of trained and competent staff.
- Arrangements to ensure the effective sharing of information about process conditions and the accurate recording of all inspection data.

1 THE HUMBER REFINERY

The Humber Refinery is located on a 480-acre site on the south bank of the Humber Estuary, approximately 1.5Km northwest of the town of Immingham and 0.5Km east of the village of South Killingholme.

The Refinery site is divided by the A160 dual carriageway (Humber Road). It is bounded to the west by Eastfield Road and to the north by the railway line which separates the Humber Refinery from Lindsey Oil Refinery.

The Humber Refinery is the only Refinery operated by ConocoPhillips in the United Kingdom (UK). The operation is supported by a considerable utilities and distribution infrastructure. ConocoPhillips employs around 750 staff on the site and can have varying numbers of contractors on site depending on the nature of projects or other work being undertaken. The company undertake other related activities, such as fuel distribution, in various parts of the country.

Ownership of ConocoPhillips Limited

The Refinery Operator (for the COMAH Regulations) in 2001 was Conoco Limited, a UK registered company. This company was in turn ultimately 100% owned by Conoco Inc, an oil company established in the United States and quoted on the New York Stock Exchange. On 31st August 2002 Conoco Inc merged with Phillips Petroleum also a United States based Oil Company, the merged company being ConocoPhillips Inc. Conoco Limited changed its name on the 1st August 2003 to ConocoPhillips Limited. The Director and General Manager of the Humber Refinery (Refinery Manager) is a member of the Board of ConocoPhillips Limited.

History of the Refinery

Construction of the Refinery commenced in 1966 and was completed in 1969. Commissioning took place during 1969/1970. The Refinery's initial capacity was approximately 90,000 barrels per day or 4.2 million tonnes per year. During the mid 1970's there was further work to increase capacity by around 60% and petroleum coke output by 50%. There have subsequently been further updates connected mainly with gasoline and fuels production including the installation of a second catalytic reformer, a fluidised catalytic cracking unit and an alkylation unit. Total investment in the refinery has been in excess of $750 million.

The COMAH Safety Report indicates that the maximum throughput, dependent upon feedstock and products, is about 225,000 US barrels of crude oil per day or 11.4 million tonnes per annum.

Management structure

In 2001, a team of six Divisional Managers and an Operations Manager managed the site. Five of the Divisional Managers reported to the Operations Manager, he and the Technical Service Manager reported to the Refinery Manager, as did other functions such as Occupational Safety, Human Resources and Finance. Together these positions formed the Refinery Leadership Team (RLT), the six divisions comprised of:

- Production – optimises production through Production Planning, Central Control Room operations etc.
- Divisions A to D – each responsible for a geographical area or group of process plants. Responsible for optimum plant availability for production including outside Operators, Maintenance etc.
- Technical Services – Process Engineers, Design, Projects, Inspection Services.

Market Conditions

In common with the other UK refineries the ConocoPhillips Humber operation is directly affected by global market forces. These arose principally from the worldwide overcapacity in the refinery industry that had existed for many years. In recent years profit margins within the industry had been very low and this resulted in strategies to increase efficiency by optimising operations, improving technology and seeking more products from the residue of crude oil.

In response to these challenges ConocoPhillips has increased the production of higher value products such as petroleum coke and gasoline. It has also invested heavily in order to produce low sulphur gasoline (petrol) and diesel to meet the increasing environmental requirement for products. The Refinery reorganised in 1993 with the aim of increasing process efficiency and to give employees more ability to make decisions. At the same time, the refinery employed more people to form a company based maintenance function in addition to the existing shift maintenance work force.

In order to provide more focus on major shutdowns a separate Turnaround Management function was formed in 1997 reporting to the Technical Services Manager. In recognition of the increasing requirement to manage assets effectively the Refinery was reorganised in 2002 with the formation of an Asset Integrity and Reliability Division. This includes Process Safety Management, Inspection, Turnaround Management, Reliability, Root Causes Analysis, Management of Change and Management of the single maintenance contractor and Compliance Assurance.

Risks associated with the Humber Refinery

The potential consequences of a major incident at the site are considerable, with possible domino effects on the adjoining operation of the Lindsey Oil Refinery. The nearest large town is Immingham with a population of around 11,000 people 1.5 kilometres to the southeast. However the nearest area of population is South Killingholme (population 1,100) 500 metres to the west, with North Killingholme (population 300) 1.5 kilometres to the northwest.

The main risks are typical of most of the oil refineries operating in Great Britain. They are fire and/or explosion risks arising from the loss of containment of flammable liquid or gases that may be at high temperatures and/or pressures, and also toxic risks arising from various toxic components and catalysts.

The HSE has set a consultation distance around the site boundary of 1 kilometre in which the local authority is obliged to consult HSE on any significant development. This area also corresponds with the Public Information Zone (prescribed in the COMAH regulations) in which ConocoPhillips are obliged to provide to the public certain information relating to risks from the site and the action to be taken in the event of an emergency.

The Refinery has a strong commitment to the environment and in addition to producing low sulphur products the Refinery has spent in excess of $100 million on environmental projects since 1990 and is registered to ISO14001.

Refinery products

The Refinery processes hydrocarbon feed stocks to produce a range of products including petroleum coke, propane/butane (LPG) and gasoline (petrol), diesel and aviation fuel.

2 THE SATURATE GAS PLANT (SGP)

Description

The Refinery can be subdivided into a number of operational units; one of these units is the Saturate Gas Plant where hydrocarbon products are separated. It was on this Unit that the incident of 16 April 2001 occurred. The SGP contained three distillation columns, the first distillation column was the de-ethaniser W413 where mainly methane, ethane and propane were removed from the liquid and vapour transferred to the condensers X452 and X453. These materials were extremely flammable. The vapour was then cooled so that some condensed, mainly into propane. The uncondensed vapour was passed to the refinery fuel gas system. Pipe 4363, shown in Figure 1, connected the top of the De-ethaniser column to the condensers.

Figure 1 - Diagram of the SGP

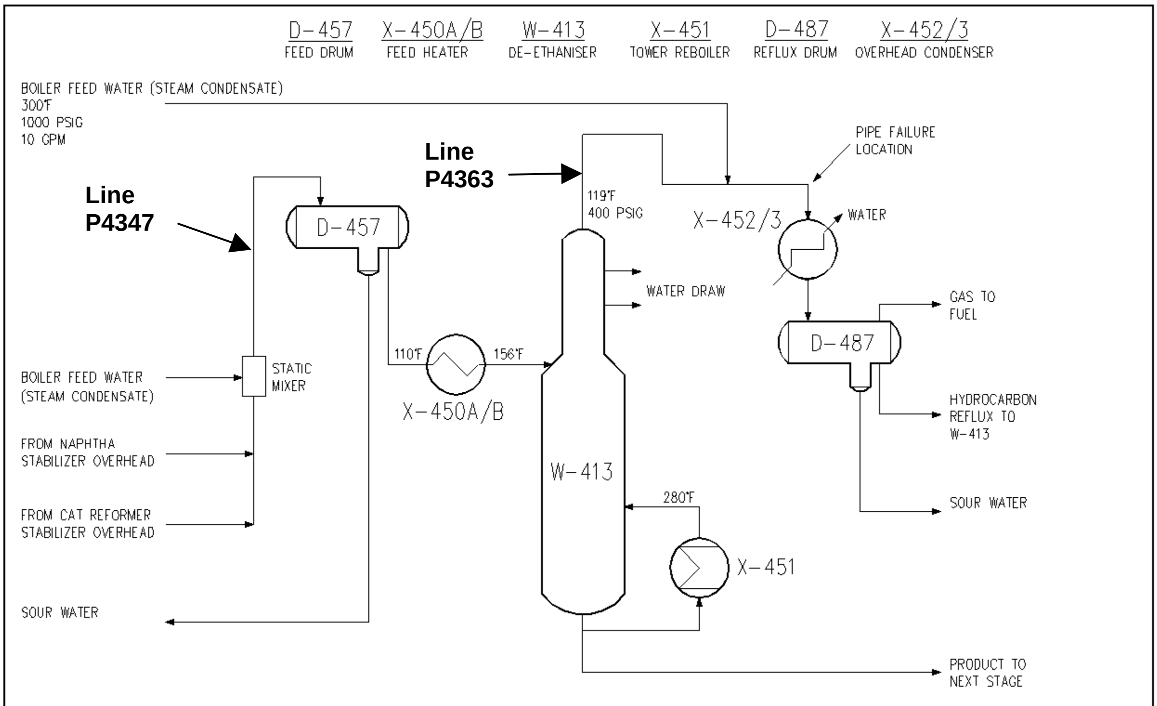

FIGURE 1 SIMPLIFIED PROCESS FLOW DIAGRAM – SATURATE GAS PLANT DE-ETHANISER (W-413)
(PRIOR TO 16th APRIL 2001)

3 THE FIRE AND EXPLOSION INCIDENT AND EFFECTS

Incident details

The incident took place on Easter Monday the 16th April 2001. During the morning the SGP was operating normally and the Central Control Room (CCR) reported a quiet shift, with no alarms showing for the SGP. In the early afternoon there were only 185 people on site, rather than a normal weekday figure of about 800. Most of the staff were inside buildings preparing for the shift handover, which was due to occur at 3pm. A number of people were working in the open air.

At approximately **14.20 hrs** a catastrophic failure of a section of pipework on the SGP plant occurred at an elbow just downstream of a water-into-gas injection point. The six inch diameter pipe P4363, (the overhead line carrying flammable gas under high pressure), ruptured releasing a huge cloud containing around 90% ethane/propane/butane. About 20-30 seconds later the gas cloud ignited. As a result a massive explosion and fire followed.

Figure 2 –The fire and secondary fireball - photo courtesy of Andy Trott

Initial release and explosion

Eyewitness accounts described a sudden very loud noise, and what looked like a jet of steam coming from the SGP pointing diagonally downwards across the plant towards the southeast that lasted about 20-30 seconds.

A contractor driving along in the crew bus heard a loud hissing sound and saw what looked like a jet of steam. He heard a loud ‘crack’, saw a massive fireball then heard the sound of an explosion. The windscreen of the van cracked and the side window shattered onto him.

From an elevated viewpoint, another eyewitness saw a very bright flash by the left hand side of one of the SGP columns at a point higher than ground level. One or two seconds later a bang was heard and at the same time a much larger flash occurred. The second flash travelled diagonally from the middle to the top of the De-ethaniser tower. The flash was followed by a massive explosion and fireball extending to a height of over 30m.

The seat of the fire was between the De-ethaniser and Stabiliser columns, in the vicinity of the surge/feed drum. One of the first members of the ConocoPhillips Emergency Response Team to arrive on the scene saw a clean yellow flame from a pressurised release burning fiercely at a point two thirds of the height of the De-ethaniser column.

Around **14.35 hrs** (10-15 minutes after the initial explosion) there was a further release, which caught fire resulting in a fireball. The fire then got much bigger, approximately 35-45m high and 30m wide and extended to the Stabiliser and the Propane/Butane columns.

The overhead stream in the ruptured P4363 had contained around 90% ethane/ propane /butane; this was an extremely flammable mixture.

As the fire burned, the overheating caused a number of failures of other pressurised pipework from loss of strength. These contributed further quantities of fuel to the fire resulting in another fireball about 15 minutes later, subsequent smaller fireballs also followed.

Effects on site

In total, about 180 metric tonnes of flammable liquids and gases were released during the incident along with just over half a tonne of the toxic gas hydrogen sulphide, which is a component of some of the refinery process streams. Around 80 tonnes of this total was released from the SGP itself and was made up of 65 tonnes gas and 15 tonnes liquid. The remainder, comprising around 60 tonnes liquid and 40 tonnes gas was lost from the upstream and downstream plants as a result of blast and fire damage to the pipework connecting them to the SGP or from piping passing through the area. It was these releases that fuelled the continuing fire until suitable valves were located and closed to stop the flow.

The SGP suffered very heavy damage as a result of the force of the blast. Fortunately, no one had been in the direct path of the estimated 175 metres by 80 metres gas cloud when it had exploded. The resultant fire caused further and substantial damage to the SGP.

Figure 3 – Damage to the SGP after the explosion (W413 column to the right)

In addition buildings normally occupied on the Refinery, up to 400 metres away from the source of the explosion, were badly damaged. The contractor's canteen building suffered severe damage, had it been occupied at the time of the explosion people could have been severely injured by the flying glass. The staff canteen, the inspection services building and the toilet block suffered blast damage with windows blown in, doors and ceilings damaged and some cracking and displacement of brickwork.

Three people in buildings 175m away from the SGP were thrown off their feet by the blast; one banged his head on a glass-reinforced panel in a door, sufficiently hard to fracture the glass. One person in the locker room was thrown across the room and suffered damage to his eyes from dust and face and neck from the glass.

Contractors working on scaffold platforms were blown over and were dazed by the fall, also suffering coughing and choking from the clouds of black 'soot' that were raised by the explosion. All these people subsequently made a full recovery.

The damage caused the Refinery to be shut down for several weeks; this was followed by a phased start up.

Figure 4 – Damage to adjacent Plant

Figure 5 – Close up views of damage to the SGP

Figure 6 – Close up views of damage to the SGP

Effects off site

The explosion at the Humber Refinery caused widespread damage to houses and businesses within a 1 kilometre radius of the site.

People and properties in surrounding areas, particularly South Killingholme, were significantly affected with some householders and businesses suffering major window breakages. Around 370 individual reports of off-site damage were made, the damage consisting mainly of broken windows and cracks to ceilings and walls. Two people attended hospital as a result of the injuries they sustained.

There is evidence of other residents who suffered shock and distress by the blast but who were not injured. In total 71 civil claims for injury damage are being pursued by workers and members of the public.

Members of the local population expressed concern about the lack of communication; they did not know if there had been a release of toxic gas and what action they should take to protect themselves. The normal precaution of shutting doors and windows was not available to those whose doors or windows had been damaged.

Local businesses were mostly closed for the Bank Holiday on 16th April. The damage to the premises of the nearby garage consisted of broken windows, with ceiling tiles and parts of the ventilation system dislodged. The roof appears to have been displaced but then resettled on the joists. There was also serious deformation to the large metal roller shutter doors of the garage.

The Lindsey Oil Refinery, which is adjacent to the Humber Refinery, sustained damage to buildings although the process plant was unaffected.

Debris from the explosion was spread over a wide area. It littered the A160 dual carriageway; so much so that the responding fire engines had to slow down to negotiate through it. Some pieces of debris, mainly cladding, thrown into the air were found between 500 metres and 5 kilometres away.

Emergency Response

The ConocoPhillips Emergency Response Team (ERT) led the fire fighting effort with the Humberside Fire Service attending; fire crew from the Lindsey Oil Refinery also assisted them as part of the existing mutual aid scheme. The following series of events during the emergency response has been constructed from witness statements.

14.20 hrs - Members of the ERT, alerted by the explosion, made their way to the scene of the fire. It took time to confirm the location of the fire. The Central Control Room (CCR) radioed that it was coming from a hydrogen compressor in the Aromatics Unit and directed the ERT to the refinery Avenue A, although the response team determined that flames were coming from the White Oils area.

The CCR has no windows and the Plant Leader, seeing the fire on a TV monitor, gave an instruction for the Refinery General Alarm to be sounded and left the building to take up his role as Incident Controller.

The Forward Control Vehicle and fire appliances attended the scene. Operators and members of the ERT set up turrets, monitors and hoses, which continually directed water onto the flames.

At the CCR the SGP control valves were put into manual mode and then closed to stop flow between the columns. At the scene the SGP feed was re-routed and the feed line isolated.

Other operators had isolated nearly all of the valves as part of the action to prevent other hydrocarbons from feeding the fire. At this time the heat was described as intense.

At **14.35 hrs**, when the second fireball occurred, personnel were exposed to the heat wave from the fireball and as they made their escape hot burning debris fell on top of them. They were unable to shut the gasoline rundown valve.

At **14.40 hrs**, the Plant Leader called the Production Superintendent, who was based in the CCR, to advise him to shut down the Refinery because the fire appeared to be out of control. The Production Superintendent then assumed responsibility and put into operation the Refinery's 'Significant Incident Plan' (SIP). Members of the SIP team were contacted (the SIP team operates from the CCR and takes over responsibility for the site). The Fire Service Incident Commander was informed that all personnel on site had been accounted for.

By **14.52hrs** the Humberside Fire Service had 10 appliances and crews on site tackling the blaze, in addition to the ConocoPhillips and the Lindsey Oil Refinery teams and appliances.

Around **15.00 hrs** another isolation valve was identified by the Control Room and was closed. The White Oils Field Leader arrived at the old Main Control Room to view the plant & instrumentation drawings for the SGP in order to locate all further isolation valves. He compiled a list of isolation valves, which was passed by radio to the scene as efforts continued to cut off sources of fuel.

The fire around this time appeared to be getting worse and it was suspected that the black smoke being produced was from heavy oils from the adjacent Closed Blow Down (CBD) unit. The Field Leader responsible for the CBD was unable to hear radio messages, so the White Oils Field Leader had to meet him to ask him to stop sending feed to the CBD, which was part of the standard procedure for shutting down other Refinery units.

A Field Operator for the White Oils area accompanied a Fire Service Fire Fighter to waste ground on the east side of the SGP to set up further monitors. The Field Operator noticed that the tank containing contaminated drill water from the Cokers, was bowing out under the heat of the fire so they dragged monitors from nearby areas and connected them up to the hoses laid out from the Calciners area. Meanwhile the isolation of feed gases to the Cryogenic unit, which was thought to be fuelling the fire from damaged pipework at the back of the SGP, was organised. It took 10 minutes but with the help of other operators the valve was closed.

Soon after, the fire at the SGP De-ethaniser (W413) was virtually extinguished but the fire in the pipe rack east of the SGP Stabiliser (W414) continued unabated.

Two members of the ERT team went to the east side of the SGP to try and identify the damaged lines but they were unable to do so because of the ferocity of the fire.

Shortly before **15.30 hrs** the White Oils Field Leader, wearing fire protective equipment and under a water curtain, was able to approach the damaged pipework to see where material was leaking. He identified 2 leaking lines and confirmed that the high-pressure line between the Fluidised Catalytic Cracker unit and the Cryogenic unit was isolated. He was able to deduce that the fire was being fed from the Cryogenic unit to the fractured pipework, despite the operation of slam-shut valves that should have closed off the supply. Three isolation valves controlling feeds to and from the Cryogenic unit were closed. The fire reduced considerably.

The incident had occurred at 14.21 hrs and by approximately 15.30 hrs the fire was under control. It was largely extinguished by 17.10 hrs and recorded by the Humberside Fire Service as 'struck out' at 21.01 hrs.

A flame from the Surge Feed drum (D457) was left burning deliberately to burn off gas; this was extinguished the following day.

The off site emergency alarm (Community Alarm) was not sounded at any point during the incident. ConocoPhillips view is that this off site emergency alarm is only used for foreseen toxic gas releases. The damage caused from the incident was immediate and without warning, the off site emergency plan was not put into effect.

In addition to the Humberside Fire Service, the other emergency services committed significant resources to tackle the incident; Police closed off roads around the Refinery, nearby residents were informed to close windows and remain indoors, ambulances were summoned to the site and the local Hospital instigated its major incident procedure. Whilst the property damage in the area was extensive, fortunately there were no serious injuries.

4 OUTCOME OF HSE'S LEGAL ACTION

Following the investigation into the incident, ConocoPhillips Limited were charged with a number of offences. On 16 December 2004 at Grimsby Crown Court the company pleaded guilty to charges under the Health and Safety at Work etc Act 1974, Sections 2 & 3 respectively that:

a) at the Humber Refinery between 1 January 1996 and 17 April 2001 that they did not ensure, so far as is reasonably practicable, the health, safety and welfare of its employees; and that

b) they also failed to conduct its undertaking in such a way as to ensure, so far as was reasonably practicable, that persons not in their employment who might thereby be affected, were not exposed to risks to their health and safety.

On 29 July 2005 the company were sentenced at Grimsby Crown Court and were fined £400,000 on each charge with costs of £218,854. They were also fined £20,000 for offences concerning pressure systems legislation and £75,000 in relation to an unconnected incident elsewhere.

5 INCIDENT INVESTIGATION BY HSE

Scope of the incident investigation on the SGP

The initial assessments of HSE's incident inspectors were communicated to the HSE Board who directed that a Major Accident Investigation of the incident be carried out.

COMAH Regulation 19 requires the Competent Authority to investigate the technical, managerial and organisational aspects of major accidents, and also specifies in detail both the investigation duties on the Competent Authority and the outcomes to be achieved.

As well as establishing the causes of the incident, it was important to ensure that the damaged site was made safe, and that any actions by ConocoPhillips to rebuild the plant and reinstate its activities were appropriate with regard to the risks involved. Access to the site was carefully controlled in order to preserve evidence.

The Humber Refinery is subject to a wide range of health, safety and environmental legislation. For sites covered by COMAH, the responsibility for regulation falls to the Competent Authority, which comprises the Health and Safety Executive and the Environment Agency (EA). The general relevant legal considerations were the Health and Safety at Work Act 1974: Sections 2 and 3 and COMAH: Regulation 4.

Immediately after the incident the HSE set up an investigation team led by an Investigation Manager with two team/site Investigation Leaders. The team comprised of three Regulatory Inspectors; a Principal Specialist Inspector; a Mechanical Engineering Specialist and a Process Safety Specialist. It was evident from initial visual examination of pipe P4363 that there was severe wall thinning at the point of the failure. The investigation sought to establish both the immediate and underlying causes of the failure, which entailed examining a number of key areas including the:

- SGP overall plant and process design and modification history.
- SGP operating history.
- potential corrosive agents in SGP process streams.
- possible degradation mechanisms over the life of the plant.
- design and operation of SGP water injection systems.
- pipework in-service inspection procedures and history.
- Management of change systems.

As part of the incident investigation ConocoPhillips carried out a Root Cause Analysis (RCA). This identified a number of corrosion management issues, which in the opinion of HSE inspectors were deficient. These, along with HSE's initial findings, were discussed between the parties. As a result an Improvement Notice was served on 11 July 2001 requiring ConocoPhillips to draw up an action plan for implementing the provisions of a suitable industry standard for pipework inspections at the Refinery and address the corrosion management deficiencies found. The Improvement Notice was complied with. It was evident that the immediate cause of the incident was the failure of a 6" diameter pipe on the SGP at an elbow close to a water injection point.

Immediately after the incident the HSE issued a Safety Alert to all UK Oil Refineries advising them of the need to have effective inspection systems in place around water injection points in process lines, particularly if these are close to bends in the pipework.

6 WHAT HAPPENED – THE BACKGROUND OF EVENTS LEADING TO THE EXPLOSION AND FIRE

The primary cause of the explosion was the erosion/corrosion of the 6" diameter pipe, known as P4363, which carried the overhead line from the De-ethaniser (W413) to the Heat Exchanger (X452) in the SGP. The failure occurred down stream of and in close proximity to a water injection point that was not part of the original design.

The pipework section containing the failed elbow was recovered from the damage site and metallurgically examined. This section of pipe also contained the water injection point, which was positioned 670 mm upstream of the failed elbow.

The examination showed that the elbow had failed owing to an 'erosion-corrosion' damage mechanism which, over time, had reduced the wall thickness at the outside of the elbow to such an extent that the wall could no longer withstand the internal pressure within. The wall thickness at the point of failure had been reduced from around 7-8 mm to a minimum of 0.3 mm. When the pipe failed it burst open catastrophically (see Figure 7), causing a 'full bore' type of release of the pipe's contents.

The extent of the thinning was mapped and shown to be localised to the elbow and to a slight degree the neighbouring sections of pipe. The pattern of thinning appeared to be directly associated with the water injection position and the downstream flow path of the water from the injection point and around the outside of the elbow. The metallurgical examination revealed that the uncorroded sections of the pipe were internally coated with black iron sulphide. This is known as a 'passivation' layer and once it has formed it serves to protect the carbon steel wall material from further corrosion. However, when the water injection was in operation it washed away the protective coating leaving it open to attack by corrosive agents in the gas stream. Hence the elbow was subject to erosion/corrosion, a process that resulted in the thinning of the pipe wall and eventual failure.

Figure 7 – The failed elbow recovered from the plant

Water washing provision on the SGP

Water washing by injecting water into a process stream was intended to dissolve salts or hydrates, these could otherwise deposit in the system and cause “fouling” which would impede the flow and cause back pressure.

At the time of the incident there were two water injection points on the SGP. As part of the original SGP design there was a water into liquid injection point in feedline pipe P4347 prior to the feed drum. This was in continuous use removing known corrosive agents from the feed stream. The other injection point was into overhead line P4363 (see Figure 1). This injection point was not part of the original design but was added shortly after plant commissioning.

Following its installation the use of P4363 water injection is not well documented. There is evidence that from the early 1980s water injection through this pipe was continuous, until 1995 when the decision was taken that it would only be used intermittently as required (or not at all). The change to intermittent use was not progressed through a Management of Change (MoC) procedure and therefore there was no evaluation of the effect this might have on corrosion potential. In February 2000 a MoC form was completed to increase the orifice size in the water feed line to the P4363 injection point in the overhead system. This intervention actually resulted in a reduction of the water flow rate due to confusion about the original orifice size, but the opportunity was not taken at this time to re evaluate the effect that the water injection could have on downstream pipework.

Sometime during 2000 or early 2001 the water injection on P4363 was put back into continuous use.

Design of the Injection point - Pipe P4363 (the pipe that failed)

Soon after the commissioning of the SGP salts or hydrates began to accumulate in the heat exchangers X452/3 causing fouling problems, which indicated that the original feed water wash into P4347 wash was not as effective as anticipated. To remedy this, around November 1981 after a detailed study of the problem, ConocoPhillips decided to add water to the vapour stream between the top of the De-ethaniser column and the Heat Exchanger ie into line P4363.

An injection point was created in P4363 by piping water to an existing 1" vent point on the pipe, 670 mm upstream of a right angle bend. At this point P4363 was 9 metres above ground level. No injection quill or other dispersal device was fitted and the water entered as a free jet.

Figure 8 – Diagram of the pipework

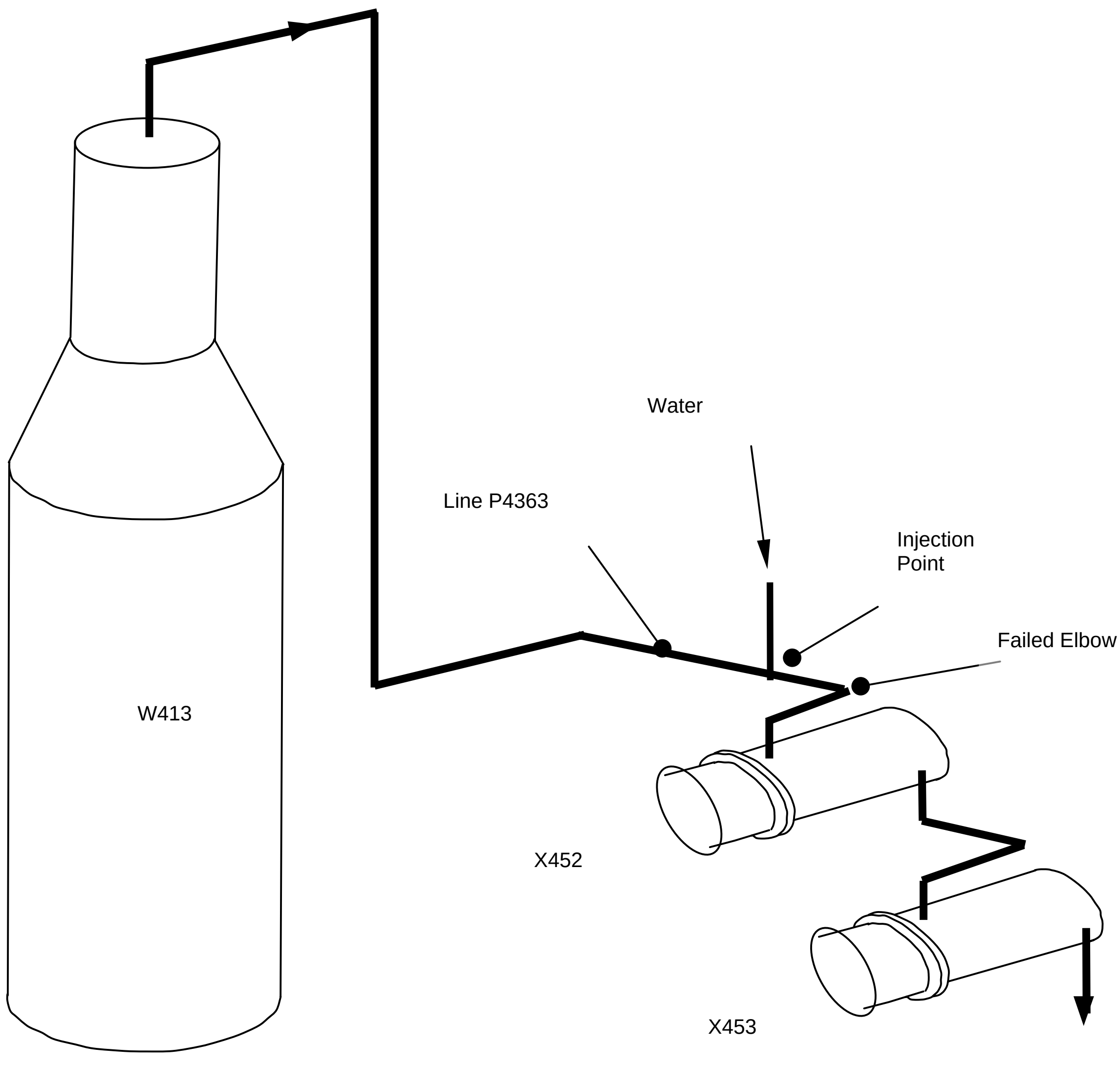

Figure 9 – In-situ failed elbow and injection pipework connection (broken off)

The modification had the hallmarks of a 'quick fix' to solve the symptoms of the immediate problem of fouling. Using an existing vent valve to connect the water into P4363 was expedient, and meant that there would have been little or no downtime required for this modification.

This perception of a 'quick fix' is supported by the failure to implement the MoC system in operation at the time that would have required a technical memorandum to be raised covering the modification. This would have given the opportunity for a multi-disciplinary assessment of the need for change and its implications.

The original Hazard Study carried out by the Plant Designers had identified that a loss of containment could be caused by modifications to the plant and had recommended the implementation of a procedure to control site modifications.

The continual flow of water from a jet into a pipe with a potentially corrosive environment should have alerted engineers to consider the influence of the erosion on the whole of the pipe. The position of the water injection point into P4363 was a major contributory factor to the subsequent failure of the pipe.

Corrosion and Inspection history

There were early corrosion problems associated with the SGP overhead system, which were revealed by X452 and X453 heat exchanger routine inspections. In the April 1994 inspection the heat exchanger shells and tube bundle baffles were found to be badly corroded. Inadequate water wash and water draw systems were thought to be the cause. The exchangers were completely replaced in December 1994.

In 1994 an inspection was carried out at the P4363 water injection location because there had been a previous failure at the P4347 water injection location on the SGP (D457 feed). The failed elbow was not included in the scope of this inspection. The inspection report raised concerns over pitting at the P4363 water injection point and recommended frequent inspections to *'determine corrosion traits and ultimate retirement'*. A request was made for the installed access scaffold to remain in place.

However, the company's safety management system failed to capture these key details, no further inspection activity was undertaken on this pipe and this was the only time that any part of line P4363 was inspected for wall integrity. There is some evidence that a re-inspection was carried out in 1994, but no record of this could be found.

In 1992 a ConocoPhillips Technical Advisory Bulletin sent to the Humber Refinery made special mention of the vulnerability of carbon steel pipework adjacent to water injection points. The Refinery Corrosion Engineer carried out a review of those gas water wash systems that were in continuous use. The injection point on P4363 did not at that time appear on the inspection department's database and therefore was not included in this review as it was believed to be not in service.

A pipework inspection survey was commissioned in 1996 using the CREDO (a computer database system – see page 30) drawings for the De-ethaniser to target pipework, but very few thickness measurements were actually taken. At the P4363 injection point and the failed elbow no measurements were carried out because there was no access, the previously installed scaffold had been removed.

In 1996 the inspection services department erroneously believed that the injection point had been blinded off and therefore assumed that further erosion/corrosion of P4363 had been halted. After 1996 no further inspections were carried out. The failed elbow had not been inspected at all in 20 years.

7 CONOCOPHILLIPS SAFETY MANAGEMENT SYSTEMS

Management of corrosion

The Refinery controlled plant degradation mechanisms using a number of measures. In addition to the selection of materials, these measures included inspection, sampling for corrosive agents and corrosion monitoring. Historically there was no Humber Refinery procedure for inspecting pipework around water and chemical injection points but there was plenty of corporate and industry guidance.

Since 1976 ConocoPhillips had relied on off-site expertise from the Corporate Corrosion Group at the Ponca City Refinery in the USA for corrosion issues, with the Refinery Metallurgist dealing with any day-to-day issues on site. In 1992, a full-time Corrosion Engineer was appointed, attached to the Inspection Services Group. From 1997 to 2000, however, the Corrosion Engineer was attached to other projects for 75% of his time. During this period some additional assistance was provided from Ponca City.

The Refinery also employed a corrosion review procedure to bring together a range of expertise on the corrosion degradation potential at each plant. Expert reviews were carried out from the early 1980's. The purpose of these reviews was to bring multi-disciplinary expertise together to discuss corrosion issues on each of the Refinery Divisions. The early reviews were not well documented, but from 1993 onwards records were kept including agreed 'next step' actions.

Corrosion reviews in 1992, 1993, 1994, and 1996 confirmed that all of the continuous water washes to the hydro-treating units were evaluated against the current guidelines for velocity, piping configuration etc by the Divisional Engineers. Despite being a water-into-gas injection, the downstream P4363 was not included in any reviews after 1994 because it was thought to be only operated intermittently, or not in use.

Sampling and analysis of SGP process streams to monitor corrosion activity began in 1993/4, as a result of divisional corrosion review meetings, and involved sour water samples from both D457 feed drum and D487 reflux drum. D457 samples gave an indication of the composition of the feed streams into the SGP, whereas D487 samples were the best available indicator of corrosion activity in the W413 overhead stream. The frequency of sampling varied in the period to 1997, when it stopped completely. D457 sampling resumed in 2000, but no sampling results for D487 were recorded after 1997. Initially high corrosion levels of certain corrosion related components were indicated in the D487 samples, but overall a clear trend was not established as the data was too variable.

In addition to process stream sampling some work was also done with corrosion probes, which were fitted in D457 outlet and X452 inlet in 1994. The X452 inlet probe initially indicated a high corrosion rate, but this does not appear to have been followed up.

The United Kingdom Accreditation Service (UKAS) raised concern following an audit of Company procedures against current legislation in 2000. The audit considered how inspections were prioritised and the methodology and procedures of how this was achieved.

The UKAS system has provision for management review, which focused on compliance with current legislation and a review of any necessary changes. It takes the form of a formal meeting between the team leader, consultant and a member of inspection services.

The 1996 HSE audit 'The Management of Health and Safety with Reference to Control of Corrosion' identified that there were no formal arrangements in place under which ConocoPhillips carried out formal audits of its safety management system or of particular risk control systems to examine in depth the adequacy of policy/objectives, organisation, planning and implementation, performance measurement and review. Elements of the UKAS system were therefore introduced.

The HSE audit report concluded that ConocoPhillips 'had a well-developed safety management system with the leaders of the organisation showing commitment to securing high standards of health and safety at work'. This conclusion was drawn from extensive interview sessions and a review of a large number of company documents. There were however 12 recommendations made, following which the Refinery presented to HSE (May 1998) a summary of how they were taking forward the audit recommendations.

For some of the time after the HSE audit in 1996, ie between 1996 and 2001, ConocoPhillips were failing to manage safety to the standards they set themselves. At the time of the audit, ConocoPhillips' health and safety policy included a commitment to maintaining a programme for ensuring compliance with the law. The auditors concluded that the policy was a true reflection of the company's commitment to health and safety.

Management of pipework inspection

Inspection Services Group

There are a number of standard techniques that can be used to assess the ongoing integrity of pipework. Inspection usually involves visual inspection, ultrasonic testing and radiography. The Inspection Services Group was responsible for the inspection function at the Refinery, operating as an in-house plant inspection authority and as part of the Technical Services Division; the group was independent of the production activity. The inspection services quality system had been in place at the Humber Refinery since 1989 and was the responsibility of the Metallurgist, the system covered procedures for inspection and technical support documents.

The roles and responsibilities of the Inspection Services Group are defined in the COMAH Safety Report submitted in February 2000 as "developing and implementing a plant wide inspection programme for ensuring equipment and repairs meet code ie ConocoPhillips engineering standards and internationally recognised engineering codes and standards; and statutory requirements ie The Pressure Systems Safety Regulations (PSSR) 2000".

There was no reference to the need to ensure continued plant integrity to meet other legal provisions, such as the Provision and Use of Work Equipment Regulations 1998 or to Regulation 4 of COMAH.

Individual members of the Refinery's Inspection Services Group did keep records of corrosion-related incidents, but there was no central database to hold the information. This was only created after the explosion and fire in 2001.

Procedures and recording systems

At the Refinery the legal requirements to provide written documentation and procedures were interpreted and written into management procedural documents to be used for the inspection of plant and pipework. The relevant ones were:

- **Inspection Services Procedure for Written Schemes of Examination (WSE)**

  The Refinery defined a 'pressure system as 'a set of components consisting of one or more pressure vessels, all associated safety devices and any pipework that is potentially dangerous'. According to procedure the Inspection Services Department were required to allocate a specific examination classification to both existing and new items (e.g. major equipment, piping systems, pipelines, mobile equipment) for entry onto the Equipment Inspection Records (EIR) database and include in a Written Scheme of Examination (WSE) as required by the Pressure Systems Regulations (PSR) that were current at the time. The classifications were:

  Class A - Existing statutory/Definite PSR items. This was allocated to items which were classed as statutory under Factories Act legislation prior to 1st July 1994, and for items where a positive decision has been made that the full 'Pressure Systems and Transportable Gas Container Regulations, 1989 applied (later these were replaced by the Pressure Systems Safety Regulations 2000).

  Class B – Intermediates (PSR may / may not apply). This was allocated to items pending a decision whether the full scope of the Pressure Systems Regulations applied or not. Until such time a decision had been made items in this class were to be treated as though the regulations did apply. If a situation of 'Imminent Danger' arose or it was desired to postpone an examination, then a decision was required as to whether the regulations applied or not and whether the item should be reclassified as 'A' and appropriate report sent to the HSE, or the item should be reclassified as 'C' or 'X' in which case no such report is required.

  Class C – PSR do not apply, but items scheduled. This classification was allocated to those items where it was confirmed that the Pressure Systems Regulations did not apply. Items in this class however were still required to be included in scheme of examination and be scheduled for periodic inspection in a similar way to those items in class 'A' or 'B'.

  The pressure systems regulations only require inclusion into the WSE those parts of the pipework in which a defect may give rise to 'danger' from the release of stored energy.

The 1997 WSE for the SGP called for generic pressure piping inspections at intervals not greater than 60 months. P4363 did not have a specific WSE requirement.

The ConocoPhillips WSE dated August 1997 and the related ConocoPhillips procedures had not been updated during 2000/2001. Importantly, there was no mention of injection points in either the WSE procedure or the ConocoPhillips procedure for its pressure piping. There were no internal specific procedures for setting inspection intervals for pipework not in WSEs.

- **Inspection Services Procedure – Pressure piping**

  This document scopes 'pressure piping' as applicable to 'those systems which fall within current National Legislation – i.e. those systems where a significant hazard is likely on failure or where integrity is likely to be impaired due to corrosion, fatigue or other forms of material degradation'.

  'Current National Legislation' was referenced as:

  - o The Pressure Systems and Transportable Gas Containers Regulations, 1989.
  - o Institute of Petroleum (IP) Model Code of Practice Part 13 – Pressure Piping Systems and Inspection Safety Code.

    A particular paragraph in the document discussed the procedures for Written Schemes of examination (WSE): '*For administration purposes and to comply with the requirements of the pressure systems regulations, Inspection Services shall prepare schemes of examination for those systems subject to regular or periodic examination. The regulations require pipework to be part of the WSE only if significant hazard is likely at failure or whether its integrity is liable to be impaired due to corrosion, fatigue etc.*

The investigation included a review of the systems ConocoPhillips had in place for the storage and management of technical data for the Refinery and also their systems that would enable the retrieval of data/information in a structured way to comply with legislative requirements. These included the following:

- **EIR –** (Equipment Inspection Records) – This was a computer software database (DOS based) for recording inspection information about static equipment such as vessels & heat exchangers. It was not specifically intended or used for pipework systems. The data in EIR was migrated to SAP in early 2001.

- **SAP** – (Systems Applications and Products; the company business processes planning tool) – introduced in 1993/4 it was found to be time consuming and difficult to use. The work lists generated by SAP were therefore inaccurate and incomplete so the database was ignored because it was unreliable. At the time of the incident it did not contain any data on pipework that was not in a WSE; it also did not contain any information on injection points, these were only entered after the incident with the next date for their inspection.

- **CORTRAN** (Corrosion Trend Analysis) **–** this was the first database used by ConocoPhillips to record pipework inspection data. It was installed as a corrosion-monitoring tool for piping as an aid for inspection management. In August 1997 when CORTRAN was superseded by CREDO all the data was electronically transferred across to CREDO.

- **CREDO** – a computer database to document the results of inspections of all pipework on the Refinery. It is linked electronically to the ‘Line List’, which is a database of all the pipework on the Refinery. CREDO is capable of planning and scheduling inspections and it has an alarm system that could highlight pipework deterioration. The system was very poorly populated due to a backlog of results waiting to be entered and a lack of actual pipework inspection. In 2000 it was estimated that it would take nearly 70 staff weeks to input the backlog of data, this work should not have been permitted to build up. CREDO should have been utilised as intended, as a system for monitoring pipework degradation; in particular the corrosion alert system was not properly implemented and alert levels were ignored because they were unreliable. There was no governing policy on determination of inspection locations and inspection intervals.

- **Inspection Notes** - a standalone access database used for recording Inspection Notes generated by plant inspectors. An Inspection Note could be prioritised in the SAP planning and actioned by the Area Maintenance Leader.

- **Paper systems** – these were kept by individual inspectors.

- **Microfilm** records stored in the Central Records Department.

Risk based inspection

ConocoPhillips considered that the introduction of a risk based inspection regime in 1999 would produce more structured and targeted inspections for vessels and pipework. This would hopefully achieve more efficient use of inspection resources. The process involves gathering information about the plant (e.g. materials of construction, process fluid constituents, foreseeable operating temperatures, pressures etc) and inputting it into a computer software programme. The computer analyses the data and produces various confidence reports about the life of the equipment and the relative risks involved. This knowledge is then used to develop an inspection plan to control the risks of a failure.

The Refinery did not have a documented strategy for inspection until October/ November 2000, when the Inspection Service Group Inspection Strategy was issued. This was linked to the implementation of Risk Based Inspection (RBI) and defined the purpose of the Inspection Services Group and the responsibilities of its members.

An RBI Study was done on the SGP in November 2000, which was the first study at the Refinery to specifically include pipework. When the software programme was run for line P4363, the injection point was not considered because the RBI Co-ordinator believed that the feed line was permanently isolated and would prevent routine operation of the water wash. Had the existence of the injection point been inputted into the RBI database, the thinning factor would have trebled and the known risk increased. Even though the injection point was not in the database the output thinning report still identified line P4363 as a high risk item. This conclusion had been arrived at from generic ‘consequence of failure’ and ‘likelihood of failure’ data in the absence of any available actual historic inspection data. However, there were no criteria established to indicate at what level of risk it would become unacceptable to justify continued operation of the SGP. An inspection date of July 2001 was planned for P4363 but it failed before that inspection.

Compliance with legislation and standards

Between 1996 and 2001 there was a number of plant items listed on the pressure systems WSE which were overdue for inspection. While the Refinery was in principle committed to health and safety management, in practice the Company was unable to manage all risks and senior managers failed to appreciate the potential consequences of small non-compliances.

Active monitoring of their systems should have flagged up failures across a range of activities. In practice either the monitoring was not undertaken, so the extent of the problems remained hidden, or the monitoring recommended by the audit was undertaken but no action was taken on the results. Both are serious management failures. There was no effective in-service inspection program for the process piping at the SGP from the time of commissioning in 1981 to the explosion on 16th April 2001.

Industry good practice for pipework inspection was available that made recommendations as to what was reasonably practicable to do in respect of in-service inspection to control the risk of pipework failures. ConocoPhillips Humber Refinery procedures and practices fell far below meeting good practice. An example of such good practice guidance is set out in the publications API 570 and API 574. These documents set out clearly what measures it is reasonably practicable to apply. Adherence with these or similar codes is not mandatory, but a company managing high hazard pipework must adopt these, or equally effective alternative arrangements, to ensure that the residual risks due to refinery pipework are as low as reasonably practical.

In particular, the pipework in-service inspection regime for the SGP overhead pipe system was seriously flawed, and ultimately led to the major accident. If a pipework inspection regime compliant with the requirements of these good practice documents had been in place at the ConocoPhillips Humber Refinery it is very unlikely that an event such as that which occurred in April 2001 could have taken place. Without such a regime in place such a failure became inevitable.

ConocoPhillips identified this failing when the company reviewed their risk assessments in the safety reports for the Refinery, at HSE's request, in 2000. In all instances piping inspection was defined as 'inadequate' resulting in either a moderate or unacceptable risk using the Humber Refinery Preliminary Risk Assessment (PRA) system.

Management of change

In 1999 the Company produced a strategy for the Management of Change (MoC). There were two methods through which change was managed, an electronic MoC form and the Technical Memorandum system.

The Technical Memorandum system was in place in 1981 when the SGP was commissioned. Technical Memoranda are used to describe the scope of proposed changes or additions to the refinery processes and equipment. They are generally prepared by process engineers and are circulated to an agreed list of approvers.

An electronic MoC system was introduced in 1999 for all changes made to the physical plant, its equipment, component parts or configuration and process changes. This involves the raising of a computer-based form that is circulated to selected specialised personnel for review.

The MoC system should have been used for the modification of P4363 to verify the reasons for the change and identify any ramifications for the safety of the plant. When it was used in February 2000 in connection with the changes to the water feed to the injection point it confirmed that previous records of the water wash system were inaccurate, but the significance of this was not appreciated.

The SGP Unit Operating Manual contained various categories of information including process description, equipment list, safety advice, start up, shutdown and emergency procedures. It was last reviewed and revised in November 2000. This Manual contained an instruction requiring the water injection point on P4363 to be commissioned when the SGP was started up, but made no reference to turning it off. No amendment was made to the

Operating Manual when the injection point was put into intermittent service detailing how this was to be carried out.

For the purposes of assessing risk of erosion/corrosion from an injection point, different levels of 'intermittent' use should have been defined. The investigation identified confusion amongst SGP operators about when the injection point had been used continuously or intermittently, over the lifetime of the plant.

The reported change from intermittent to continuous use in late 2000 was again not subject to a MoC (or any other) assessment. There should have been a requirement for changes in the pattern of use of an injection point to be flagged up to the relevant personnel so that the reasons for the change and any increase in risk could be assessed and acted on. There was a lack of communication between the Production Department and other interested personnel, who saw the more frequent 'plugging' resulting from the deposits impairing the flow as a processing problem and did not initiate any consideration of the wider issues.

8 CONOCOPHILLIPS RESPONSE AND ACTION

Immediate

One of the 'next steps' identified from the RCA was the inspection of pipework around all water wash systems, this required pipework adjacent to water injection points to be inspected. These were identified on a list produced for the start-up inspection. When the relevant injection points were inspected one was found to be suffering significant corrosion and the pipework was replaced.

At a 'start up' meeting ConocoPhillips presented information to demonstrate progress towards ensuring the integrity of pipework and vessels. A document was presented which detailed the work that was being undertaken by the Refinery in order to demonstrate this. In particular, the document detailed that a review of international, national and company standards with respect to injection points and associated pipework was complete.

As a result of this review the Company had identified two documents as being key in respect of inspection around injection points. These were API 570 (American Petroleum Institute) Code for inspection, repair alteration and re-rating of in-service piping systems; and NACE (National Association of Corrosion Engineers) draft Publication 34101: Refinery Injection & Process Mixing Points.

Start up was to take place in three successive phases. It was agreed that the presentation of the inspection data needed to satisfy HSE would be supplied for each phase in turn. ConocoPhillips presented information to demonstrate their progress towards compliance with the scope of Phase 1. An analysis of the information provided revealed that:

- 6 of the injection points were inspected as part of the Written Scheme of Examination (WSE);
- of the remaining 16 injection points, 5 had no inspection history;
- another 5 of the injection points with inspection history had not been inspected within the previous three years;
- the Company reviewed inspection frequencies and a number of inspection rates were increased.

As a result of the inspection following the April 2001 pipe failure, 4 injection points were identified by the Company as requiring more frequent inspection (less than 1 year intervals) because of what was then discovered to be the apparent rates of corrosion.

Longer Term

The learnings from the emergency response on-site and off-site were shared with local industries, Emergency Planning and the Emergency Services through the Humber Bank Major Hazards Group   One learning was the process set up to handle concerns among the community and to carry out repairs in a timely fashion. The second action item was to install an additional offsite community alarm, specifically for South Killingholme residents furthest away from the Refinery, as they could not always hear the existing alarm. Improved annual notification of the action to be taken on the sounding of the alarm was achieved with the production of a video as well as the annual calendar.

In order to provide more pipe thickness data to verify believed integrity, a piping inspection programme called 'Hawkeye' was carried out on all the higher risk Refinery piping systems over a 3-month period from October 2002. This was essentially a Risk Based Inspection review. An 'expert review' was held using the operating department personnel coupled with corrosion and inspection personnel. The output was an inspection plan for these higher risk piping systems. As a result, approximately 3,200 lines were inspected which represented about 15% of the total Refinery system.

Implementation of this plan involved the deployment of ConocoPhillips' top 18 corrosion engineers and 86 API 570 trained inspectors from around the world.

The Hawkeye project cost £10.16 million to complete, requiring a refinery shutdown of several weeks.

A further project, 'Project 570' was initiated to review the remaining 85% of the Refinery piping (18824 lines). These were to be inspected with at least 1 thickness measurement location and once again the results were used for remnant life and replacement assessments. This project involved the deployment of 82 API 570 trained inspectors over an 8-month period.

A total of 62,000 inspection locations were reviewed following this plan. The project 570 protocol follows the guidance in the American Petroleum Institute Piping Inspection Code API 570. This covers the inspection, repair, alteration and re-rating of in-service piping systems.

These two projects were inspected by the HSE for quality and timeliness.

ConocoPhillips senior management requested a third party audit of all ConocoPhillips facilities world wide, both upstream (exploration and production) and downstream (refining and marketing).

Specialist consultants with a worldwide reputation in the field of process safety were chosen to carry out the work, which was completed in late 2001. The audit team comprised of Management Systems and Mechanical Integrity specialists. A wide range of interviews with over 120 staff (16% of the workforce) was undertaken as the primary basis for the assessment.

All ConocoPhillips sites reported annually to the Corporate Headquarters on the progress status of the recommendations of this report.

The Refinery organisational structure was revised to provide clearer definitions of the responsibilities for Mechanical Integrity. Inspection and Mechanical Integrity and their associated actions are Key Risk Control activities, and the monitoring of their performance metrics are reviewed routinely by the Refinery Leadership team. There is also a corporate review of key metrics for all ConocoPhillips locations.

Work in the Community has been continued and enhanced following 16 April 2001. ConocoPhillips has set up the Killingholme Area Advisory Group (KAAG), a Community Group that is externally facilitated and made up from key members of the local community and senior Refinery Management.

Specialist consultants were employed to review the blast damage and explosion over-pressure calculations to improve predictive knowledge. As a result of this work, software used to predict explosion over-pressure was updated and used for all the Humber Refinery occupied building risk assessments.

This data was shared with the Petroleum & Chemical Processing Technology Co-operative in the USA for the benefit of other refinery and chemical sites worldwide.

9 CONCLUSIONS AND KEY LESSONS

Management of pipework inspection

ConocoPhillips failed to implement an effective system for the inspection of pipework on the SGP, to complement that in place for process equipment. The system used fell far below recognised industry good practice at the time. In addition they failed to use knowledge and experience from other sections of the plant that should have identified the need for more inspection of the SGP pipework. Over time sufficient pipework condition data should have been obtained, and entered onto an inspection database, to verify the believed integrity and inform assessments of future inspection requirements. Without this both the system and the assessments were inadequate.

Key lessons:

- Effective pipework inspection systems are a vital major accident prevention measure for high hazard pipework.
- Such systems should at least meet current industry good practice standard.
- Decisions on inspection intervals should be informed by suitable and sufficient information on process conditions and previous inspection findings.

Management of change

The design and installation of the water injection point in P4363 was not subject to any MoC assessment. Had such an assessment been carried out the corrosion risk that the injection point introduced for the downstream pipework could have been identified. Similarly no assessment was made of the changes in use of the water injection point, between continuous and intermittent, over the lifetime of the plant. The frequency of use was a major factor in the rate of the corrosion of the pipework. During periods of continued use more frequent or detailed inspections of the pipework should have taken place to adequately monitor the integrity of the pipe.

Key lessons:

- Effective management of change systems, which consider both plant and process modifications, are essential to prevent major accidents.
- Particular care is needed to ensure that ‘quick fix’ modifications, during the commissioning and early operation phases of new plant, are covered.

Management of corrosion

ConocoPhillips corrosion management on the SGP was not sufficiently thorough or systematic to prevent the failure of P4363. Some positive actions were taken, including the appointment of a full time Corrosion Engineer for the Refinery, introduction of divisional corrosion reviews and monitoring of process streams by sampling and the installation of corrosion probes, following receipt of specific information in 1992 about the vulnerability of carbon steel pipework in the vicinity of water injection points. Unfortunately these activities were allowed to lapse with the result that there was both insufficient data on, and inadequate resource or focus applied to, corrosion as a potential major accident initiator on the SGP.

Key lessons;

- Systematic and thorough arrangements are necessary for the effective management of corrosion on major hazard installations.
- Such arrangements should ensure that any available information on relevant corrosion degradation mechanisms is identified and acted on.
- Adequate resource, including relevant expertise, should be applied to ensure that adequate standards are achieved and maintained.

Communication

Two significant communication failings contributed to this incident. Firstly the various changes to the frequency of use of the P4363 water injection were not communicated outside plant operations personnel. As a result there was a belief elsewhere that it was in occasional use only and did not constitute a corrosion risk. Secondly information from the P4363 injection point inspection, which was carried out in 1994, was not adequately recorded or communicated with the result that the recommended further inspections of the pipe were never carried out.

These failings were confirmed in a subsequent detailed inspection of specific human factors issues at the Refinery. Safety communications were found to be largely 'top down' instructions related to personal safety issues, rather than seeking to involve the workforce in the active prevention of major accidents. The inspection identified that there was insufficient attention on the Refinery to the management of process safety.

Key lessons;

- Effective communication is an important element of any safety management system. In the context of major hazard establishments the accurate recording and effective sharing of information and data relevant to plant corrosion is essential for major accident prevention.
- Communication systems should aim to actively involve the workforce in the prevention of major accidents as part of an adequately resourced process safety management system.

10 KEY LESSONS FOR THE COMPETENT AUTHORITY

The Incident Investigation, together with the conclusions from other investigations, clearly showed that resources should be put into ensuring pipework and plant integrity. HSE has done this including the introduction of a special programme that addressed pipework integrity at Oil Refineries.

The Safety Report assessment process touched on issues relating to the root causes of the incident, and this confirmed the importance of that process. However, HSE accepts that in order to capitalise on the benefits of the process a more proportionate approach is required with the express aim of moving quickly onto testing issues through site intervention programmes. The Competent Authority has now moved to this strategy.

11 HSE SAFETY ALERT

Pipework failure at an oil refinery

A recent incident at a UK oil refinery has reinforced the need for detailed attention to pipework integrity.

A hydrocarbon release from pipework within a saturate gas plant led to a major vapour cloud explosion and subsequent fire damage with further explosions. The initial source of the release is believed to have been from an overhead line from a de-ethaniser column at a forged pipework bend downstream from a water injection point. After the incident the bend was found to be ruptured with corrosion to the inside surface. The process stream is likely to have contained contaminants.

Operators of refineries are reminded to take all necessary measures to prevent major accidents including appropriate inspection and maintenance programmes. Industry codes such as API 570 Piping Inspection Code and IP Model Code of Safe Practice Part 13 give details of such practices. Attention is drawn to the need for inspection of piping systems that are susceptible to specific types and areas of deterioration such as at injection points.

12 GLOSSARY OF ABBREVIATIONS

API	American Petroleum Institute
CBD	Closed Blow Down
CCR	Central Control Room
COMAH	Control of Major Accident Hazards Regulations 1999
EA	Environment Agency
ERT	Emergency Response Team
FCC	Fluidised Catalytic Cracker (Unit)
GB	Great Britain
HSE	Health and Safety Executive
IP	Institute of Petroleum
LPG	Liquefied Petroleum Gas
MM	Millimetere
MoC	Management of Change
NACE	National Association of Corrosion Engineers
PRA	Preliminary Risk Assessment
PSR	Pressure Systems Regulations
PSSR	Pressure Systems Safety Regulations 2000
RBI	Risk Based Inspection
RCA	Root Cause analysis
RLT	Refinery Leadership Team
SAP	Systems Applications & Products
SGP	Saturate Gas Plant
SIP	Significant Incident Plan
UK	United Kingdom
US	United States
USA	United States of America
UKAS	United Kingdom Accreditation Service
WSE	Written Scheme of Examination
P4347	Pipe carrying combined feeds to D457
P4363	Overhead pipe from top of W413 to heat exchangers
D457	Surge (feed) drum to W413 De-ethaniser column
D487	De-ethaniser reflux drum
W413	De-ethaniser column
W414	Stabiliser column
W415	Propane/butane splitter column
X452/3	Water cooled heat exchangers