MAJOR INCIDENT INVESTIGATION REPORT

BP GRANGEMOUTH SCOTLAND

29th MAY – 10th JUNE 2000

A PUBLIC REPORT PREPARED BY THE HSE ON BEHALF OF THE COMPETENT AUTHORITY

Date of Publication 18th August 2003

HSE Health & Safety Executive

SEPA Scottish Environment Protection Agency

First published 2003

LEGAL BASIS

The powers of the Health and Safety Commission and the Health and Safety Executive ("the HSE") are set out in the Health & Safety at Work etc. Act 1974. The Commission has the power to direct the HSE or authorise any other person to investigate and make a special report on a matter, or with the consent of the Secretary of State to direct an inquiry to be held into that matter. However, in relation to the matters addressed in this report the Commission decided that it was not necessary to direct the HSE to carry out an investigation and make a special report in terms of the Act, or to direct that an inquiry be held. Instead the Commission and the HSE agreed that the HSE would prepare this non-statutory report and would make it available to the public in accordance with the HSE's policies. This report explains how and why the incidents occurred and the actions taken by BP and the HSE. The report will help industry to learn lessons from the incidents.

The extent of alignment of the HSE's findings and recommendations with those of BP's own investigations and BP Task Force is an important feature of this complex investigation. The HSE acknowledges BP's openness and cooperation in their response to the incidents and in the preparation of this report.

Note: All references to website addresses were correct on date of publication (18th August 2003). HSE will periodically review website links quoted.

ROUTE MAP FOR THE REPORT

This Major Incident Investigation report has been produced by the Health and Safety Executive (HSE) on behalf of the Competent Authority and is available on the Internet via the HSE home page at www.hse.gov.uk.

The report contains a description of the following:

- The three incidents that occurred at the BP Grangemouth Complex between 29th May 2000 and 10th June 2000;
- The immediate response of BP following the incidents (this includes the investigation carried out by the BP Task Force);
- The series of investigations carried out by the Competent Authority in the aftermath of the incidents;
- The subsequent findings of the Competent Authority investigations.

The report also summarises the following:

- BP's learnings from these incidents and the actions taken by BP;
- The key lessons for major accident hazard sites;
- Wider messages for industry.

The report contains hyperlinks to enable the reader to move around the report, and internet links to other information available on the HSE website and external websites. This allows the reader to access additional information directly from this report and hence to broaden their knowledge and understanding of the information described should they wish to do so.

Although the report is predominantly concerned with the series of incidents that occurred at the BP Grangemouth Complex in 2000 it is being published at a time when the HSE has embarked on the "Revitalising Health and Safety" strategy. This strategy aims to "prevent major incidents with catastrophic consequences occurring in high-hazard industries". The opportunity is therefore also taken to remind industry of its responsibilities with some messages from the HSE.

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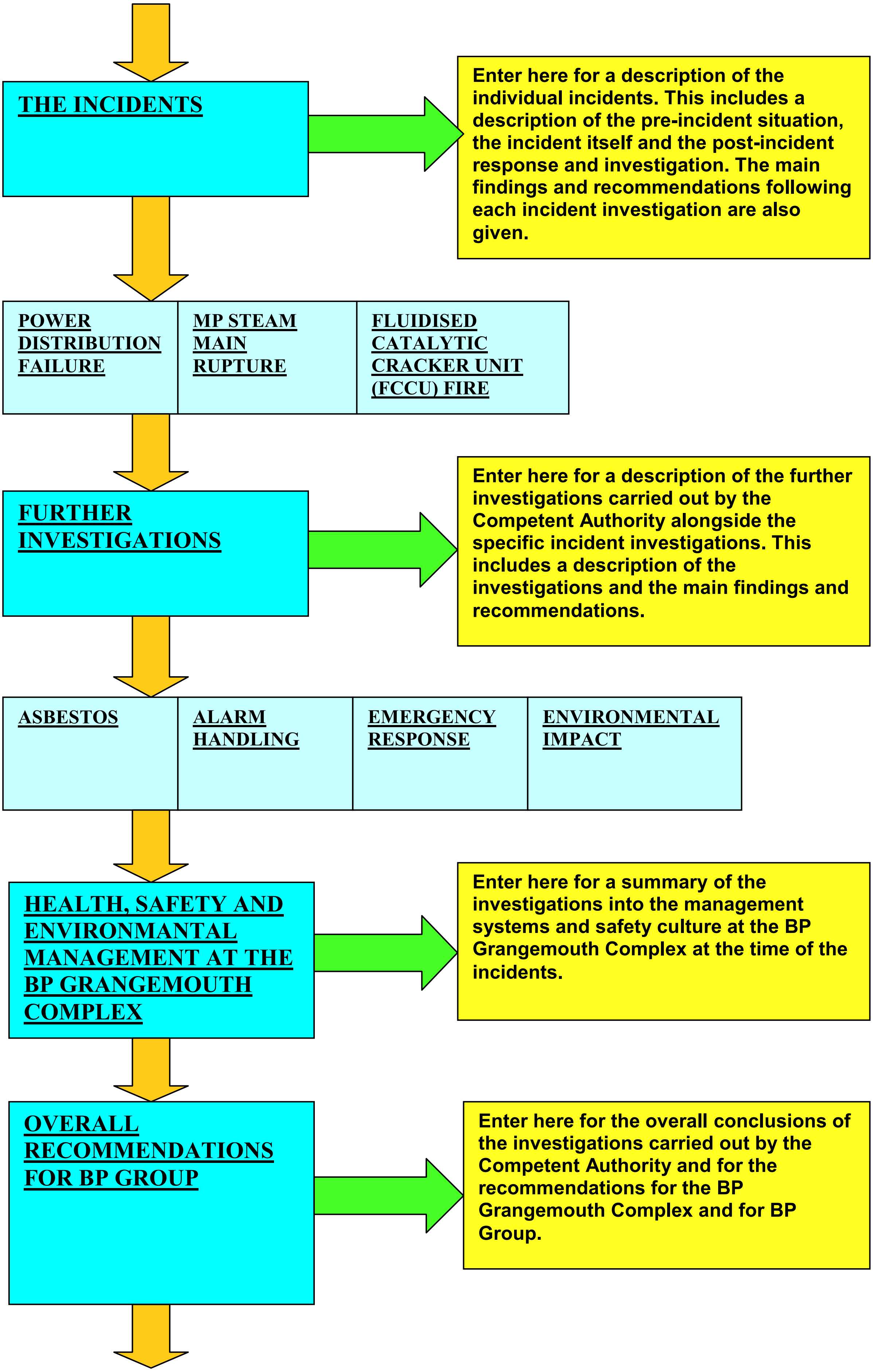
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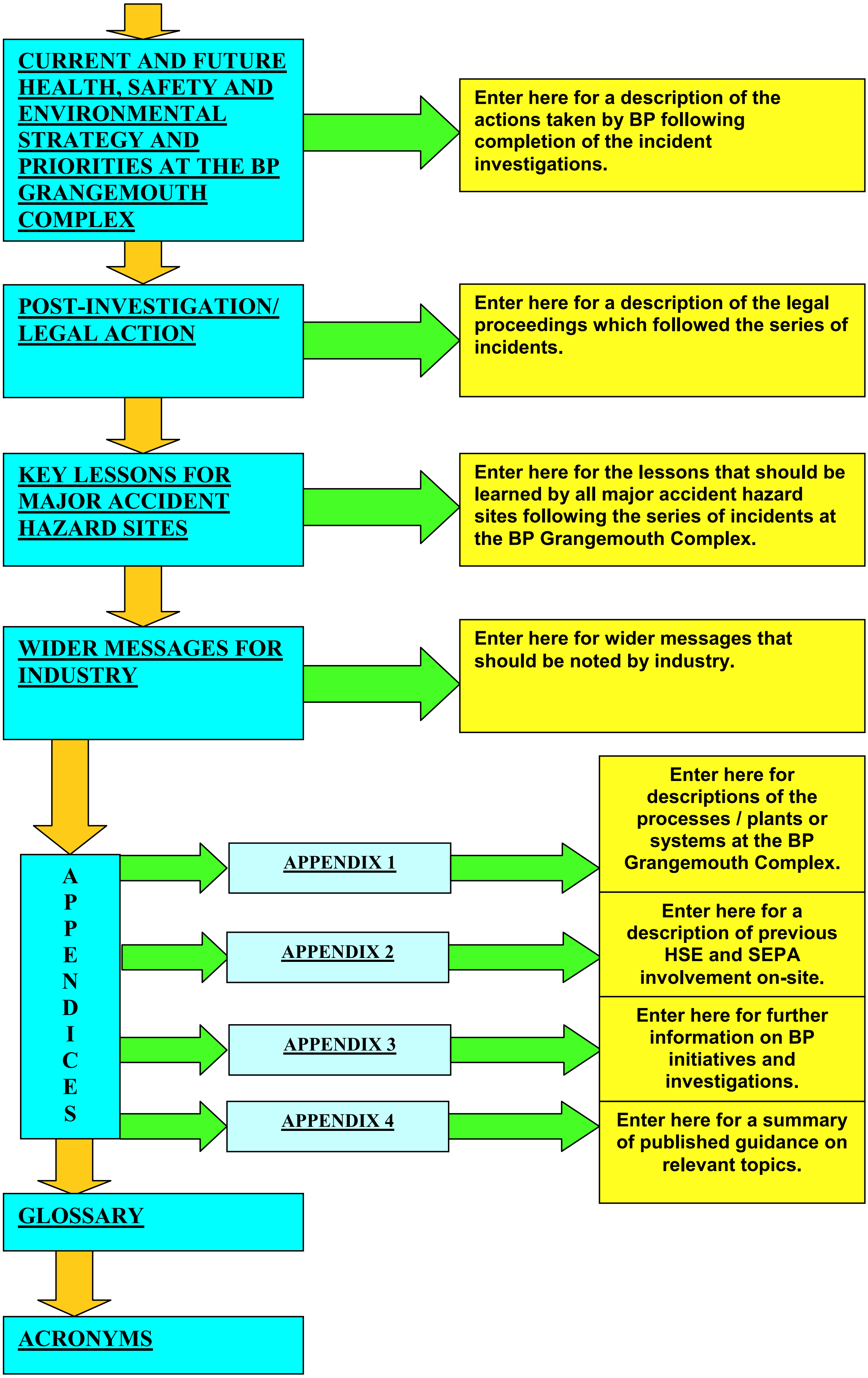
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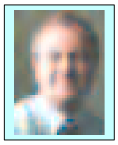
FOREWORD – A Message from Dan Mitchell, Head of Land Division, Health and Safety Executive



In response to public concern over the series of three major incidents at the BP Grangemouth Petrochemical Complex during May/June 2000 a commitment was given to produce a report summarising the Competent Authority's investigation. This report could not be published until the completion of legal proceedings for criminal offences. On 18th January 2002 BP Chemicals Limited and BP Oil Grangemouth Refinery Limited were each convicted of an offence under the Health & Safety at Work etc. Act 1974. BP Chemicals Limited were fined £250,000 and BP Oil Grangemouth Refinery Limited were fined £750,000. This reflected the seriousness that the courts hold for failings in controlling major hazard risks.

The Health and Safety Executive and the Scottish Environment Protection Agency jointly carried out the investigation under the COMAH Regulations where they operate as the joint Competent Authority. The Health and Safety Executive led the investigation team as safety issues predominated.

The Competent Authority believes it is important that the public in Grangemouth are openly informed of the way major hazard sites are regulated, of the investigations conducted and actions taken to improve health, safety and environmental performance on-site. It is also important that the chemical and oil refining industries learn the lessons from these three incidents and take the necessary measures to minimise the number of major accidents.

Recent work reviewing thirty years of "Large Property Damage Losses in the Hydrocarbon-Chemical Industries" published by Marsh provides a number of lessons for this major hazard industry and also shows that there was little new in the events leading to the BP Grangemouth incidents.

The Health and Safety Commission Strategic Plan for 2001-2004 details the initiatives underway by the Health and Safety Executive and challenges all who have an interest in the industry to "revitalise health and safety". For COMAH sites the plan sets the challenge for the industry, its advisors, and the Competent Authority to work together to reduce the number of major accidents by 20% by 2004.

Of a total of nine refineries operated in the UK overall three have had major accidents of sufficient seriousness to require notification to the European Commission in the space of one year. Only good fortune prevented workplace and public casualties from the Grangemouth incidents. Industry must not become complacent about the risks posed by major accident hazards.

BP comprises one of the world's largest group of companies and has committed itself to being a leader in health, safety and environmental management and performance both in the UK and worldwide. Their policy "Getting HSE Right (GHSER)" represents good business practice and corporate governance of risk. We welcome this commitment from BP.

In response to the incidents BP formed a BP Task Force to carry out a "root and branch" audit, the largest ever assembled in the company's history.

The Competent Authority's investigation was complex and wide ranging extending beyond the plant and installations to human factors and safety culture. It was started immediately following the first of the three incidents and continued until legal proceedings were successfully completed.

The recommendations arising from the Competent Authority investigation closely aligned with those of BP's Task Force. BP has committed substantial resources to implement all these recommendations.

Since the incidents occurred there has been a sustained improvement in operational performance across the Complex. Work is continuing to maintain the momentum and is being integrated into the on-going business process.

The Competent Authority is committed to following up the recommendations in this report through our inspections and we will track the remedial action taken to ensure that BP's improved performance is sustained.

We would welcome any feedback from you on the investigation and this report. Email to d.mitchell@hse.gsi.gov.uk.

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EXECUTIVE SUMMARY

Background

The BP Grangemouth Complex (the Complex) is a Major Accident Hazard (MAH) site as defined under the Control of Major Accident Hazard Regulations (COMAH) 1999 which implements the Seveso II Directive in the UK. It is one of the largest of the 950 COMAH sites in the UK.

The Complex is an important centre of UK operations for BP and of major strategic importance for the BP Group.

The COMAH Regulations require a MAPP (Major Accident Prevention Policy) to be produced for the Complex which requires a very high standard of management of major accident hazards to be demonstrated and that the operator will take all measures necessary for the control and prevention of major accidents.

Operators of "top tier" sites are also required to prepare safety reports which identify the systems used by the operators to ensure their processes are operated safely at all times and that adequate steps are taken, so far as is reasonably practicable, to prevent major accidents or in the event of such accidents, to limit the effects on people and the environment.

Such reports for the top tier installations at the Complex (incorporating a MAPP for the Complex) had been prepared and submitted to the Competent Authority for examination and assessment and were under review in May 2000 when the incidents took place.

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

The Competent Authority is required 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. Prior to the series of incidents that occurred in May/June 2000 the Complex was already the subject of significant regulatory activity and the HSE were in discussion with the management at the Complex concerning a number of safety issues which were of concern. The new Complex Director appointed in October 1999 had accepted that the Competent Authority concerns were valid at a meeting in November 1999 and a major management action plan was already underway to improve safety performance on-site prior to the incidents.

During the period between 29th May and 10th June 2000 three incidents occurred at the Complex. These incidents were subsequently investigated, as required under COMAH Regulation 19, by the Competent Authority and by BP in order to determine the underlying root causes of the incidents and to identify any lessons that needed to be learned.

In addition the Complex Director also immediately set up a BP Task Force to undertake a wider review of all operating units and functions across the Complex and commissioned some external independent investigations and assessments. These were aimed at determining the overall effectiveness of current arrangements at the Complex for health, safety and environmental affairs. The BP Task Force was the largest audit team ever assembled for a petrochemical complex and completed 4 man years of work in 8 weeks.

The power distribution failure (29th May), the medium pressure (MP) steam main rupture (7th June) and the Fluidised Catalytic Cracker Unit (FCCU) fire (10th June) each 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. BP were prosecuted on indictment in Falkirk Sheriff Court on 18th January 2002 and pleaded guilty to two charges relating to the FCCU fire and the MP steam main rupture incidents. BP Chemicals Limited were fined £250,000 and BP Oil Grangemouth Refinery Limited were fined £750,000.

This public report into the series of incidents is designed to summarise the incidents and the following investigations carried out by the Competent Authority and by BP. Full details of all the detailed investigative work carried out by the Competent Authority and BP and all the detailed incident specific findings and legal work are not presented here.

The report seeks to reassure the public that a series of thorough and detailed investigations into the causes of the incidents have 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 BP and by the regulators and actions have been taken in order to improve safety performance at the 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 incidents and to ensure the lessons are widely learned.

Description of Each Incident

Power Distribution Failure – 29th May 2000

On 29th May 2000 at 18:07 p.m. all power was lost to No. 1, 5 & 10 electrical sub-stations that supply electrical power to the North Side of the Complex which contains the Oil Refinery, various chemical plants, utility plants and logistics facilities.

As a result, emergency shutdown of the Oil Refinery and the chemical plants on the North Side occurred and the utility plants were also affected due to a loss of power to the main cooling water pump systems. (There was some smoky flaring visible as a result of the emergency shutdown.)

In addition because of the duration of the power failure, a controlled shutdown of some other facilities elsewhere on-site (some chemical plants on the South Side and the Kinneil operations) was also necessary because the supply of steam for the correct operation of the flare system could not be maintained.

No injuries resulted.

MP Steam Main Rupture – 7th June 2000

An 18” medium pressure (MP) steam main located near to the A904 Bo’ness road ruptured at 23:18 p.m. on 7th June 2000 resulting in a significant loss of MP steam directly into the atmosphere. The steam leak damaged fencing immediately adjacent to the ruptured pipework. Debris and steam was blown across the road until the leak was isolated. The leak also caused significant noise (similar to a jet engine) being heard in the Grangemouth area. A member of the public walking the dog 300 metres away sustained rib injuries from tripping over the dog.

There was significant disruption to the steam supply system for the Complex for approximately one hour until the steam leak could be isolated and as a result of the incident the A904 Bo’ness road was closed for public access until 22nd June whilst repairs were carried out.

Fluidised Catalytic Cracker Unit (FCCU) Fire – 10th June 2000

The Fluidised Catalytic Cracker Unit situated on the Oil Refinery had been shut down on 29th May 2000 following the power distribution failure. On 10th June 2000 at approximately 03:20 a.m. during start up procedures which commenced on 9th June there was a significant leak of hydrocarbons from the Fluidised Catalytic Cracker Unit (FCCU or Cat Cracker) creating a vapour cloud which ignited resulting in a serious fire. On and off-site emergency services were mobilised, the BP Incident Management Team (IMT) were called in and the Grangemouth Petrochemicals Complex Major Incident Control Committee (MICC) was convened. The fire was brought under control in approximately 90 minutes and totally extinguished by 10:30 a.m.

During the fire and in the fire-fighting efforts some damage resulted to asbestos cladding surrounding pipework and vessels. Some hydrocarbons in the contaminated firewater run-off were discharged directly into the River Forth.

No injuries occurred to the workers in the vicinity. They followed the emergency response procedures. However, there was the potential for injury to people and greater damage to equipment.

Competent Authority Response

Following the incidents major public and political concern was expressed to the Competent Authority and the Competent Authority was concerned due to the frequency and pattern of the serious incidents, their major accident potential and the apparently deteriorating performance of the Complex.

It was apparent that the main concerns centred on health and safety issues so it was agreed at an early stage with the Scottish Environment Protection Agency (SEPA) that the HSE would take the lead in the investigations with assistance from SEPA as necessary. The FCCU fire in particular was a reportable major accident under the COMAH Regulations and a major accident investigation was therefore required.

The HSE Board called for a "Level 1" Major Accident Investigation to be carried out by Land Division, Hazardous Installations Directorate (HID) in accordance with the then corporate major accident investigation procedures.

A series of incident specific investigations for the power distribution failure, MP steam main rupture and FCCU fire in order to examine the direct and underlying causes were accompanied by a series of further investigations into related issues from the incidents such as the emergency response, the environmental impact and the response to the presence of asbestos during the FCCU fire.

Evidence of the extent of the Competent Authority's concern is provided by the scale of investigations carried out which involved significant HSE Inspector, HSE Specialist Inspector and Health and Safety Laboratory (HSL) resource as well as involvement from SEPA Inspectors. Investigations continued until February 2001, when the "Summary of Findings and Recommendations Report" was sent to BP and the prosecution report was sent to the Procurator Fiscal (the public prosecutor in Scotland).

Consideration was given by the Competent Authority to carrying out a full-scale audit of the entire Complex of the type the HSE had carried out at BNFL Sellafield and UKAEA Dounreay. The Complex Director set up a BP Task Force to carry out an extensive safety and environmental audit of the Complex led by a senior executive from outside the Complex. The setting up of such a major BP Task Force, which involved independent overview from a respected expert, allied with the thoroughness and open sharing of findings with the Competent Authority eliminated the need for a Competent Authority audit running alongside the major accident investigation. The Competent Authority received regular electronic updates of the current status of audits, actions and tracking of progress from BP. BP reported to the HSE daily any issues that were identified during the 6 week period over which the units in the Complex were brought back into operation.

Direct and Underlying Causes

Power Distribution Failure

The loss of electrical power was caused by damage to a 33kV underground electricity feeder cable which eventually resulted in an earth leakage (electricity flowing to earth) from the cable. The damage had been caused to the electrical cable during excavation of a trench for the installation of a new cable, sometime before the distribution failure occurred.

The local circuit breaker on the distribution system failed to operate due to the insertion of small plastic connectors which isolated the relay. Two circuit breakers located elsewhere in the distribution system subsequently tripped to clear the fault resulting in the loss of power supply to significant parts of the Complex.

Subsequent investigations revealed a number of weaknesses in the safety management systems on-site over a period of time which contributed to the succession of events that resulted in the power distribution failure.

MP Steam Main Rupture

The site wide power distribution failure on 29th May 2000 resulted in excess amounts of water (associated with the shutdown of utility supplies) being sent to drain, as well as the unavailability of electrical power to drainage pumps. This led to the flooding of culverts (service tunnels) beneath the A904 Bo'ness road through the site which contained medium pressure (MP) stream distribution lines. During the following investigations to determine whether the flooding had caused any damage to the pipework a steam trap located in a low point in the section of pipework beneath the road in the West Gemec culvert was closed to allow safe access for inspection. The steam trap was subsequently not re-opened and this prevented the removal of condensate (hot water produced by the condensation of steam) from this section of the system. As the liquid condensate level built up in the pipework a quantity of steam (or "steam bubble") was trapped between the hot condensate and closed isolation valves on the southern side of the culvert beneath the road. Eventually collapse of the steam bubble resulted in a phenomenon called "condensation induced water hammer" which led to a gross overpressure and the subsequent catastrophic failure of the pipeline.

Subsequent investigations revealed a number of weaknesses in the safety management systems on-site over a period of time which contributed to the succession of events that resulted in the MP steam main rupture.

Fluidised Catalytic Cracker Unit (FCCU) Fire

The Fluidised Catalytic Cracker Unit had been shutdown as a direct consequence of the power distribution failure. During start-up of the unit on 10th June there was a leak of hydrocarbons which were subsequently ignited and resulted in a fire on the plant.

Investigations revealed that the leak was as a result of failure of a tee-piece connection at the base of the Debutaniser column which then found a source of ignition nearby (probably an uninsulated hot flange).

During the investigations the tee-piece connection which had originally been installed in the 1950s was found to be correctly specified but incorrectly fitted and then covered in lagging. (A set-on tee-piece had been installed whereas a seamless forged weld reducing tee-piece had been specified.) There had been no subsequent amendment to the plant layout drawings to identify the change.

Prior to the mid 1980's modifications had been made to the pipework at the base of the column and a valve removed which resulted in there being inadequate support for the remaining pipework and the tee-piece connection.

Further modifications to the FCCU in 1996/1998 had resulted in the FCCU being increasingly difficult to operate reliably. This had resulted in an increase in the number of start-up/shutdown cycles for the plant and pipework.

Failure of the tee-piece connection pipework was probably caused by a combination of the incorrectly fitted tee-piece connection, the inadequately supported pipework and the cyclic stresses/vibration caused by the increased start-up/shutdown activity on the plant. Eventually this led to "fatigue" failure of the pipework in the vicinity of the welded connection.

Subsequent investigations revealed a number of weaknesses in the safety management systems on-site over a period of time which contributed to the succession of events that resulted in the FCCU fire.

Findings and Recommendations

The investigations carried out by the Competent Authority identified a number of key findings for each of the three incidents. Further investigations into alarm handling, the overall safety management systems at the Complex, the response to the presence of asbestos during the incidents, the overall environmental impact of the incidents and the emergency response during the incidents were also carried out by the Competent Authority and also identified a number of issues. Key recommendations relating specifically to the circumstances surrounding each of the incidents were made and are included in the main text of this report.

The investigations also identified a number of common themes and a number of wider conclusions were drawn as a result of the investigations relating to the health, safety and environmental management system at Grangemouth. These were:

- BP Group Policies set high expectations but these were not consistently achieved because of organisational and cultural reasons;
- BP Group and Complex Management did not detect and intervene early enough on deteriorating performance;
- BP failed to achieve the operational control and maintenance of process and systems required by law;
- The BP Task Force findings and recommendations properly addressed the way forward to ensure safe and reliable operations at the Complex.

Recommendations were made by the Competent Authority for the BP Grangemouth Complex and for BP Group and these are included in the main text of the report.

Key Lessons for Industry

The investigations into the circumstances surrounding the three incidents at the Complex have resulted in a number of issues being identified from which BP and the HSE consider lessons can be learned. These lessons are of relevance to all companies who are regulated under the Control of Major Accident Hazards (COMAH) Regulations 1999 for major hazard installations and also to a wider audience throughout industry.

These lessons should be addressed by other operators, and management systems put in place to prevent any major accidents (including a repetition of any of the three incidents reported here) from occurring.

The HSE consider that these lessons will assist the major hazards industry in reducing the probability of major accident incidents occurring and in reducing the severity of any events which do subsequently occur. This should help in achieving a significant reduction in the number of reportable incidents. The “Revitalising Health and Safety” strategy document from the HSE sets a goal to “prevent major incidents with catastrophic consequences occurring in high-hazard industries” and sets a target of “a 20% reduction in RIDDOR dangerous occurrences and COMAH Regulation 21 major accidents (accidents of sufficient seriousness to require notification to the European Commission)” by 2004. These lessons, if learned, should help to achieve this target which has been set as an industry objective and signed up to by many of the leading companies in the major hazard industries.

Key Lessons for Major Accident Hazard Sites

A summary of the key lessons for industry from the series of incidents at Grangemouth is given below. Full detail can be found in Section 9 and it is recommended that these lessons are read in full.

Lesson 1 - Major accident hazards should be actively managed to allow control and reduction of risks. Control of major accident hazards requires a specific focus on process safety management over and above conventional safety management.

Lesson 2 - Companies should develop key performance indicators (KPI's) for major hazards and ensure process safety performance is monitored and reported against these parameters.

Lesson 3 - Disruption to utility supply systems (steam, electricity etc.) on a major hazard site can cause significant problems and have the potential to result in a major accident.

Wider Messages for Industry

In addition the Competent Authority considers that it is important to re-iterate some important messages for industry at this stage of the implementation of the "Revitalising Health and Safety Strategy". Full detail can be found in Section 10 and it is recommended that these messages are read in full.

Message 1 - Major hazard industries should ensure that the knowledge available from previous incidents both within their own organisation and externally are incorporated into current safety management systems.

Message 2 - Operators should give increased focus to major accident prevention into order to ensure serious business risk is controlled and to ensure effective corporate governance.

Message 3 - The COMAH safety regime is a "living process" and should be used as a management tool to assist in process safety management

1. Summary Description of the BP Grangemouth Complex

1.1 Description of the Complex

The BP Grangemouth Complex (the "Complex") is located on the south bank of the Firth of Forth approximately 20 miles to the west of Edinburgh and close to the eastern boundary of the town of Grangemouth.

Access by road to the Complex is from the M9, which runs close to the south of the Complex, and via a network of local roads.

The Complex is divided into a North and South Side by the A904 Bo'ness road which is a public access road that runs west-east through the middle of the Complex. Pipework carrying products and utilities runs beneath the road in several places to connect facilities on the North Side to those on the South Side. For example, steam generated in the boiler plant which is situated on the North Side is distributed to plants on the South Side, and hot condensate (condensed steam) collected on the South Side is returned to the boiler plant. The North and South Sides are also divided by the River Avon which enters the Firth of Forth.

Jetty facilities for ships for multi-product loading/unloading are located within the Port of Grangemouth to the north of the Complex and there are also extensive storage tank facilities available on-site.

The Complex has been in operation since 1924 and continues to be developed to the present day. Throughout the 1990's BP invested in new plant at Grangemouth as well as upgrading existing equipment.

Around 2,000 people are currently employed on the 700 hectare site and production is carried out continuously 24 hours a day, 365 days a year. In addition approximately 11,000 people are employed in the Central Belt of Scotland in activities associated with the Complex.

The Complex handles a wide range of chemicals that are hazardous to human health (toxic, explosive, fire hazard etc) and dangerous to the environment if released from containment. Special precautions have to be taken for the range of hazardous properties that are encountered. The design of the process plant and equipment and the management control systems on the Complex are therefore designed to minimise the safety and environmental risk (that is the potential for the hazards that are present on-site to be realised).

The management systems in place include on-site and off-site emergency response plans which have been developed in consultation with the Local Authority, the emergency services, the police and the regulatory authorities in order to respond to the major hazards that have been identified. An on-site Incident Management Team (IMT) and an off-site Grangemouth Petrochemical Complex Major Incident Control Committee (MICC) can be mobilised in the event of a major incident on-site which may have off-site consequences.

1.2 Overview of the Management Structure

The Complex is unique within the BP Group worldwide in that it is the only site which has all three of BP's major business streams – Exploration, Oil, and Chemicals - together on one site and integrated into a single interdependent operation.

Each business stream consists of a number of processing facilities (Operational Units) which are supported by a large utilities and distribution infrastructure including a new Combined Heat and Power (CHP) plant and a logistics operation (warehousing, packaging and distribution) operated by third parties with specific expertise in these areas. These logistics facilities are located predominantly on the South Side.

Historically the three business streams on-site were operated as independent businesses using a range of Complex wide support services. The management control and coordination problems associated with this structure were recognised and in April 2000 the responsibility for all three operations on-site were brought together under a single management structure for the entire Complex. A Grangemouth Leadership Team (GLT) was set up with overall responsibility for all operations on-site and led by a single Complex Director.

The purpose of this re-alignment between the individual businesses and the Complex - wide support services was to ensure that Grangemouth could operate as a single Complex with common values and processes and common approaches and standards. The overall aims of this re-alignment were to increase profitability, reliability and health, safety and environmental performance in order to realise the potential of this unique Complex.

In addition to those employed in the main business streams others are employed in a number of Central Resource Groups on-site which include Health, Safety and Environment (HS&E), Human Resources (HR), Operations Support Group (OSG) and Shift Management.

The HS&E department coordinates all health, safety and environmental activities on-site. It also coordinates the approach taken on-site to fulfil the stated aims of the BP Group in relation to these areas.

BP Group Health, Safety and Environmental Policy and Expectations are translated into local working arrangements, policies and procedures for the Complex.

Further detail on health, safety and the environment at the Complex can be obtained from the BP website (www.bp.com).

1.3 Overview of the Processes and Products at the Complex

Three business streams are present on the Complex.

Exploration Business Stream

This business includes the Forties Pipeline System (FPS) which is routed into the Oil & Gas Processing complex at the Kerse of Kinneil. This is situated on the northern side of the A904 Bo'ness road to the east of the river inlet. The Exploration Business Stream provides the raw materials for use in the Oil Refinery and the petrochemical plants. The oil and gas arriving at Kinneil go through a two-stage process of heating and separation to produce a stabilised crude oil and raw gas streams. The crude oil is then either exported directly from the Complex or supplied to the Oil Refinery.

Oil Business Stream

This business consists of the Oil Refinery which is located in the middle of the North Side. It processes stabilised crude oil and has an annual capacity of around ten million tonnes. At the Oil Refinery several processes occur:

- Distillation which is the process of product separation by boiling;
- Conversion and upgrading which are processes whereby low value products are turned into more saleable products;
- Purification which is the process of removing contaminants before final blending and shipping to market.

The major products from the Oil Refinery include liquefied petroleum gas (LPG), petrol, diesel, jet fuel, kerosene, fuel oil and heating oil. Naphtha is produced and fed into the petrochemical processing facilities.

Chemicals Business Stream

This business consists of a number of petrochemical plants which are located on both the North and South Sides. The petrochemical plants use gas separated from the oil as their main feedstock to produce petrochemicals. Initially by a process known as "cracking" the mixed raw gases fed from the Kinneil operations (a complex mixture of large and small gas molecules) are broken down into smaller molecules which are then used as feedstocks for a range of petrochemical plants. These plants produce a range of products including ethylene, propylene, benzene, ethanol, and polymers such as linear low density polyethylene and polypropylene. These chemicals are sold as basic raw materials for a number of further industries including textiles and pharmaceuticals.

Further detail on the facilities at the Complex can be obtained from the BP website at www.bp.com.

2. Scope of the Competent Authority Investigation

2.1 Organisation

Responsibility for regulation of the Complex in relation to health, safety and environmental affairs falls to the Competent Authority which in the case of Grangemouth comprises the HSE and SEPA, both of which have a long history of regulatory involvement at the Complex. Further details on the roles and functions of these regulatory authorities can be found at www.hse.gov.uk and www.sepa.org.uk respectively. See Appendix 2 for further details of the involvement of the HSE and SEPA on-site prior to the series of incidents. For the HSE, inspectors from Land Division, Hazardous Installations Directorate (HID) are responsible for the regulation of the Complex.

Immediately following each of the three incidents an investigation team was set up by the Competent Authority in line with the HID Major Incident Investigation Procedure of the HSE. As each incident had mainly safety implications it was agreed between the HSE and SEPA that the HSE would lead the investigations (this is in line with the Memorandum of Understanding between the different organisations).

Formal roles were allocated to an Investigation Manager and Investigation Team Leader.

The Investigation Manager was an HSE Inspector from outside of the HSE team routinely involved in regulating the Complex and his role was:

- To provide an overview of the investigation and independence from the HID Unit which normally dealt with the Complex;
- To keep the Health and Safety Executive Board informed of progress;
- To investigate the prior involvement of HID Inspectors at the Complex to see if HID needed to learn lessons from its regulatory approach.

The Investigation Team Leader was the HSE Principal Inspector who routinely manages the inspection team dealing with the Complex. He was also the HSE Inspector with responsibility for ensuring consistency of regulatory approach to all BP sites in the UK (BP Lead Unit Coordinating Inspector).

In view of the short period of time between the three incidents the Health and Safety Executive Board decided that a major incident investigation would look at the three incidents together and the findings would be made public in line with the HSE Major Incident Investigation Policy. The purpose of this public report is to fulfil that commitment and also:

- To inform the public and industry;
- To re-assure the public;
- To shift the approach of industry in relation to the control of major hazards.

The purpose of the Competent Authority investigations was to determine the underlying root causes of the incidents and identify any lessons that needed to be learned so that BP could then take corrective actions to prevent recurrences. The Competent Authority investigations initially focused on the incidents. Then where appropriate, and where wider issues were identified, the investigation was broadened to encompass these as necessary. For example, alarm handling was identified as a problem in relation to two of the incidents and as a consequence a specific investigation into alarm handling on the Complex was carried out by the Human Factors team from the HSE.

2.2 Legislation

The Complex is subject to a wide range of health, safety and environmental legislation. The safety legislation covers both "conventional" safety (slips, trips and falls etc.) and "process safety" with the HSE being the enforcing authority for all health and safety legislation at the Complex.

"Process safety" legislation, such as the COMAH Regulations, is aimed specifically at those industries identified as having a major accident potential which could result in significant on-site and off-site effects to employees, members of the public and the wider environment.

In terms of environmental legislation BP Grangemouth is subject to the Environmental Protection Act 1990 and various Integrated Pollution Control (IPC) Regulations made under this Act. SEPA is the enforcing authority for environmental legislation at the Complex.

The three incidents were investigated by the Competent Authority under duties contained within the following legislation:

- The power distribution failure was investigated with respect to the Health & Safety at Work etc. Act 1974 (HSWA) (Section 20) and the Construction Design and Management Regulations 1994;
- The MP steam main rupture was investigated under the HSWA 1974 and the Pressure Systems Safety Regulations 2000;
- The Fluidised Catalytic Cracker Unit fire was investigated as a major accident as defined under the COMAH Regulations 1999 (Regulation 19).

For further information on the enforcement strategy for the Complex see Appendix 2.

The HSE considered whether the power distribution failure and the MP steam main rupture should also be considered as a major accident under COMAH. However it was recognised that other regulations were more appropriate to these incidents and were the mainstay of those investigations.

Another major role of the HSE is to enforce relevant health and safety statutory provisions and consider whether evidence exists of possible contraventions of those statutory provisions. The powers of the HSE derive from HSWA Section 20 and the criminal offences are derived from Sections 33, 36 and 37.

The HSC Enforcement Policy statement forms the basis for the enforcement decisions of the HSE. SEPA has a similar policy. (See Appendix 2 for more detail). In Scotland crime is prosecuted by the Procurator Fiscal as public prosecutor. Shortly after the series of incidents the Procurator Fiscal visited the Complex.

The HSE and SEPA are amongst a number of bodies who report alleged offences to the Procurator Fiscal. Health and safety law investigations involve examination of physical evidence, documentary evidence, direct witness statements and expert evidence of expert opinion. The legal test in criminal law is proof beyond reasonable doubt. In addition to prosecution, the HSE has powers to issue enforcement notices (Improvement or Prohibition) and the Competent Authority has a prohibition duty under COMAH Regulation 18 if serious deficiencies are evident involving the risk of a major accident. Failure to comply with an enforcement notice is a criminal offence.

2.3 Scope of the Investigation

Standard HSE investigation techniques were used in the investigations. These included analysis of the events that took place and the causes (events and causal factors analysis). The investigation findings were compared against the following five themes.

Legislation

Whether statutory legislative requirements (e.g. Schedule 2 of COMAH re safety management systems) had been met.

Best Practice/Guidance

Whether best practice/internal guidance had been followed. For example whether the approach taken to the management of health and safety on-site was consistent with the POPMAR model approach specified in the HSE publication HSG65 – "Successful Health and Safety Management" and whether the BP Grangemouth on-site rules/procedures and guidelines had been followed.

BP Grangemouth Safety Reports

Whether the claims made in the relevant COMAH/CIMAH safety report where appropriate (e.g. COMAH safety report for the FCCU) could be supported by the findings of the investigations.

BP Group Objectives

Whether BP's Group Health, Safety and Environmental Policy and Expectations were being met.

Previous Incidents

Whether there was a history of previous incidents of a similar nature at BP Grangemouth or within the wider BP organisation from which lessons could have been learned and actions taken.

In addition consideration was given to whether the findings and recommendations outlined in the HSE reports of other major accidents (such as those at Texaco and Associated Octel) and other published information had been noted by BP and implemented where appropriate.

2.4 Competent Authority Investigations

Due to the number of incidents, the complexity of the investigation and the scale of the Complex it was necessary initially to sub-divide the overall investigation into the three incidents into a number of separate investigations each led by a separate Investigation Leader. Subsequently a number of common issues and themes from the initial investigations into the three incidents were identified and a series of additional investigations were also carried out.

HSE Specialist Inspectors in a range of disciplines (electrical, mechanical etc.) from a variety of different locations joined the investigation teams. Investigations carried out by SEPA concentrated on the emergency response and the environmental impact of the MP steam main rupture and the FCCU fire in particular.

Individual investigations were carried out covering the following areas shown below.

Incident Specific Investigations

- Power Distribution Failure
- MP Steam Main Rupture
- FCCU Fire – see Regulation 18 duty below.

Further Investigations

- Asbestos
- Alarm Handling
- Emergency Response
- Environmental Impact
- Health, Safety and Environmental Management Systems, Safety Culture and Human Factors

During the course of the investigations members of the investigation teams:

- Carried out detailed examinations;
- Made photographic records of the plants involved in the incidents;
- Took possession of damaged equipment for further detailed examination at the HSE's Health and Safety Laboratory (HSL);

- Interviewed witnesses;
- Interviewed management and operators;
- Examined documents relevant to the plants/processes and to the company's management systems.

The Company, its employees and their Trade Union representatives provided full cooperation throughout the investigations and there was close liaison between the BP incident investigation teams and the Competent Authority incident investigation teams throughout the investigations.

Regulation 18 Duty

In the event of a Major Accident COMAH Regulation 18 requires the Competent Authority to prohibit continued operation or restart if there is evidence of a serious deficiency. In the case of the FCCU fire there was clear evidence to this effect. However a prohibition notice was not issued as many of the plants were already not operating owing to the previous power loss and MP steam incidents. In addition the response of BP was to instigate a BP Task Force to carry out a site wide review of all operations to ensure continued safe operation of plants that were currently operating and that plants that were currently shutdown were not restarted until they had undergone a full safety review.

BP immediately carried out an audit of each facility to identify concerns and tracked progress against the identified findings and recommendations. The Competent Authority received regular electronic updates of the current status of audits, actions and tracking of progress from BP and BP reported to the HSE daily for a 6 week period any issues that were identified. These actions on the part of BP addressed the concerns of the Competent Authority in relation to the restart and continued safe operation of plants under COMAH Regulation 18 and accordingly a formal prohibition notice was not considered necessary.

In the case of the FCCU the dangerous substance inventory had burned off or had been removed, the FCCU was badly damaged and could not be restarted, and BP had given a written undertaking that the FCCU would not be restarted until the Competent Authority had agreed BP proposals for increased safety measures. As a result the Competent Authority concluded that a COMAH prohibition notice under the regulation 18 duty was not required to ensure safety.

BP's open and constructive dialogue with the Competent Authority was a welcome feature of the investigation and BP shared findings with the Competent Authority and sought Competent Authority views throughout the investigations.

2.5 Actions and Recommendations

The HSE and SEPA held discussions throughout the investigations and jointly prepared a set of Competent Authority actions and recommendations which are presented in this report.

2.6 BP Investigations and Responses

The Complex Director commissioned independent reports into the root causes of the incidents that occurred on-site. In addition, the Complex Director commissioned a BP Task Force to carry out a "root and branch" review of all operations across the whole Complex. BP identified a number of specific actions arising from the BP Task Force review and agreed these with the HSE. All these BP Task Force actions have now been completed and subjected to internal and independent BP review.

The decision of BP to carry out an audit of this type was welcomed as a vigorous and positive response demonstrating that BP was prepared to identify the actions needed to improve performance and respond to public and regulator concerns. The BP Task Force audit approach eliminated the need for an independent Competent Authority audit of the entire Complex.

BP has now set further testing targets for continuous improvement in the areas of health, safety and the environment.

3. The Incidents

In the space of a fortnight covering the period 29th May to 10th June 2000 three separate incidents occurred on-site. Each of the individual incidents is considered in further detail below.

3.1 Power Distribution Failure – 29th May 2000

3.1.1 Background

For a general introduction to the basic design of power distribution systems and the power distribution system at the Complex see Appendix 1.

Construction of a new facility (known as E4 – Ethanol plant) began early in 2000. As part of the project to supply electrical power to the E4 facility it was necessary to dig a 700m long trench for the installation of new high voltage (11kV) cables between electrical sub-station No.5 and the E4 plant. At an early stage existing underground services, including the 33kV feeder which ran between electrical sub-stations No.1 and No.5, were identified as being in the vicinity of the new trench which ran from the Oil Refinery area into the Chemicals area of the Complex.

3.1.2 Organisation

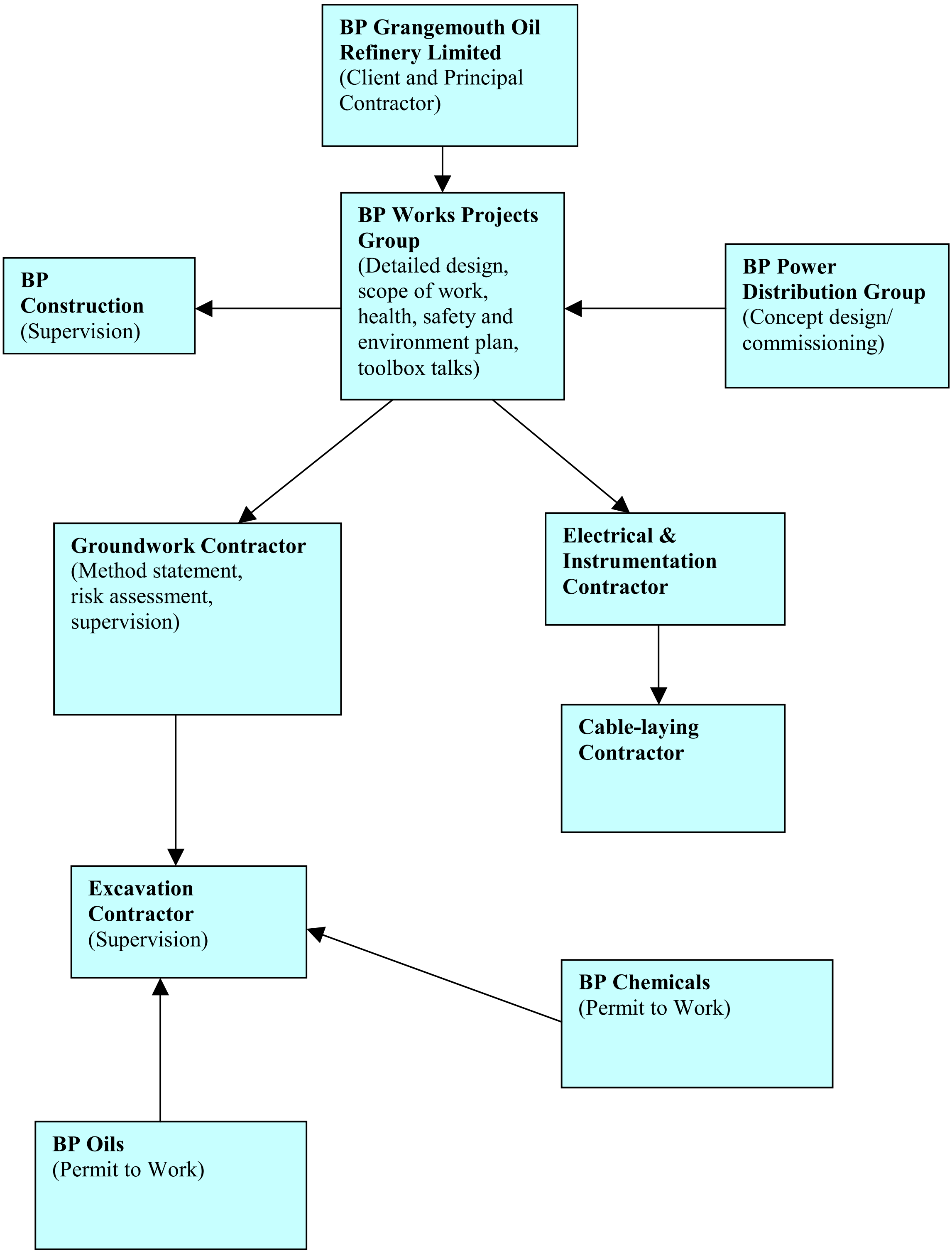
The overall project was organised and managed by BP Works Projects Group. Personnel from the BP Power Distribution Group were also involved in the design concept for the provision of the 11kV electrical power supply to service the E4 plant and were to be involved later at the commissioning stage. They were however not actively involved at the detailed design stage and a member of the BP Works Project Group produced the scope of work and the health, safety and environment plan for the project.

BP Oil Grangemouth Refinery Limited was the client for the works and also the principal contractor. They engaged a term contractor, who had been present on-site for many years, as the main sub-contractor for the groundwork. The groundwork contractor in turn sub-contracted the actual excavation work to an excavation contractor who supplied the manpower with the groundwork contractor responsible for the supply of other items including tools, facilities, plans and a level of supervision. The groundwork contractor carried out a risk assessment and produced a method statement for the excavation work to be carried out.

BP Oil Grangemouth Refinery Limited also engaged a main electrical sub-contractor for the electrical & instrumentation work to be carried out. The electrical sub-contractor in turn sub-contracted the laying of the cable in the excavated trench to a cable-laying contractor.

Supervision of the trench work was provided by representatives from the excavation contractor, the groundwork contractor and by a supervisor from the BP Construction

Group. See below for a schematic showing the relationship between the different groups.



Due to the route of the trench, which ran across areas controlled by different business streams (Oils and Chemicals) the involvement of operatives from the different areas in the day to day operation of the Complex permit-to-work systems was required. Since the excavation and cable-laying activities were carried out in areas under the control of the Oils and Chemicals businesses, authorisation from these business areas for the work to be carried out in their areas and the safety requirements specific to each of these individual areas had to be sought on a daily basis by the excavation teams.

Prior to the start of the excavation, operatives from the excavation contractor were given a "toolbox talk" which identified the correct tools and their manner of use for the excavation work to be carried out. Instructions were given to dig down to 900mm or until cable tiles covering existing cables were discovered. It was permitted to break the ground surface to a depth of 300mm using a compressed air power tool known as a clayspade and then to excavate the remaining depth only using special non-ferrous tools.

3.1.3 Events leading up to the Incident

Prior to the start of the excavation of the trench representatives from the groundwork contractor, the excavation contractor and BP walked the length of the proposed trench on 17th April in order to identify any difficulties/obstacles likely to be encountered during the excavation and to mark the route. The cable route selected required a trench to be dug between two groups of cables, and above a third group of cables. The area was scanned using a detector prior to commencement of the excavation work.

Digging for the trench commenced on 18th April with the intention of excavating a trench 600mm wide and 900mm deep or until the cable tiles for the 33kV cable were reached. Several squads excavated the trench simultaneously along the length and the work was carried out over a three week period and completed on 5th May.

Despite the earlier instructions from the "toolbox talk" on the 20th April a BP employee observed operatives from the excavation contractor using a clayspade to the sides of the trench at a depth greater than 300mm. Another "toolbox talk" was subsequently given to reinforce the message of safe working practice.

The 11kV cable was due to be installed in the trench on 8th May but was delayed. Following further inspections some additional trench work was carried out by the excavation contractor (8/9th May and 18/19th May).

On the 25th May a cable-laying operative from the cable-laying contractor observed a damaged tile and cable while laying rollers in the trench in preparation for laying the cable which had been rescheduled for 30th May. At this stage however he did not report the damaged cable in the belief that the cable was dead and it had already been reported.

Supervision during the excavation period was limited. The supervisor from the excavation contractor provided daily but not continuous site supervision since he was required to organise and supervise permits for several teams in addition to this trench work. Similarly the supervisor from the groundwork contractor and the BP Construction supervisor had other commitments and did not provide continuous supervision. In particular the BP Construction supervisor first visited the site of the excavation on 20th April since he had not been made aware by BP Works Projects Group that the excavation work had started.

3.1.4 Details of the Incident

A serious loss of electrical power occurred at 18:07 p.m. on 29th May when an earth fault occurred on the 33kV feeder cable that ran underground from No.1 to No.5 electrical sub-stations. The occurrence of the fault was recorded by Scottish Power who reported a fault current in the order of 3000 amps for just over one second.

The fault should have been detected by the 33kV circuit breaker in No.1 electrical sub-station. If this had happened supplies would have been maintained to No.5 electrical sub-station through two other feeders and power supply to the Oil Refinery area would have been maintained. However the 33kV circuit breaker had previously been disabled and as a result the fault was cleared by the two 33kV circuit breakers in No.2 switchboard that fed No.1 switchboard. No.2 switchboard supplied a wider area and as a result mains power was lost to No.1, No.5 and No.10 sub-stations. This had a major impact on the operations of the Complex.

Figure 1

Power Distribution Grid

3.1.5. Emergency Response

The power failure to the North Side resulted in a controlled emergency shutdown of the Oil Refinery and other facilities on the North Side. This included the power station (although some of the boilers were maintained on line), the North Side utilities, chemical plants and the product distribution centre. Diesel equipment provided back-up electrical supplies in many areas in order to ensure that power for essential users was maintained.

Initially Kinneil (FPS) operations and the South Side chemical operations (including the G4 Ethylene Cracker) remained operational.

Eventually however cooling water and feedstocks (naphtha) could not be provided from the North Side and the flare steam integrity could not be fully maintained. This resulted in a controlled shutdown of G4 and the Kinneil operations. There was also some concern in the operation of other critical areas such as the LPG spheres and the flare drums.

The disruption to the electrical supplies resulted in some smoky flaring from the North Side and black emissions from the power station for a period of time.

No injuries to personnel and no significant damage to plant or equipment resulted from the power loss. The on-site Incident Management Team (IMT) were mobilised and took charge of the immediate response within 10 minutes of the power failure. The Major Incident Control Committee (MICC) was also initiated in response to the power failure.

There were some minor leaks that were managed and controlled but no environmental excursions and there was little off-site impact as a result of the power distribution failure.

Provision of safety assurance for the Complex restart was provided by putting in place the following:

- The BP investigation team determined the actions that had to occur before further power circuits were re-established;
- The order of plant re-starts was agreed by the recovery planning team for the Complex with final permission given by the shift site manager.

Prior to re-establishment of any power circuits and restart of plants, appropriate risk assessments were requested by the investigation team and completed by the various operating teams.

No.5 feeder was repaired and the operation of the Oil Refinery and the electric load carefully managed whilst on two feeder operation only.

The process followed for the restart of the Complex was closely monitored by the HSE and the power was restored to all plants on the Complex by 2nd June.

3.1.6. Competent Authority Investigation

Although the incident caused no injuries or significant damage to equipment or plants the scale was such that it was notified to the HSE and SEPA.

As a result the HSE set up an investigation team within 24 hours to investigate the causes of the incident. BP independently carried out an investigation following their major incident investigation guidelines and cooperated fully with the HSE investigation. The BP investigation made a number of key proposals for corrective actions as a result of the incident investigation

The HSE Inspectors interviewed a range of personnel from BP, the groundwork contractor, the excavation contractor, the electrical and instrumentation contractor, and the cable-laying contractor in the course of their investigations and examined a wide range of project related documentation including risk assessments, method statements, drawings, permits-to-work and maintenance records.

3.1.7. Key Findings – Cause and Effects

1. The HSE concluded that the power loss which occurred on the 29th May 2000 was caused by an earth fault on a 33kV underground power cable between No.1 and No.5 sub-station and the failure of the 33kV circuit breaker in No.1 sub-station to trip and clear the fault.

   The source of the earth failure was not immediately apparent. The cable which failed was situated in the bottom part of the excavated trench, almost in the side wall of the trench and only protruded from its protective cable tile over a short length.

   Figure 2
   Trench Diagram

   Figure 3
   Trench Photo

   Figure 4
   Trench Photo

2. The fault was ultimately cleared by two 33kV circuit breakers in No.2 electrical sub-station resulting in power loss to No.1, No.5 and No.10 electrical sub-stations.

3. The immediate cause of the power distribution failure was a combination of two direct causes:

   The Earth Fault

   Forensic evidence indicated that the earth fault was caused by physical damage to the cable from an air powered tool known as a clayspade. The clayspade equipment was operated by a number of different personnel during the construction of the trench and the cable was protected over the majority of its length, except in the location where the damage occurred, by the protective cable tile system. All personnel were aware of the responsibility to report any problems during the construction of the trench but none were reported. As a result of the damage the integrity of the lead sheath on the cable was breached, allowing water ingress, weakening of the cable's insulation and the resultant earth fault.

   Figure 5
   Damage Photo

   Figure 6
   Cable Photo

   Figure 7
   Clayspade Photo

   Despite interviewing all the personnel who worked in the trench and who operated the clayspade there was a lack of corroborative evidence for the HSE to prove beyond reasonable doubt who struck it and when. However the investigation concluded that the cable was most likely damaged during digging of an adjacent trench for installation of a new 11kV cable to be run from the No.5 electrical sub-station to a new facility on the Chemicals area of the Complex on or around the 18th April.

Circuit Breaker Failure

The cable fault described above should have caused the 33kV circuit breaker in No.1 electrical sub-station to operate and clear the fault. However it failed to operate because its earth protection relay had been disabled by two small sections of plastic (cable ties with the ends cut-off) inserted in the connections between the relay and its current transformer. This meant that the earth fault protection relay was disabled and would not operate.

Figure 8

Panel Photo

Figure 9

Plastic Panel Inserts

The HSE identified no evidence to suggest that the relay was disabled for malicious intent or in conjunction with the failure of the 33kV feeder cable. It is possible that it occurred during performance testing of the relays. Work activity was recorded as having taken place in 1999, 1993 and in the 1980s. Certainly in the 1980s there is evidence to suggest that the appropriate connector block was not available for the relay tests and that temporary plastic inserts would have allowed the testing to take place. If this was the case then they should have been removed after testing since the consequence of leaving them in-situ was to disable the functionality of the trip system. It is however difficult to envisage how the plastic inserts would not have been noticed during the secondary injection testing of the relay which was undertaken in 1993.

3.1.8 Findings of the Competent Authority Investigation

The findings of the Competent Authority investigation in relation to the five themes identified earlier are given below.

Legislative Compliance

The project to install the new 11kV feeder cable was a CDM Project and as such the requirements of the CDM Regulations should have been met in addition to the requirements of the Management of Health and Safety at Work Regulations. Due to the fact that electrical systems were involved the investigation also considered the requirements of the Electricity at Work Regulations.

A number of deficiencies were identified but due to the lack of positive, corroborative evidence linking identified persons to the actions which ultimately caused the cable failure no legal proceedings were initiated against any of the parties involved for failing in their legal duties. This was discussed with the Procurator Fiscal. The criminal law standard of evidence would have required evidence to prove beyond reasonable doubt who struck the cable and when and this was not available.

The HSE took enforcement action in this case by means of a formal letter to BP and the contractors involved.

Best Practice/Guidance

Comparison of the organisational set-up with the "POPMAR" safety management system model in the HSE Booklet HSG65 "Successful Health and Safety Management" suggested major weaknesses in organising (in particular communication, control and competency), in planning and implementing and in monitoring. Underlying problems were identified in the following areas:

- Systems of work;
- The clarity and adequacy of instructions;
- The adequacy of supervision;
- Operatives behaviour;
- BP planning processes;
- Risk assessments carried out by the contractors;
- Details in the method statements;
- Inconsistent and different methods of application of the permit-to-work (PTW) system;
- Procedures, systems of work and test equipment for the testing of the 33kV circuit breaker;
- Implementation of maintenance policies.

Specific examples include:

- There was no written evidence of a specific risk assessment being carried out regarding the choice of cable route and the risk of installation of the E4 11kV electrical supply cable on existing high voltage cables;
- Lack of organisational resource meant that power distribution personnel were not actively involved in the planning and execution of the E4 11kV electrical supply project although it had the potential to impact on the power distribution system for the Complex;
- Although the contractors assessed the risk to operatives of working in close proximity to high voltage cables it appears that there was a failure to implement acceptable control measures, including adequate supervision and method of work;
- Inconsistent application of standards existed between the Oils and Chemicals business streams;
- BP failed to adequately resource the maintenance of relays by manual testing every two years and failed to have adequate written procedures for carrying out secondary injection testing.

BP Grangemouth Safety Reports

The number of failures and underlying causes demonstrated a failure in BP's control of contractors and in the management of change in this incident.

BP Group Objectives

BP failed to fully meet its own high performance expectations in "Getting HSE Right (GHSER)".

Previous Incidents

A previous power failure incident occurred on-site on 27th July 1999. A 33kV interconnector tripped due to a commissioning error leading to a site wide loss of electricity supply. This resulted in a loss of steam, plant shutdowns and significant flaring. On this occasion the plant emergency shutdown systems and the uninterruptible power supply (UPS) on the whole operated effectively preventing any further consequences.

By May 2000 at the time of the power distribution failure 17 out of 27 recommendations following the earlier incident had been completed, one had been superseded and one was not accepted. The remaining eight were scheduled to be completed by the end of 2000.

On a wider front a national study involving 100 chemical companies was previously carried out by the HSE during 1992/93 to identify the extent of the current awareness of power loss/surge issues at chemical companies and whether specific risk assessments had been carried out, back-up systems installed and maintenance issues identified. The study was carried out following a major power loss at a chemical complex on Humberside.

The previous study identified that although there was a general awareness, the perception of power loss/surge incidents amongst industry at that time was that they were mainly related to quality, production and profit issues rather than having safety implications. In addition at that time although there was considerable evidence that power loss/surge incidents were not uncommon there was no evidence of a major problem having occurred as a result.

Recent power loss incidents (including the incident at BP) have highlighted that power loss incidents may result in significant safety risks.

Certainly in view of the requirements of the COMAH legislation in relation to the control of major accident hazards it is important that other COMAH sites review power loss/surge issues for their own sites. (The COMAH Safety Report Assessment Manual SRAM Criterion 5.2.1.4 covers the issue of security of power supply.)

3.1.9. Competent Authority Actions and Recommendations

The following recommendations were made by the Competent Authority after the incident investigation into the power distribution failure.

1. Planning of Electrical Work

BP should review the system for the planning and execution of future electrical supply work to ensure:

- Adequate competent staff resource;
- Adequate risk assessment to consider the impact of the work on the electrical supply and power distribution system of the Complex as a relevant COMAH issue;
- Contractors are properly controlled.

The findings of the HSE were consistent with those of the BP Task Force and were accepted by BP. A single complex wide power group was established immediately after the power distribution failure, with appropriate competencies and resource. This group forms part of the Power Station and Utilities Delivery Team which itself is part of the Forties Pipeline System and Infrastructure (FPSI) Availability Team. The power group has a clear remit to deliver fully available power systems across the whole Complex, in line with the FPSI overall goal to deliver 100% availability of site infrastructure systems.

2. Standards and Procedures

BP should review standards and procedures for safe location of and digging around high voltage cables and standardise safe working procedures across the Complex.

The findings of the HSE were consistent with those of the BP Task Force and were accepted by BP. Work procedures and practices have been reviewed and revised to ensure appropriate assessments are in place prior to excavations relating to or in the vicinity of high voltage cables.

3. Maintenance of Relays

BP should adequately resource the maintenance of relays by manual testing every two years, and keep adequate records. BP should also review its written procedures for secondary injection testing to ensure a safe system of work is followed.

The findings of the HSE were consistent with those of the BP Task Force and were accepted by BP. Electrical inspection and test procedures have been reviewed and revised for use across the Complex. The Power Station and Utilities Team is responsible for the implementation of these procedures.

3.2 MP Steam Main Rupture – 7th June 2000

3.2.1 Background

For a general introduction into the basic design of steam supply systems and on the layout of the steam system at the Complex relevant to this incident see Appendix 1.

Steam is generated in the power station situated on the North Side of the Complex and is distributed to steam users on the South Side of the Complex through steam distribution mains that run through culverts (service tunnels) that go beneath the A904 Bo'ness road that runs through the middle of the Complex.

A number of different steam mains and routes are available in order to give flexibility and to allow sections of the pipework to be isolated for maintenance. Many isolation valves, pressure relief safety devices and steam traps are located throughout the distribution system in order to ensure the correct routing and to maintain the correct conditions within the steam distribution system (for example the correct pressure, removal of hot liquid condensate etc.).

The mains located in the culverts represent a low point in the distribution system and rainfall collected in the culverts must be pumped out to ensure that the culverts do not flood and external damage to the pipework/lagging etc. does not occur.

Figure 10

Steam Distribution System

For a period of at least three years preceding May 1999 the pipework through the West Gemec culvert was not being used and had been isolated by closing a number of valves on both the northern and southern sides of Bo'ness road. The steam supply to the South Side was via the East Gemec culvert for this period.

In May 1999 as part of the tie-in between the existing power station (northern side of Bo'ness road) and the proposed new Combined Heat and Power plant located on the South Side it was decided to re-utilise an existing medium pressure steam line which ran through the West Gemec culvert.

As a new project it required the preparation of a Plant Modification Proposal (PMP) which required consideration to be given to the safety issues associated with the proposed modification.

In order to test the line one of the valves on the North Side was opened and steam was used to test the line overnight by holding the line at the MP steam working pressure of 200 psig. Following completion of the tests some minor repair work was carried out including renewal of a steam trap and drain line. The line was then re-tested to check the modifications before being isolated again on the North Side in June 1999. The line then remained isolated until the following March 2000.

3.2.2 Events leading up to the Incident

In order to connect the new Combined Heat and Power plant (CHP) and the Above Ground Gas Installation (AGI) units into the South Side steam supply main a new connection (300mm/12") was installed and new valving arrangements were added on the South Side in the vicinity of the West Gemec culvert. Commissioning of the new line started on 22nd March and this involved many operations of the valves in the area around the culverts in order to test the new system. The valve isolating the MP steam supply through the West Gemec culvert on the North Side (V1) was then opened. During testing some of the isolation valves on the South Side (V2/V3) were also routinely opened for testing which effectively brought the MP steam line through the West Gemec culvert back into use.

At 18:07 p.m. on 29th May the Complex suffered a power loss as described earlier (power distribution failure incident) which affected many of the process plants and utility systems on-site. As a result of the power failure, there was no power available to pump water out of drainage pits, and this water overflowed into the culverts, whose electrically-driven drainage pumps were not available. Around 12 hours later one of the safety valves on the new line to the CHP plant was reported to be lifting and venting condensate. Operators described it as being in powerful spurts every 5 minutes over a 30 minute period. Operators also described very loud banging noises and movement of the pipework in the vicinity of a manifold installed on the South Side.

In response the steam main was re-isolated on the southern side of the culvert but the MP steam main beneath the road in the West Gemec culvert was left connected to the North Side MP steam supply. Condensate was drained from some sections of the steam pipework and the MP steam supply re-established to the South Side. No report was raised regarding this incident (a Total Loss Control (TLC) report was normal practice on-site) and the immediate and root causes of the incident were not determined. The BP site inspection department were not informed that the pipework had experienced water hammer and no formal assessment was made to confirm the integrity of the pipework.

Steam was identified as blowing across the Bo'ness road from the vicinity of the East Gemec culvert on 30th May. Investigation revealed that both culverts were flooded and action was then taken to pump out the East Gemec culvert followed by the West Gemec culvert. Overall the culverts had been flooded for a period of 36 hours. Initially it was suspected that there was a steam leak in the East Gemec culvert. However on further investigation it was concluded that heat lost from the submerged MP steam pipeline (which provided a steam flow to the South Side of the Complex) boiled the water in the East Gemec culvert and generated the steam that was observed. The West Gemec culvert was isolated on the South Side even though it was open to the MP steam supply on the North Side. This effectively created a "dead-leg" in the steam supply system with MP steam able to enter at the North Side but not to exit at the South Side. The rate of steam flow into the West Gemec culvert and heat loss was insufficient however to boil the water in a similar fashion to that observed for the East Gemec culvert.

Following the pumping out of the water from the culverts the steam mains in the East Gemec and West Gemec culverts were inspected on 2nd and 5th June respectively. The BP Inspector was not told of the serious system upset, nor were those responsible for arranging the confined entry permits told of the severe water hammering and relief valve discharge of condensate in adjacent pipework. Prior to the inspection one of the steam traps in the West Gemec culvert, which discharged directly to atmosphere, was isolated for safety during the inspection, because it was continually "firing". The steam main however was not isolated on the North Side and remained connected to the section of MP steam main located in the West Gemec culvert

The inspections found that although some of the lagging was dislodged there was no evidence of structural damage having occurred as a result of both mains having been totally submerged.

Following completion of the inspections the steam trap in the West Gemec culvert that had been closed was not re-opened and therefore this condensate removal device serving the low point of the system continued to be isolated.

From the 30th May to 7th June in the period immediately prior to the subsequent incident the length of line in the West Gemec culvert was effectively a "dead leg" since the MP steam supply system had been isolated on the South Side but was open on the North Side. This allowed steam to continuously enter the section of MP steam main in the culvert. In the absence of a pathway through on the South Side MP steam entering the system therefore gradually cooled and condensed. The resulting change in state from vapour (steam) to liquid (hot condensate) resulted in a reduction in volume. This allowed more MP steam to enter the culvert section and hence to cool and condense. As a result steam was continuously entering the culvert section and condensate was continuously being produced. As the steam trap at the lowest point in the system had been isolated it allowed condensate to accumulate in the system.

3.2.3 Details of the Incident

At 11.18 p.m. on 7th June a catastrophic failure occurred to a section of the MP steam pipeline. The failure, which occurred suddenly and without warning, involved the rupture of a tee-piece on a 450mm (18" diameter) section of line operating at a pressure of 14 barg (200 psi). Failure occurred in a horizontal section of pipework located on the southern side of the West Gemec culvert immediately before the isolation valves as described previously. The failure resulted in an "open end" to the MP steam supply to the South Side from the power station through the 18" pipework that ran through the West Gemec culvert. MP steam therefore escaped direct to atmosphere as a result of the failure of the section of pipework and the pressure in the steam distribution system fell due to the escape of a large quantity of steam via this route.

Figure 11

Rupture Photo

The section of pipeline which failed was parallel to and only 9 metres from a pavement and the A904 Bo'ness to Grangemouth public road.

Minor damage to surrounding fencing occurred as a result of the failure and debris was also blown onto the Bo'ness road. There were no eye witnesses to the failure with the nearest person being identified as a woman walking a dog approximately 300m away. Clearly however there was the potential for fatal and serious injury on/off-site had passers-by been in the vicinity when the pipe failed. The woman walking the dog tripped over the dog and fell to the ground. She was treated for three cracked ribs.

At the time of the incident, all but one of the power station technicians were in the Thermal Control Room (TCR) and the last person confirmed his safety immediately after the incident.

As all the instrument readings for the steam lines on the Complex had been affected by the rupture the technicians were unable to immediately identify the specific line that had ruptured. Identification was further hindered by the fact that the steam line that ruptured was not shown on the new DCS control system in the control room. Security cameras located in the area however were able to confirm that a burst had occurred on the southern side of Bo'ness Road.

The first priority of the TCR technicians was to stabilise the boilers in the power station since there was now a high demand and usage of steam as it escaped through the 18" main. This operation required approximately 10 minutes to complete.

As the technicians were unable to establish which line had burst from the instrumentation they began shutting steam lines in turn starting with the high pressure (HP) steam lines (640 psig main) and working their way down to the MP steam system in order to isolate the leak.

After checking that the HP steam main had been isolated they checked the valves for the MP steam supply to BP Chemicals South Side and proceeded to close the isolation valves installed on the system. These valves are large, taking two technicians approximately 5 minutes to close. Closure was hampered by the steam and noise from the rupture (the density of steam meant that the operators were working "blind" when attempting to locate these valves) since the location of the isolation valves was close to the rupture on the South Side adjacent to Bo'ness Road.

The Lead Power Station Technician was unable to assist in the process of closing the valves until the standby Lead Technician arrived at approximately 23:50 p.m. to take over control of the boiler control panels in the control room. He then assisted the other technicians in identifying and closing the isolation valves.

Unable to identify the required isolation valve for the leak, the power station technicians returned to the Thermal Control Room and began to consult drawings of the steam distribution system. One of the power station technicians then remembered that there was an MP steam line that ran through the West Gemec tunnel, checked an outside gauge and confirmed that this was the source of the leak. The isolation valve on the North Side was subsequently identified and closed resulting in isolation of the leak and recovery of the pressure in the other steam mains at around 00:25 a.m. (rupture 11.18 p.m.).

Visibility in the area was poor through a combination of darkness and the volume of steam escaping from the rupture and access to the isolation valve once identified was hampered by a poor standard of housekeeping in the surrounding area and the presence of scaffolding.

The MP steam line through the West Gemec culvert had not been previously identified because its presence was not shown on the DCS, and the Power Station Technicians on shift were not aware that it was in use and open to the MP steam distribution system on the North Side.

The conditions in the control room under which the operators were trying to operate to identify and isolate the leak were very difficult. Following the rupture multiple audible and visual alarms activated in the control room resulting in significant noise. (See Alarm Handling for a discussion of the investigation into issues raised by this incident and the FCCU fire incident). The extreme noise levels outside made radio communications between the control room and outside virtually impossible. Due to the lack of knowledge on the current status of the system and the lack of information available a process of elimination was used by the technicians to identify and isolate the leak. This delayed their effective response and increased the duration of the incident.

As a result of the failure of the MP steam line the Olefins and Polyethylene plants on the South Side lost steam supply and were shutdown.

3.2.4 Emergency Response

The rupture was first reported by the Complex mobile security patrol who immediately radioed the fire station, and then proceeded to close off the east side of A904 Bo’ness Road.

The noise and disturbance (reduced visibility) from the release of the steam was considerable (described as being like the noise from a jet engine) and this continued until the section of pipeline involved was isolated.

On arrival at the scene the BP Station Officer initiated an emergency and informed the BP shift manager. By 23:24 p.m. the Central Scotland Police had been informed of the incident and the fire brigade were in attendance.

BP emergency command procedures require the shift lead technician for the area of the emergency to assume an “on-scene” commander role – however the lead power station technician was a control room operator and fully engaged in stabilising the boilers and so could not leave the control room until replaced by a control room operator from another area.

The Complex Incident Management Team (IMT) was in place by 23:50 p.m. and the MICC (Major Incident Control Centre) was set up at Grangemouth police station. The fire brigade were stood down at 00:45 a.m.

At 01:25 a.m., the IMT informed the fire station about the presence of an acrylonitrile line in the vicinity of the rupture. At 01.50 a.m. concern was also raised regarding the possibility of damaged asbestos lagging being present.

In response a fire fighter, lab technician and the Asbestos Services Manager dressed in gas suits visited the scene to test and confirmed that neither substance was present.

Police at the scene were concerned that the incident may have been caused by sabotage. They quarantined the site of the steam rupture until they established that the incident had not been sabotage or was the result of bomb damage and during this time only controlled access was allowed to the scene to establish that no major damage or loss of containment had occurred to the adjacent pipework.

The scene was released back to BP by Central Scotland Police, at approximately 05:00 a.m. on the morning of 8th June but Bo'ness road was closed to the public and employees by Central Scotland Police until 22nd June.

3.2.5 Competent Authority Investigation

As a result the HSE set up an investigation team to investigate the causes of the incident. BP independently carried out an investigation following their major incident investigation guidelines and cooperated fully with the HSE investigation. BP also contracted the services of an independent consultant in order to assist in their enquiry (Kirsner Consulting Engineering Inc. Atlanta, Georgia, USA). The BP investigation made a number of key proposals for corrective actions as a result of the incident investigation

The HSE investigation focused on the pressure systems aspects of the failure and associated management issues. The incident was not considered to be a defined COMAH major accident. The investigation did however consider the wider (COMAH related) view of steam as an essential utility service to the Complex, and system vulnerabilities and knock-on major accident related consequences, as a safety report issue. These issues were also addressed by the BP report into the incident.

The HSE and BP investigation teams worked closely together, especially at the early stages, and also with the external consultant appointed by BP to assist in identifying the technical causes. The BP and HSE investigation teams compared their analysis of the causes and findings in order to check alignment and they were generally close.

The investigation immediately following the incident concentrated initially on the failed tee-piece and around the area close to the failure. Sections of damaged pipework were removed on 22nd June and sent to the Health and Safety Laboratories in Sheffield for detailed metallurgical analysis. The tests indicated that the pipework was in satisfactory condition and the cause of failure was extreme internal overpressure significantly in excess of the design pressure of the pipework.

The investigation determined that the pipework installation was around 25 to 30 years old and generally in very good condition.

Initial inspection of the section of damaged pipeline, which showed that the pipe had almost unwrapped, suggested that considerable energy was involved in the failure but the precise cause of failure was not immediately apparent.

Figure 12

Steam Main Photo

Figure 13

Rupture Photo

As far as could be determined there were no process or steam generation upsets just prior to the incident and no direct activity (e.g. opening or closing valves near the point of failure) at the time of the incident.

Pipework and Supports

Observation of the pipework revealed some pipe movement and damage mainly to cladding and supports and bulge distortion to the MP steam main in the West Gemec culvert. Valves in the supply system on the South Side were disassembled and found not to be providing full isolation but allowing some leakage.

Steam Traps

The two steam traps in the section of pipework, which ran through the culvert and which discharged directly to atmospheric drain, were tested and found to be functional but that they had been isolated. Only one of these traps was identified as having been recently isolated for the purposes of the culvert inspections following the flooding. Calculations subsequently showed that the capacity of this trap, which was situated at the lowest point of the line and closest to the point of failure, should have been sufficient to cope with condensate being produced in the line, had it not been isolated.

Mechanism of Failure

Due to the evidence of condensate being vented (30th May) and water hammer being identified in pipework close to the rupture point the most likely cause of failure was determined at an early stage to be water hammer. However there was an absence of steam flow in the dead leg which is a critical component of conventional water hammer (i.e. steam velocity was not present).

It is not unknown, but less well appreciated however that water hammer can also be caused by the rapid collapse, or imploding, of a steam bubble and the mechanism and theory of this are referred to as "condensation induced water hammer".

This mechanism occurs when steam comes into contact with relatively cold condensate or when condensate meets a trapped steam bubble. Due to temperature differences heat transfer between the two is rapid, causing a collapse of the steam (significant reduction in volume occurs as steam vapour changes to a liquid condensate). This is followed by an inrush of more condensate at high velocity to fill the void. The nature of this mechanism is such that it inherently involves much larger volumes of water because lines need to be flooded to isolate a steam bubble. Thus when water hammer occurs a large volume, and hence mass of water travelling at high speed is rapidly decelerated. The high energy dissipated as a result of the rapid deceleration results in a pressure wave travelling at high speed back through the water column.

Due to the isolation of the last remaining functional steam trap in the West Gemec culvert for inspection purposes (the other one was already isolated) this effectively removed the ability to release condensate from this section of the steam supply system. Therefore as the steam cooled and condensed the condensate built up whilst more steam was still available from the North Side supply main to replace the steam that had condensed. As a result of the U configuration of the pipework beneath the road when the condensate built up to the point where it flooded the horizontal section the steam present on the South Side was trapped between the condensate in the culvert and the isolation valves on the South Side. This effectively created a trapped steam bubble.

Figure 14

Culvert Diagram

Figure 15

Culvert Diagram

Since the North Side was connected to the steam supply MP steam fed into the dead leg to the culvert continued to cool and condense and thus the condensate level in the culvert U bend arrangement continued to rise up the vertical legs whilst still continuing to cool. Due to the fact that the isolation valves on the South Side were leaking, some steam was passed back through the valves and into the leg of the steam main south of the culvert maintaining the pressure and temperature of the steam bubble.

The geometry of the system was such that eventually the condensate level rose to a point where it ran underneath the steam bubble, creating a much larger surface area in contact with the steam. By this time the condensate had cooled significantly leading to rapid heat transfer and collapse of the steam bubble. The collapsing steam bubble created a differential pressure across the accumulated condensate causing it to accelerate into the void. The mass of condensate involved was in the region of 4 tonnes and this was stopped abruptly when it reached the isolation valves. The resulting pressure wave is believed to have caused the failure of the tee-piece.

Figure 16

Culvert Diagram

The investigation team concluded that the most likely reason for the pipe line failure was internal overpressure caused by "condensation induced water hammer".

3.2.6 Key Findings – Cause and Effects

The critical factors that led to the incident were created a week earlier. Significant levels of condensate built up in the steam line following isolation of a steam trap to gain access for inspection of the tunnel, after the culvert was flooded following the power distribution failure.

1. The immediate cause of the catastrophic failure of an MP steam distribution pipeline was "condensation induced water hammer" which caused gross overpressure.
2. There was agreement between the HSE and the BP expert on this being the most likely theoretical mechanism of failure; although determining the definitive sequence of events was not possible due to uncertainties in parameters such as heat transfer rates and steam passage through the leaking isolation valve.

3.2.7 Findings of the Competent Authority Investigation

The findings of the Competent Authority investigation in relation to the five themes identified earlier are given below.

Legislative Compliance

There was a breach of Section 3 of the Health & Safety at Work etc. Act 1974 in that BP failed to conduct their work undertaking to ensure that persons not in BP's employment were not exposed to risks to their health and safety.

Best Practice/Guidance

In relation to the operation of the MP steam line comparison of the organisational set-up with the "POPMAR" safety management system model in the HSE Booklet HSG65 "Successful Health and Safety Management" suggested major weaknesses in organising (in particular communication, control, competence and coordination), in planning and implementing and in monitoring and review. Underlying problems were identified in the following areas:

- Management of change (change control procedures);
- Failure to adequately investigate significant plant upsets and to carry out risk assessments;
- Operating regimes and lack of certain site standards;
- Inspection and maintenance of equipment;
- Management structure and organisation;
- Failure to learn lessons from previous incidents/events on-site.

BP Grangemouth Safety Reports

There were no findings for this incident linked to the BP Grangemouth safety reports.

BP Group Objectives

BP failed to fully meet their own high performance expectations in “Getting HSE Right (GHSER)”.

Previous Incidents

In the week prior to failure, downstream pipework had suffered significant water hammer and condensate was ejected from a pressure relief valve. Action was taken to isolate that particular section of pipework from the network, but the main pipeline which subsequently failed was not isolated at the main steam header and remained live to the system. The investigation into the upset was incomplete and inadequate.

Another section of the same MP steam line, located to the North of Bo’ness Road, failed previously in January 1975 due to severe water hammer. Following the incident a series of key recommendations were made including the following:

- As far as possible “dead legs” in steam lines should not be permitted and sections should be taken completely out of commission by shutting block valves at both ends. Where this is not possible, drains along the line should be “feathered” to ensure that sufficient steam passes into the line to keep it hot and its contents above saturation temperature;
- Steam trapping facilities should be improved by increasing the condensate well to not less than half the diameter of the line. At critical zones e.g. in the tunnel, two traps should be installed to improve security, preferably situated at each end of the tunnel section;
- A specific crew should be created responsible for the inspection, checking and repair of steam traps. Sufficient repaired steam traps should be available to replace faulty traps immediately;
- All main isolating valves should be numbered and official steam main drawings exchanged. All factories should be made aware of the operation of any major valve on the steam reticulation and the condition of all valves should be indicated on a permanent check board held at the power station.

Many of the recommendations made following the 1975 incident were relevant to the June 2000 incident but appeared not to have been followed.

3.2.8 Competent Authority Actions and Recommendations

The Competent Authority actions/recommendations have been accepted by BP and were in line with the findings and recommendations of the BP incident investigation and BP Task Force reports.

1. Management Systems

BP should ensure that the management system for the steam distribution system identifies ownership/control/responsibility, especially at culverts, battery limits etc., and that sufficient technical competence (see note) on steam safety systems is available.

The findings of the HSE were consistent with those of the BP Task Force and were accepted by BP. A programme of focused training has been put in place for relevant personnel in the Power Station and Utilities Team. Competence is assessed on an on-going basis through a complex wide assurance process.

Note: In this context, overall the personnel who are involved in the operation of steam systems should have the appropriate level of knowledge, skills and competence. This should include knowledge of the requirements of the Pressure Systems Safety Regulations (2000), the role and function of steam traps, and the possible mechanisms for the failure of steam systems (including condensation induced water hammer). An awareness of the warning signs and investigative actions required is necessary to ensure that steam systems operate safely.

2. Change Management

BP should ensure that changes to the steam pressure system are subject to rigorous change management procedures and comply with the Pressure System Safety Regulations 2000 as a minimum legal standard.

The findings of the HSE were consistent with those of the BP Task Force and were accepted by BP. The plant modification process has been reviewed and revised and includes more rigorous tracking with respect to compliance with applicable legislation, in this case the Pressure Systems Safety Regulations 2000.

3. Plant Upsets

BP should ensure that significant plant upsets are identified, recorded and risk assessed, and that a technically competent person and BP Plant Integrity Branch Inspectors are informed so that safety implications and correct actions can be considered.

The findings of the HSE were consistent with those of the BP Task Force and were accepted by BP. Additional incident reporting and investigation training *has been implemented for relevant personnel within the Power Station and Utilities Team. A process for reporting and investigating deviations from agreed operating envelopes is being systematically introduced throughout the Complex. The Complex Process Safety Committee provides site assurance on deviations from operating envelopes and has direct connection into the site integrity management personnel.*

4. Resource Management

BP should ensure that the necessary amount of resources are made available for maintenance of various steam system parts in particular that steam traps are inspected in safe operating condition and that an appropriate number are provided.

The findings of the HSE were consistent with those of the BP Task Force and were accepted by BP. A full review of steam system operating and maintenance procedures has been conducted and required changes implemented. Revised inspection programmes have been developed for these systems.

5. Circulation of Information

As condensation induced water hammer is a poorly understood and little known phenomenon BP should alert other BP sites. BP should also alert industry, and/or other relevant competent industry bodies to the mechanisms of pipe failure in the 7th June 2000 and 21st January 1975 steam incidents.

BP accepted the findings of the HSE and agreed to publication of a technical paper which addressed the circumstances of the incident and the lessons learned. The HSE published the paper in the Loss Prevention Bulletin to increase awareness of condensation induced water hammer as a first step to increasing knowledge of possible initiating events for steam system main ruptures.

6. BP Investigation

To maximise learning by the BP Complex, contribution to corporate memory as well as for completeness, BP was recommended to reference all issues which it believed were relevant within its investigation report. For example that part of the system was in poor repair and that further training on the location and criticality of traps was required.

Together the BP Investigation Report and the wider BP Task Force investigation addressed these issues and covered both all relevant technical matters and ownership issues.

3.3 Fluidised Catalytic Cracker Unit (FCCU) Fire – 10th June 2000

3.3.1 Background

The Fluidised Catalytic Cracker Unit (FCCU), which was originally installed in the early 1950's, is one of the process units in the Oil Refinery on the North Side of the Complex.

FCCU's are standard installations widely used throughout the world on oil refineries for converting the heaviest components of crude oil into a range of useful products such as motor fuels. There is a significant history of operational incidents involving FCCU's throughout the world and also at the Complex and information is widely publicised and readily available.

For a general introduction to the basic design and important features of the FCCU and the layout of the facility at BP Grangemouth see Appendix 1.

Since the original construction of the FCCU several sections had been significantly modified. Major modifications to the "front end" reactor and catalyst handling sections (where the heavy crude products are "cracked" into a number of lighter components) had taken place in major revamp projects in 1996 and 1998. The "back end" fractionation section (where the lighter components are subsequently separated) however remained predominantly the original design and installation with only a few minor modifications and improvements.

3.3.2 Events leading up to the Incident

Following the last major revamp project in 1998 the FCCU had been experiencing considerable difficulties and had not been able to operate consistently. This was due to a combination of technical problems with the "front end" catalyst handling section and other issues such as loss of utility supplies (steam, power etc.). This had resulted in the plant being subjected to numerous start-ups and shutdowns over the intervening two year period and especially during the few months preceding the fire. In the 11 weeks preceding the incident, 19 start-up attempts had been made, of which 7 reached the stage of starting to bring the Vapour Recovery Unit on line.

FCCU start-ups are periods of intense activity for the operators whilst the plant is brought up to the steady-state design and normal operating conditions from ambient and hydrocarbons are gradually introduced into the system. This requires significant manual involvement to open/close valves as necessary on the plant as well as assistance from the control room operators monitoring the plant from the DCS plant control system.

Starting up a process unit results in significant changes (operating temperature and pressure etc.) on the pipework and vessels as they are brought up to the required operating conditions from ambient. Increasing the frequency of start-ups results in fluctuations in conditions and increased cyclic stresses on mechanical systems as a result of these. Under such cyclic conditions the pipework can become "fatigued" with defects developing that can subsequently lead to failure.

The FCCU was shut down on the 29th May following the power distribution failure and was being restarted after an 11 day shutdown. The shut down of 29th May was preceded by a short period of steady operation after the last successful start-up on 24th May.

3.3.3 Details of the Incident

On the evening of the 9th June the FCCU was in the process of being restarted. The "front end" i.e. the cracking section was started up successfully by about midnight. The intention was to then start the "back end" Vapour Recovery Unit (VRU or "light ends" section) of the plant by progressively introducing hydrocarbons into each of the columns in turn.

The main fractionator and absorber columns were successfully brought on line and then material was introduced into the Debutaniser column (E5) sometime after 01.00 a.m.

At this stage the control room operator had difficulty in achieving the correct temperature and pressure at the base of the column E5 and this resulted in the relief valves lifting.

Problems were also experienced in maintaining the correct levels in the next column downstream (the Re-run column E6) due to gas being present in the pump which controlled the liquid levels in the column. This was a common problem experienced during start up conditions.

During start-up and before transferring liquids from E5 to E6 standard operating practice for plant operators is to dewater the transfer line using a number of drain points on the system. Dewatering is essential because if the water in E5 (which is operated at a high temperature and pressure relative to the conditions in the column E6) was transferred into E6 it would result in the water immediately "flashing off" to produce steam. As discussed previously (for the MP steam main rupture incident) the transition between liquid and vapour phases is accompanied by significant volumetric changes and this could potentially damage the Re-run column E6.

In order to dewater the column a drain point at the base of the column E5 on the outlet pipework is opened and water is allowed to escape to the local ground drains until hydrocarbons are observed coming out. This operation is carried out several times prior to transfer commencing in order to ensure that all the water has been removed. *Note: The hydrocarbons discharged to the drain system are subsequently removed in the effluent treatment systems for the Complex and are not discharged off-site.*

Following the dewatering procedure the transfer of liquid from the base of column E5 to column E6 was initiated by the control room operator at about 03.15 a.m. This was achieved by opening a flow control valve in a 6" transfer line between the two columns.

Shortly afterwards (approximately 03.19 a.m.) operators working on the plant in the vicinity of the Debutaniser column reported a leak of hydrocarbons (described as a white vapour smelling of “spirit”) coming from the base of E5 and drifting northwards towards the hot oil pumphouse. The control room operator was notified of the leak and immediately stopped the feed to the unit.

At approximately 03.23 a.m. whilst the plant operators were investigating the source of the leak and beginning to isolate valves, the release ignited and the operators ran quickly to a place of safety. A serious fire developed at the base of E5 and affected the adjacent columns and equipment. There were no injuries as a result of the incident. The fire was automatically detected by a fire detector located in the Hot Oil pump house facing the Debutaniser column E5, which alerted the Control Room

The control room operator isolated the feeds to the “light ends” system using the DCS and within two minutes despite the number of audible and visual alarms significant isolation of inventories had taken place. The damage to instrumentation during the fire also meant that the control room operator was unable to view the condition of parts of the process through the DCS system. For a summary of the key findings of the investigation into the alarm handling issues of the FCCU fire and the other incidents see the alarm handling investigation.

The prevailing wind direction at the time of the incident took the vapours into a relatively open area of the plant where the vapours were able to disperse relatively easily. If however the wind had been in a different direction towards an area where there was a congestion of plant and equipment and ignition had occurred the consequences may have been more serious. Such a scenario had previously been identified in the BP CIMAH/COMAH safety reports for the FCCU whereby the possibility of a vapour cloud explosion (VCE) had been considered.

3.3.4 Emergency Response

In response to the original identification of the leak, the on-site emergency services were called to attend (03:21 a.m.) and by the time they arrived at the scene, ignition had occurred. They quickly set up portable fire appliances to control the spread of the fire.

The Central Scotland Fire Brigade was notified by a 999 call at 03:29 a.m. following the ignition. They arrived at the scene at 03.39 a.m. and assisted in controlling the incident. The fire was initially attended by five mobile units along with a decontamination and control unit. Subsequently a further five mobile units attended with a standby foam tanker

At 03.33 a.m. the Oil Refinery muster point alarm was sounded.
Plant operators helped the emergency services by closing manual valves (for example at the fractionator column) and by shutting down pumps to minimise the quantity of material released. The control room operator was limited in the extent to which he could assist to isolate inventories remotely because many isolations could only be done manually.

The BP Grangemouth Incident Management Team was called out and within 30 minutes the Grangemouth Petrochemical Complex Major Incident Control Committee had been activated at Grangemouth police station. Some difficulties were experienced with the reception of emergency responders and with MICC communications. Control of the access to the incident site was initially difficult to achieve.

The fire reached its maximum intensity within 20 minutes but within 40 minutes started to decline as a result of a reduction in available fuel and the use of aggressive fire-fighting techniques (water and foam). Within 90 minutes the fire size had reduced considerably to the point where the remaining inventory could be allowed to burn off.

The incident was brought under control and several hours later (around 10:00 a.m.) the incident was declared to be over. Damage was mainly limited to columns and associated equipment on the "light ends" section in the vicinity of column E5. Passive structural fire protection prevented significant damage to surrounding structures.

During the initial incident response, consideration was not given to the potential asbestos hazard to fire-fighting teams. It was only later that it was suspected that asbestos from vessel/piping insulation may have become damaged either directly by the fire or by the fire-fighting attempts and tests were carried out to determine the extent (if any) of the asbestos contamination. Whilst most of the asbestos was retained on the plant, some asbestos material was subsequently found in the plant drains, most probably as a result of having been deposited by firewater. There was no evidence of air-borne asbestos having been deposited outside the plant area. For a summary of the key findings of the investigation into the response to asbestos concerns following the FCCU fire see the asbestos investigation.

Gas sampling carried out on the north bank of the River Forth found no abnormal levels of atmospheric pollutants following the incident. For a summary of the key findings of the investigation into the environmental impact of the FCCU fire and the other incidents see the environmental impact investigation.

Towards the end of the incident, due to the large quantity of water used for fire-fighting, and the fact that the capacity of the storm water tanks was effectively reduced by recent heavy rain, the storm water tanks in the Oil Refinery effluent treatment system became filled. Contaminated effluent from the FCCU containing hydrocarbon liquids was diverted directly into the Forth Estuary.

BP made the plant safe by isolating sections of the plant using existing valves and then by determining how to safely dispose of inventories of flammable material. There was substantial damage to high level steelwork and access to parts of the site of the fire was restricted until the danger from falling steelwork had been assessed.

For a summary of the key findings of the investigation into the emergency response to the FCCU fire see the emergency response investigation.

3.3.5 Competent Authority Investigation

Soon after the incident BP notified the Competent Authority's duty officer by phone of a major accident falling within COMAH Regulation 2. There was a delay in contacting the relevant HSE Inspectors and their arrival on-site. Investigation started by phone at 07:30 a.m. and HSE s were on-site investigating by 11:00 a.m. The delay did not effect the investigation as the HSE Inspectors would only attend the fire locus once it is safe to do so. In this case it was not until after 10:00 a.m. when the fire was out.

Approximately one month later after calculating the inventory that had been lost it was also reported to the European Union under COMAH Regulation 21 and schedule 7 as the losses of dangerous substances exceeded 5% of the qualifying quantity and probably also exceeded the financial loss threshold.

From the outset the Competent Authority treated the incident as a major accident and applied the major accident investigation procedure (MIRAIM) which lays down a procedural response. HSE Incident Inspectors communicated their initial findings to the HSE Board and the HSE Board directed that a Major Accident Investigation of the three incidents taken together was to be carried out by the Competent Authority.

COMAH Regulation 19 requires investigation of the technical, managerial and organisational causes by the Competent Authority, and specifies the investigation duty on the Competent Authority in detail and the outcomes to be achieved.

The Competent Authority investigation was split into the following areas:

- An investigation of the major accident on 10th June 2000, including relevant underlying causes;
- Identification of any serious deficiencies requiring a prohibition notice as per the Competent Authority COMAH Regulation 18 duty;
- Operating history of the FCCU;
- Safety related electrical, instrument and control systems;
- Technical background to plant design, modification, operation and maintenance;
- Alarm handling;
- Emergency response;
- Asbestos.

As well as establishing the causes of the incident, it was important to ensure that the damaged site with its highly hazardous inventories was made safe, and that any actions by the Complex to rebuild the plant and reinstate its activities were appropriate with regard to the risks involved. As a result because of the risks from damaged equipment and exposed asbestos and in order to preserve evidence, access to the site of the incident was carefully controlled.
Using legal powers under Section 20 of the HSWA 1974 the Competent Authority issued a legal notice to leave the scene of the incident undisturbed and to control access to the site of the incident and the surroundings so that evidence could be

obtained. Using the same powers the Competent Authority also formally requested in writing that documentation was provided by BP and impounded certain items of equipment as evidence for forensic analysis during the course of the investigations. A formal legal notice of possession document was issued.

A BP major incident investigation team was also immediately set-up to investigate the circumstances leading to the fire in accordance with the requirements of "Getting HSE Right (GHSER)" (Element 12 – Major Incidents) led by a BP senior manager from outside the Oil Refinery business unit. The BP investigation made a number of key proposals for corrective actions as a result of the incident investigation and identified a series of actions to be completed prior to the unit restart.

The leak source was identified as being upstream of the first isolation valve on the 6" transfer line at the base of the E5 column at the point where a 3" branch to a redundant pump out system connected into the transfer line. The result was that the entire contents of the column E5 plus associated vessels and pipework escaped with no possible means of preventing it from happening.

Figure 17

Pipework (1)

Figure 18

Pipework (2)

Investigations revealed a number of issues:

- On examination of the failed 3" branch connection it was discovered that the connection used was a set-on tee-piece. This differed from the original project drawings and piping specifications from the 1950's, which specified a forged weld-reducing tee-piece. The change was probably made during the initial installation in the 1950's. Following installation the tee-piece had been covered by insulation and the plant drawings had not been updated.
- At the time of the incident the failed 3" branch was supported only at the weld connection to the main transfer line. There were no other pipe supports or restraints on this section of the pipework. The branch comprised pipework suspended vertically from the horizontal transfer line with two manual valves and spool pieces fitted. Hence there was a significant load placed on the support connections when the pipework was full of liquid. Further investigation into the pipework at the base of the column revealed that there had been a modification to the Debutaniser pump out system some time before the end of October 1986. The Debutaniser pump out line had been decommissioned and disconnected from the rest of the plant pump out system by the removal of a valve at the base of the Debutaniser column below the set-on tee-piece. This removed the support provided by the rest of the pump out system pipework and only left the weld at the set-on tee-piece to support the redundant section of the pipework.
- Investigation revealed several issues on the adequacy of emergency isolation of the Vapour Recovery Unit.

In addition to the above (incorrect tee-piece design and inadequate pipework support) the pipework was also subject to increased cyclic mechanical stresses as a result of the poor operating performance of the FCCU and the increased number of plant start-ups over the last two years.

Evidence was obtained from the operators that the pipework at the base of the Debutaniser column had also on occasion been subject to vibration over the previous two years and that this had occurred on two occasions previously during start-ups. This information however had largely not been passed on and no investigations had taken place. Subsequent modelling work carried out suggested that this section of the pipework was prone to flow conditions likely to promote vibration in the pipework.

In addition there had been an earlier failure (March 1999) of a flow transmitter impulse line on the Debutaniser bottoms line caused by vibration and fatigue.

The pipework which failed in the FCCU fire was examined by the Health and Safety Laboratory (HSL). The investigations were hampered by the condition of the fracture surface following the subsequent fire and the full detail of the nature of the fracture could not be resolved. It was established however that there was no evidence of progressive internal or external corrosion of the pipework that led to a condition that promoted failure, nor were there any abnormalities in terms of material composition or condition. There was no evidence of mechanical impact on the pipework.

It was established that there was an element of weld fatigue associated with the crack initiation, which originated from a number of initiation sites and grew to the point where failure occurred. What the HSL investigation failed to establish is whether the weld fatigue took place over a long period of time due to low levels of cyclic stress (as might be present during normal operation of the plant) or whether high levels of cyclic stress resulted in relatively short term fatigue failure (as might be present during abnormal operation at start up or shutdowns).

The HSL investigation concluded that the failure of the pipe was the result of multiple fatigue cracking followed by overload failure of the final ligament. The fatigue cracking probably arose as a result of vibration of the unsupported pipework.

Figure 19

HSL (1)

Figure 20

HSL (2)

Figure 21

HSL (3)

The investigation was unable to draw any conclusions as to the potential source of vibration that led to crack initiation by weld fatigue but modelling carried out showed that the set-on tee-piece was over-stressed for the dynamic loads in the pipework system once the valve in the draindown line had been removed.

Another focus of the investigation was to identify the source of ignition following the release of hydrocarbons. The electrical equipment was found to be suitable for installation in the area concerned. The most probable source of ignition was identified as adjacent uninsulated hot slurry pipework which was used to supply heat to the reboiler for the Debutaniser column E5. This pipework was operating at a temperature of around 300^{o}C some 80-90^{o}C above the auto-ignition temperature of a hydrocarbon (naphtha-like) mixture.

The Competent Authority wrote a COMAH Regulation 15 letter requiring BP to inform the Competent Authority when decisions were made on the future of the FCCU and notifying BP of the Regulation 18 duty on the Competent Authority. BP confirmed that the FCCU would not be restarted without Competent Authority acceptance of the modifications to enhance safety.

Figure 22

Damage (1)

Figure 23

Damage (2)

Figure 24

Damage (3)

Figure 25

Damage (4)

Figure 26

Damage (5)

Figure 27

Damage (6)

3.3.6. Key Findings – Cause and Effects

1. The primary immediate cause of the FCCU incident was the fracture of an unsupported 6x3" reducing tee branch pipe to the main transfer line between the Debutaniser column (E5) and the Re-run column (E6) due to fatigue failure. This resulted in the release of highly flammable liquid/vapour at elevated temperature and pressure, which subsequently ignited.
2. It was fortunate that no fatal or serious injury occurred to the four or five workplace members in the immediate vicinity. This was due to a combination of the way the fire started and progressed, and the workers positioning at the time of the incident and presence of mind to move to safe positions. Weather conditions assisted and the vapour did not accumulate in and around the buildings or in the plant. Under different circumstances this could have led to a vapour cloud explosion, (a scenario envisaged in the CIMAH safety report), which would have increased the likelihood of fatal injuries and further escalation of the incident.
3. There were serious operational problems associated with the FCCU stage two modifications in 1997/98 which were a relevant underlying cause of the major accident on 10th June. These were inadequately dealt with by BP despite recommendations in writing from the HSE to review the process after the torch oil explosion late in 1999.
4. BP reviewed the FCCU earlier in 2000, partly to try to determine why it was not operating properly (eventually traced to a blocked cyclone dip leg) and to compare it with BP FCCU world standards. The review findings were not implemented or communicated properly.

3.3.7. Findings of the Competent Authority Investigation

The findings of the Competent Authority investigation in relation to the five themes identified earlier are given below.

Legislative Compliance

This was a major accident as defined under the COMAH Regulations that could have resulted in multiple fatalities under different circumstances. It was identified that there were a series of deficiencies which resulted in BP being prosecuted under the Health & Safety at Work etc. Act 1974.

Best Practice/Guidance

Comparison of the organisational set-up with the "POPMAR" safety management system model in the HSE Booklet HSG65 "Successful Health and Safety Management" suggested major weaknesses in failing to organise to meet the high standards required in the Major Accident Prevention Policy (required by COMAH) and in planning and implementing and in monitoring, audit and review. Underlying problems were identified in the following areas:

- Organisational structure – the HSE accept that these were historic and had been identified by BP who were taking steps to address the issue when the incidents occurred;
- Operational review system;
- Maintenance of integrity of pipework to avoid loss of containment scenarios;
- Risk assessment procedures;
- Consideration of Human Factors issues.

BP Grangemouth Safety Reports

The CIMAH FCCU installation safety report 1997/98 revision claims and concludes that – "hardware and software controls in place on the FCCU are adequate to prevent the occurrence of a major accident which could affect the general public, the personnel working on-site or the environment around it." Based on investigation findings, this was partly unjustified even in 1997 when it was submitted, and certainly did not reflect the reality by 10th June 2000 when the cumulative effects of unreliability, numerous plant start-ups, vibration and unsupported pipework factors came together. The safety report was not proactively used as a management standard for reviewing continued safe operation, nor used as an audit tool to verify the claims made for safe operation. There were serious deficiencies in the COMAH compliance regime and the safety report did not reflect the reality of the plant operations and maintenance.

BP Group Objectives

BP failed to fully meet its own high performance standards in "Getting HSE Right (GHSER)".

Previous Incidents/Recent History of Operation

Between spring 1998 and June 2000 there was an increased number of start ups and shut downs on the Vapour Recovery Unit. Further, a number of incidents had occurred over the previous two years in which vibration was a relevant issue. A summary list of these previous incidents is given below:

- 1998 - Two incidents occurred which involved vibration of the transfer line between E5/E6. The problem was resolved by adjusting the flow between the columns;
- March 1999 - Vibration of the transfer line between E5/E6 caused failure at a screwed connection for a flow transmitter impulse line. The impulse line was repaired and back-welded. The origin of the vibration was not ascertained;
- December 1999 - On starting up the "light ends" section, a leak was noted at a vent stub on a slurry circuit common header. This header was linked to circulation pumps and contained hot slurry i.e. hydrocarbons at or above their auto-ignition temperature. The cause of failure was attributed to transmitted vibration due to cavitation from the pumps. This vent stub had not been used since the header was installed two years previously and the line was unsupported 1" carbon steel piping with two manual valves attached;
- May 2000 - A plant operator noted significant vibration, or shock-loading, of the transfer line E5/E6 on two occasions. Both occurred shortly after start-up. The information was not passed onto the BP's Asset Technical Support or BP's Plant Integrity Branch;
- May 2000 - A plant operator noted violent movement of the slurry return circuit shortly after start-up. This is located adjacent to the E5 column. The line contains hydrocarbons above the auto-ignition temperature. The information was not passed onto the relevant persons;
- May 2000 – Leak of propane from a screwed coupling on a 1" drain line on the Depropaniser overheads line. The screwed plug leaked due to transmitted vibration when a high pressure in E7 during start-up caused relief valves on the column to lift. The drain line was only supported at the welded joint to the overhead line. At the time of the release, the drain line was at a pressure of approximately 23 barg and there was no means of isolating this section of line. Operator's by-passed the E7 column to prevent further inventory from entering the column, but could do little other than wait for the line to depressurise (over two hours). Light winds at the time meant that propane gas did not accumulate on the plant and no ignition resulted. The cause of failure i.e. vibration due to a process upset and RV's lifted, was not passed onto BP's Plant Integrity Branch.

In addition to the incidents identified above there had been another incident in November 1999 when a prolonged start-up attempt on the FCCU resulted in an ignition of a torch oil vapour cloud within the ductwork of the CO boiler. Contrary to plant operating instructions in the master operating manual (1997), the torch oil had been admitted to the Regenerator when the unit was at too low a temperature. As a result ignition of the torch oil did not occur in the Regenerator. Although ignition had not been verified, a considerable further quantity of torch oil was injected and it is believed that hot spots in the slumped catalyst bed vapourised the torch oil. The provision of a temperature interlock had previously been considered and discounted, as it was decided that operating procedures alone were a sufficient control.

As a result of the torch oil incident the HSE issued an improvement notice to BP requiring an abnormal operations risk assessment procedure to be developed and recommended review of the operation of the FCCU to be undertaken. BP complied with the terms of the improvement notice.

3.3.8. Competent Authority Actions and Recommendations

The Competent Authority investigation required that BP should take the following measures before re-introduction of hydrocarbon to the FCCU "light ends" section. The incident has substantial commercial implications for the site. (The Fluidised Catalytic Cracker Unit is currently not operational whilst BP are evaluating the option of re-building the facility).

FCCU Recommendations – Prior to restart

1. Mechanical Integrity

Demonstration that the mechanical integrity of pipework on the "light ends" section of the FCCU is assured, in particular, with respect to the following:

a) Stresses caused by:

- Fabrication;
- Assembly and erection, including misalignment and structural attachments;
- Mechanically induced vibration cycling;
- Temperature effects and thermal cycling;
- Self weight and effect of supports, restraints and guides;
- Reaction forces and other shock loading;
- Pressure;
- Erosion, corrosion and environmental cracking.

b) Dead legs and drain points to be minimised and, where retained, assessed against the above failure modes.

c) Redundant equipment and pipework, including drain/vent points, to be removed, where practicable.

BP confirmed that the recommendations would be addressed before the FCCU was started up again and would be dealt with in the design of the revamped "light ends" section.

2. Emergency Shutdown Arrangements

Demonstration that adequate arrangements have been identified for the emergency shutdown of the "light ends" section of the FCCU need to be considered (in particular the following):

a) Installation of remotely operated shut-off valves (ROSOVs) to allow rapid remote isolation of significant process inventories in order to minimise the consequences of an uncontrolled leak and allow remote emergency shutdown of ancillary equipment, such as pumps.

b) Safe means for emergency depressurisation of columns or vessels, where reasonably practicable.

BP confirmed that the recommendations would be addressed before the FCCU was started up again and would be dealt with in the design of the revamped "light ends" section.

3. Alarm Flooding

Demonstration that adequate arrangements have been identified to ensure a timely and effective response by Central Control Building operators to those alarms necessary for the prevention and mitigation of major accidents, taking due account of the number, presentation and rate of presentation of alarms during plant start up, or other upset conditions, and any relevant factors set out in industry best practice guidelines (the EEMUA guidelines).

BP confirmed that the recommendations would be addressed before the FCCU was started up again and would be dealt with in the design of the revamped "light ends" section.

Further FCCU Recommendations

The HSE investigation also recommended that improvements be made in the following areas of FCCU operation.

- Change control – rigorous change control procedures should be employed;
- Risk assessment – a review of the FCCU risk assessment should be undertaken which considers critical process effects on start-up, e.g. de-watering, opening FCVs, exceeding process parameters, thermal cycling, transmitted vibration etc;
- Control/instrumentation/electrical equipment;
- Management review – a high level overview of unit operations should be maintained to ensure abnormal operation of the process plant is identified and the full implications assessed;
- Communications/competency – process technicians should receive additional training and instructions to enable them to recognise situations where there may be serious implications for process plant.

Recommendations for the Complex

The HSE investigation also recommended that improvements be made in the following areas site wide.

- Pipework inspection regime – a review of the corporate inspection regime should be carried out in the light of the FCCU history and other refinery incidents;
- Redundant equipment – a policy should be put in place for redundant equipment;
- Remote isolation of process plant – BP's philosophy on remote isolation of plant should be reviewed. The implications for other plants on the Complex should be considered;
- Project review – the corporate system for reviewing the effect of significant projects (PHSER Stage 6) should be followed;
- Process safety review – systematic reviews should be initiated at regular intervals to help assure the overall integrity of process units. They should include the following elements:
    - Operating and inspection histories;
    - The validity of previous risk assessments;
    - Hardware and software changes;
    - Significant incidents and near misses;
    - Audits;
    - Measurement against current standards and legislation;
    - Major accident hazards identified in safety reports.

4. Further Investigations

4.1 Asbestos

The FCCU fire, which occurred on 10th June 2000, affected plant and pipework which was insulated with asbestos lagging. Some asbestos was released during the course of the fire.

As part of their initial response to the incident, the HSE instructed BP to take action to prevent further spread of asbestos, and to control access to the potentially contaminated area. (The latter was part of a legal notice to leave the area undisturbed which was issued to BP on 10th June.) BP, in response, implemented a scheme of thorough wetting of the area and restricted access to the site to people wearing suitable PPE.

Subsequently, and following public concern about the possibility of asbestos contamination which was expressed at local meetings, the HSE carried out specific investigations into the management of asbestos on the site, and into the spread of asbestos and potential exposure arising from the fire. The latter investigation involved the Health and Safety Laboratory in Sheffield who carried out a series of tests on the effects that fire and heat have on asbestos, and on the probable dispersion mechanisms for asbestos materials in fires.

With regard to the management of asbestos, the investigation revealed that BP had written policies and procedures to address hazards associated with the use of asbestos. However the HSE concluded that BP's procedures could be improved. A legal notice was issued specifying the matters requiring attention. BP has further developed their system of asbestos management to meet all the recommendations made by the HSE.

With regard to the spread of asbestos, the investigation concluded that the majority of the asbestos that was released was deposited in the area in the immediate vicinity of the FCCU. It also concluded that asbestos had not been released in significant quantities over a wider area. In addition the investigation concluded that any risk to health from airborne asbestos exposure for members of the public and personnel on the site as a result of the FCCU fire was negligible.

The detailed findings from HSL's research into the effects of fire on asbestos materials are to be published in a separate report addressing the wider issue of fire in relation to managing asbestos in premises.

4.2 Alarm Handling

One of the underlying issues raised during the initial investigation of the incidents was the response on the Complex to the handling of alarms. There was clear evidence from both the FCCU fire and the MP steam main rupture of operators in the control room experiencing significant "alarm flooding" during the incidents.

In order to specifically investigate this issue further an inspection visit was made by specialists from the HSE's Human Factors team.

The investigation at Grangemouth took a wide view of alarm handling across the whole Complex. It included discussions with operators and management personnel from the different business streams and reviewed the status of current initiatives at the Complex aimed at improving alarm handling. Many of the issues had already been identified by management at the Complex and much work was currently on-going (but not completed) in preparing an alarm philosophy and in standardising alarm handling for the Complex.

The key findings of the specific investigation into alarm handling at the Complex were:

- BP did not have adequate arrangements for alarm handling. Although the management understood the nature and broad extent of the problem, projects were stalled or solutions had not been implemented. Although BP reviewed the HSE Texaco major incident report in 1997-98 which made recommendations on alarm handling, the actions from this review had not been completed;
- BP had not allocated sufficient priority or resources to plan, and because of the organisation structure at the Complex, coordination and direction was poor and tracking progress and tackling alarm handling issues was limited;
- The alarm management review process had not been carried out to an agreed standard and staff at the Complex had not undergone specific training for tackling alarm handling problems;
- The BP Task Force audit report and BP incident investigation team reports identified the alarm handling issues correctly.

BP recognised the problems caused by alarm flooding and work had been commenced at the site to address the problem. A project is now under way to put software in place to manage the prioritisation of alarms properly. The projected timescale of 5 years for completion has been accepted by the Competent Authority.

4.3 Emergency Response

The Control of Major Accident Hazards Regulations 1999 (COMAH) Regulation 19(4) places duties on the Competent Authority in the event of a report of a major accident to:

- Obtain information from the site operator about (amongst other things) the emergency measures taken;
- Analyse the effectiveness of those emergency procedures;
- Take appropriate action to ensure the operator takes any necessary remedial measures;
- Make recommendations on future preventative measures.

A separate investigation into the effectiveness and the implementation of the emergency plan was therefore carried out by the Competent Authority following the FCCU fire which was classified as a major accident.

BP also investigated the emergency response as part of the in-house investigation of the FCCU fire.

The BP Grangemouth Emergency Incident Management Plan was initiated as a result of the FCCU fire. *(Note: The plan was also initiated following the MP steam main rupture).* This plan sets out the procedures to be followed and the roles and responsibilities of staff to be involved in order to provide a structured response to incidents. As a result of the FCCU fire BP's own on-site emergency fire service were in attendance. Following on from mobilisation of the on-site resources the off-site emergency resources were mobilised and incident management teams both on-site (BP Incident Management Team) and off-site (the Grangemouth Petrochemical Complex Major Incident Control Committee – MICC) were set up to deal with the incident.

In the course of the investigation carried out by the Competent Authority a number of documents (including COMAH safety reports, the on-site emergency plan and incident log printouts from the MICC, fire brigade and BP) were examined and key personnel from BP, the MICC and the fire brigade were interviewed.

Key Findings of the Competent Authority Investigation

The overall findings of the Competent Authority investigation in relation to the FCCU fire were that the on-site emergency response achieved what it was intended to do and the overall objectives of the on-site plan (as required by COMAH Regulations 9, 10 and 12 and Schedule 5) were met. However some difficulties and failings occurred. Key findings are given below:

- During the early part of the incident site personnel were actively investigating the source of the release as well as isolating adjacent inventories. Consideration needs to be given to the risk they were exposed to;

- Isolation of the inventory could only be achieved by a combination of manual intervention close to the seat of the fire and the plant control system. There were no remotely operated shut-off isolation valves located on the section of plant under consideration;
- Personal protective equipment, PPE, (including close proximity heat protective suits) was not properly worn during attempts at isolation of inventories. Consideration should be given to PPE design for mobility and vision in situations such as this;
- Fire plans for the areas were out of date. The fire plans were in the process of being updated in content and to a format previously agreed with the Competent Authority;
- The Incident Management Team (IMT) maintained a log covering events and actions focused mainly on fire ground reports and activities;
- Consideration of the potential for asbestos and radioactive sources of hazard and risk during the fire was inadequate within the emergency response plan. The realisation of an asbestos issue was identified late in the initial response.

BP have reviewed and improved the on-site incident management plan. Area fire plans have been updated to the agreed format. A full review of the on-site emergency support provision has been carried out and improvements to the team organisation and facilities have been implemented.

4.4 Environmental Impact

The Control of Major Accident Hazards Regulations 1999 (COMAH) Regulation 19(4) places duties on the Competent Authority in the event of a report of a major accident to:

- Obtain information from the site operator about (amongst other things) the effects of the accident on persons and the environment;
- Take appropriate action to ensure the operator takes any necessary remedial measures;
- Make recommendations on future preventative measures.

The Competent Authority led by SEPA carried out an investigation into the environmental impact of the three incidents and the effectiveness and suitability of the emergency response plans and contingency arrangements that were in place to deal with the incidents from an environmental perspective. At the time of the incidents there was some public concern about the smoky flaring which occurred during the power distribution failure and MP steam main rupture incidents.

None of the three incidents resulted in a major accident to the environment (MATTE) as defined in the COMAH Regulations. The Competent Authority investigations revealed the following.

For the power distribution failure a combination of quick and effective actions by individuals minimised the environmental consequences.

For the MP steam main rupture incident although only steam/condensate was lost directly to the environment as a result of the pipework failure the loss of steam to the South Side of the Complex resulted in significant disruption to operations at the Complex and some smoky flaring.

For the FCCU fire contaminated firewater containing hydrocarbons from the plant was generated in excess of the capacity of the stormwater retention facilities on-site and this resulted in the release of untreated firewater direct to the River Forth. Smoke and combustion products were also generated as a result of the fire. However, subsequent analysis of the surrounding environment both on and off-site showed no sign of significant levels of contamination as a result of the incident.

The FCCU has several very small radioactive sources which are used for non-intrusive level measurement in the catalyst section. These were not involved in or affected by the fire.

Overall the investigation concluded that the emergency response met its COMAH objectives in preventing, or limiting the environmental consequences of the three incidents and no significant environmental consequences were identified. Several key areas worthy of follow-up were identified by both BP and the Competent Authority during the investigations and are detailed below.

- The power station back-up and stand-by effluent pumping provision was less than adequate. As a consequence of the power failure the pumps for the culverts beneath Bo'ness Road failed and this allowed the culverts to flood;
- Telephone computer communications and effluent system instrumentation suffered problems with their uninterruptible power supply (UPS) facilities;
- The pre-fire emergency plan for the FCCU (and other installations) did not include reference to the presence of radioactive substances on the plant;
- The storm tank capacity was insufficient for the combination of the preceding period of heavy rainfall and the volume of fire fighting water used. The original design for storm water retention capacity specified three tanks but only two had been installed. The assumed available total tank capacity was also reduced by the necessity to keep a minimum working level in the tanks at all times;
- The effluent treatment plant contingency plan did not consider the range of substances, including asbestos, which might be released during a fire or major incident. As such no special precautions had been considered for sludge disposal in the event that these substances were released;
- Environmental lessons learned from previous incidents were not adequately communicated across the Complex.

BP has implemented a range of measures to address these issues. Emergency response plans have now been updated to an agreed format and include reference where required to radioactive sources. Storm water tank capacity is being reviewed as part of the Complex sustaining capital programme. Procedures have been established to address the possible release of a range of substances into the effluent treatment plant during a fire or major incident.

5. Health, Safety and Environmental Management at the BP Grangemouth Complex

5.1 Overview

During the initial investigations into each of the incidents the Competent Authority decided to carry out a site wide investigation by members of the HSE's Human Factors team into overall health, safety and environmental management at the Grangemouth Complex to consider whether underlying human and managerial factors provided a possible explanation for the incidents. The investigation addressed the safety management system and safety culture and explored wider human factors issues both as possible explanations for the incidents and to establish the current situation across the entire Complex.

The occurrence of three separate incidents on the Complex within a two week period was of concern not only to the Competent Authority and BP, but to others including the Local Authority, Trade Union safety representatives, Members of Parliament (MP's), Members of the Scottish Parliament (MSP's) and the local Grangemouth population. There was, in addition, some public speculation of whether issues such as alleged lack of investment or de-manning were contributory factors to the incidents. In the event the Competent Authority did not find any evidence to support the allegations that either a lack of investment or de-manning were contributory factors to the incidents. Further the information considered by the Competent Authority did not justify the view that there had been a lack of investment at the Complex. BP provided evidence that the investment level in the Complex was above relevant industry benchmark levels.

Previous concerns about health, safety and environmental management on COMAH issues at Grangemouth had been expressed directly to the management of the Complex by the Competent Authority in November 1999. These concerns were accepted as valid by the Complex Director and as a result there were already on-going discussions between BP and the Competent Authority, prior to the series of incidents, about how to effect improvements.

It had been recognised by BP prior to November 1999 that the historical management and business structure at the Complex required to be changed. As a result a new Complex Director was appointed in November 1999 with specific responsibility for integrating and unifying the management structure. The Complex Director immediately took action to strengthen the senior management team and in April 2000 established the Grangemouth Leadership Team. A new single site health and safety management system and standard was also introduced as an integral part of the new unified management structure. Implementation of these initiatives had not been fully completed by the time of the incidents.

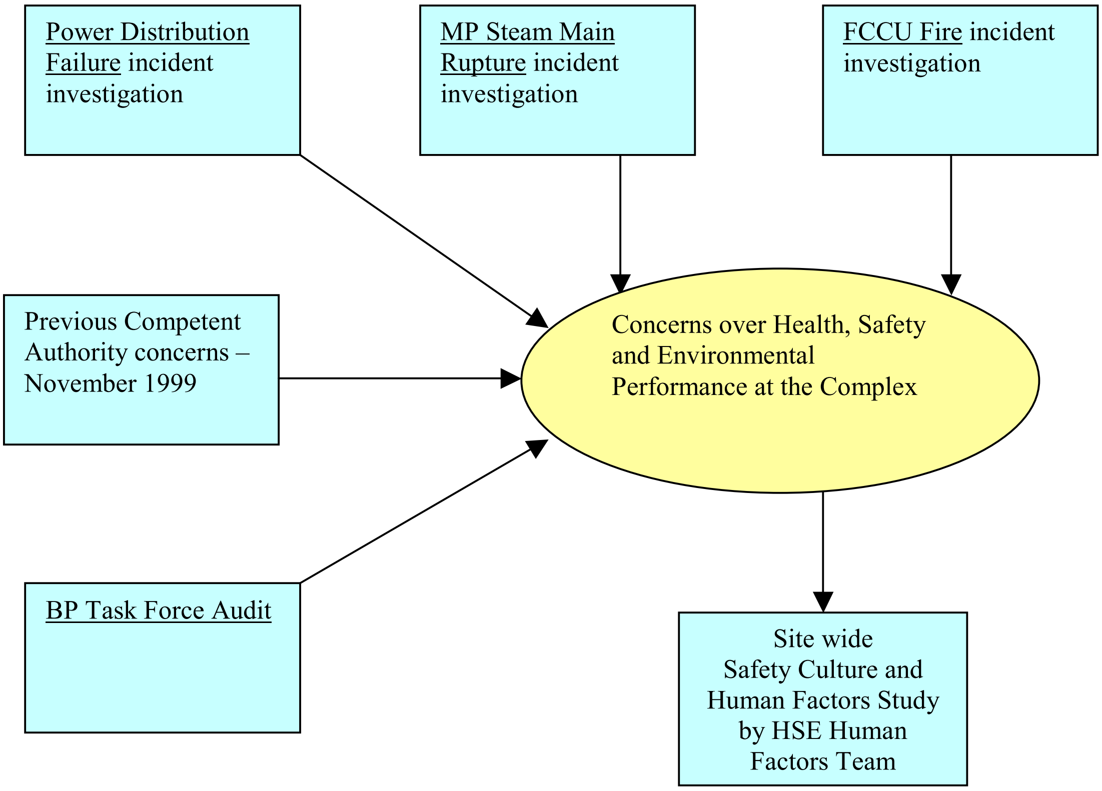
The single health and safety management system introduced at the Complex was directly linked to BP's health, safety and environmental management system framework "Getting HSE Right (GHSER)". This overriding commitment to excellence in health, safety and environmental matters can be summed up in three simple goals:

- No accidents;
- No harm to people;
- No damage to the environment.

The incident specific investigations and key findings have been discussed in the previous sections and each identified a number of technical issues for the incidents. Each separate incident investigation also highlighted some weaknesses in the management systems and procedures which contributed to the series of events leading up to each incident. Similar findings were also found by the BP Task Force audit team.

The investigation by the HSE's Human Factors team found that, due to the history of decentralised management, strong differences in systems, style and culture persisted across the Complex. This history had also inhibited development of a strong, consistent overall strategy for major accident prevention, and had been a barrier to cross-site communication and sharing of learnings. The key findings of the Human Factors team explained why, notwithstanding the high standards set by BP, those standards were not always implemented and met consistently over each part of the Complex. The consequences of a non-unified management structure and differences resulting from the three historical business streams operating at the Complex, in large part provided a compelling explanation of the incidents which occurred.

The following schematic sets out the relationship between the various investigations.



The HSE's Human Factors team interviewed a sample of people from all levels across the Complex either individually or in groups. The questions were aimed at looking for behaviours that were known from published research to be indicators of safety culture. For example questions were asked about visible leadership and employee involvement, as well as on more specific issues raised by employees or HSE Inspectors, such as management of change, de-manning and commercial pressures.

Historically there were three business streams operating at the Complex - Oils, Chemicals and the Forties Pipeline System ("FPS" - Exploration). Although a unified management and health and safety management structure had been introduced there remained significant differences in both culture and management systems. The investigation concentrated on the former Oils business, with Chemicals and the FPS mainly functioning as useful comparisons. The conclusions reached by the investigation refer therefore in the main to the former Oils business and are not consistent features of the Complex as a whole.

The Human Factors team found that whilst shortcomings were present in the Oils business, health, safety and environmental issues were nevertheless taken very seriously. However the tendency was to place relatively high emphasis on short-term benefits of cost and speed and to be readier to make compromises over longer-term issues like plant reliability. Management was perceived by technicians as hurried, and managers expressed similar concerns about technicians. In the Oils business considerable effort and enthusiasm were put into capital projects and fixing problems, but less focus was given to longer term programmes of review and continuous improvement of existing plant than was evident in other parts of the Complex.

The investigation also found that there was a more optimistic perception of safety performance than might be borne out by comparison with different performance indicators. This was due to real and commendable success in managing personal injury rates down to a very low level, together with a failure to adequately distinguish these successes from process safety management. This imbalance between the effort put into personal injury versus major accident prevention was by no means unique to BP. The Competent Authority and others have found similar tendencies in other comparable businesses.

While the investigation team found deficiencies in management style and culture in the former Oils business these shortcomings were not replicated in other parts of the Complex. The FPS was, in particular, found to have a more careful and considered approach to management and general health and safety issues. The investigation also found that while the Chemicals business in the Complex did require to improve in some respects there were many examples of good practice.

BP also employed an independent consultancy to carry out a detailed analysis of the procedures and systems in place at the Complex for health and safety management. (See Appendix 3 for further details).

5.2 Safety Management at the BP Grangemouth Complex - Findings

The key findings of the Competent Authority in relation to health, safety and environmental management at Grangemouth resulting from the incident specific investigations and the site wide safety culture and human factors investigation are given below.

1. BP Group Policies

BP Group Policies set high expectations but these were not consistently achieved because of organisational and cultural reasons at the Complex:

- BP Group Policies (Getting HSE Right (GHSER)); Getting Maintenance and Reliability Right and the Major Accident Prevention Policy) set high standards and follow the principles of the HSE POPMAR model for successful health and safety management, and are capable of delivering compliance with the law and the company stated aims of "no accidents, no harm to people and no damage to the environment";
- The management structure based on separate business streams acting in a loose federation remained substantially in place until April 2000, despite the changes implemented by the new Complex Director from November 1999. The historical structure did not enable consistent leadership and a strong site safety strategy to be set and consistently achieve high standards across the Complex;

- The three incidents would not have occurred if BP's high standards and policies and procedures been followed consistently across the Complex.

2. BP Group & Complex Management

BP Group & Complex Management did not detect and intervene early enough on deteriorating performance:

- Prior to the appointment of the new Complex Director and Health, Safety and Environmental Manager in October 1999 significant weaknesses existed in recognition of and acceptance of the safety and reliability performance with major accident hazard implications. A series of major initiatives had been instigated by BP in November 1999 to address this. However these did not have sufficient time to fully effect a significant improvement in culture and performance in the 6 months leading up to the series of incidents;
- Inadequate performance measurement and audit systems, poor root cause analysis of incidents, and incorrect assumptions about performance based on lost time accident frequencies (DAFWCF – days away from work case frequencies) and a lack of key performance indicators for loss of containment incidents meant that the company did not adequately measure the major accident hazard potential. Since the incidents BP have worked in conjunction with the wider chemical industry and with the HSE to develop new Key Performance Indicators for process safety.

3. COMAH and Pressure Systems Process Safety Regime

BP failed to achieve the operational control and maintenance of process and systems required by law:

- Insufficient management attention and resources was given to maintaining and improving technical standards for process operations and enforcing adherence to standards, codes of practice, good engineering practice, company procedures and the HSE guidance;
- Maintenance of containment and integrity of high hazard plant was inadequate at the FCCU and in the MP steam main incidents;
- Process safety review used elsewhere in BP for major accident hazard installations review (to analyse installation condition and ensure prevention of major incidents) was not used and no effective equivalent procedure was in place;
- Learnings from major chemical industry accident reports (Texaco and Associated Octel) were not adequately actioned. On-site loss of containment incidents of relevance to the FCCU incident were not properly analysed and actioned. The BP approach to ROSOV fitment in the FCCU did not appear to be based on a robust ALARP case;
- The safety report for the Fluidised Catalytic Cracker Unit (FCCU) installation claimed a higher level of reliability and safety performance than was actually present and therefore claims and conclusions made in the safety report that " hardware and software controls in place in the FCCU are adequate to prevent the occurrence of a major accident which

could affect the general public, personnel working on-site or the environment" was unjustified (and probably partly unjustified even in 1997 when the statement was made). The safety report was not proactively used as a management standard for continued safe operation, nor used as an audit tool to verify the claims made for safe operation. It is acknowledged however that BP was actively trying to improve safety reports under the COMAH regime;

- Public speculation in the aftermath of the three incidents was that demanning may have been a cause. No evidence was found of this. Senior management asserted that maintenance spending and manning was well above par for the BP Group. However, demands on maintenance resource were high, largely due to the unreliability of the plant. Outsourcing of maintenance had increased lead times;
- BP did not apply the required degree of expertise to some key technical tasks and had no overall plan as to what resources of technically competent people were required to manage the major accident hazards effectively;
- Management of change, required in the COMAH Major Accident Prevention Policy, was less than adequate in all three incidents. The BP Task Force audit identified initiative overload which caused a prioritisation problem for managers.

4. BP Task Force

The BP Task Force findings and recommendations properly addressed the way forward to ensure safe and reliable operations at BP Grangemouth, but will require sustained visible leadership and enhanced employee involvement over a period of years to continue to improve safety culture:

- The BP Task Force audit, set up after the incident, was thorough with independent oversight. The findings, if successfully implemented, should lead to the BP aim of a safe site with upper quartile performance in the petrochemicals industry and achieve full compliance with the law;
- The Competent Authority are tracking BP's implementation of the action plan arising from the findings of the BP Task Force by means of a 5 year inspection plan as required by the COMAH Regulations.

6. Overall Recommendations for BP Group

The BP Group comprises many companies. Through these companies BP carry on business in many countries. The ultimate Group parent company is BP plc. BP plc has developed high level policies to ensure the health and safety of people and to protect the environment. Among the high level policies developed are those set out in the policy document Getting HSE Right (GHSER). Given the size of the BP Group, the range of activities carried on within the Group and the number of countries in which Group companies carry on business, the focus for ensuring that high standards of operation at the site level are achieved rests with those companies who are carrying on operations, rather than the Group parent company.

In February 2001 the HSE issued a "Summary of Findings and Recommendations report" to BP which contained the broad conclusions and recommendations resulting from the investigations carried out at the Complex. Because the incidents at BP Grangemouth had implications for other BP sites in the UK (Coryton, Bacton, and Hull etc) the "Summary of Findings and Recommendations report" therefore contained the following additional recommendations.

1. BP Group

BP Group should ensure that relevant findings and conclusions which impact on Group level activities are addressed.

BP have reviewed the findings, recommendations and lessons from these incidents, and have implemented a number of improvements to Group level processes as outlined below.

2. Communications

BP should communicate findings and conclusions to the wider BP Group in the UK which will enable learning at other BP establishments.

BP have conducted a global and regional integrity management review following these incidents, paying particular attention to particular lessons arising from these incidents. Further work is underway to fully embed the wider organisational learnings from these incidents, for example in further improving the learning capability of the organisation. Shortly after the incidents, BP communicated initial findings to operating companies throughout the UK sites via the internal COMAH Liaison Group. The incidents and lessons are logged on the BP Reporting system accessible to all employees with a connection to the intranet. A workshop was held where the lessons learned from these specific incidents were disseminated across key contacts within the BP Group. This workshop also addressed the wider issue of improving lessons learned, systems and performance.

3. Safety Performance

It was recommended that BP consider the period from the Hydro-Cracker Major Accident in 1987 in order to consider similarities between the accidents and establish if safety performance improved after this accident, when it deteriorated, and why the stated continuous improvement culture failed to fully materialise.

BP's Task Force fully reviewed the incidents and why they happened, including review of past performance across the Complex. A significant number of actions were identified which have now been completed. The development of process safety Key Performance Indicators (KPIs) will help the site to monitor on-going process safety performance and prevent any future deterioration.

4. Group Safety Assurance

BP should review its Group safety assurance process as a key part of corporate governance. In particular BP should:

- Develop performance measures for major accident hazards;
- Review the targeting of audits to major hazards;
- Review regulators letters and enforcement notices so that regulatory concerns and trends can be identified;
- Introduce a review system for plant reliability so that the safety implications of unreliable plant can be identified at corporate level;
- Analyse reports of process safety review findings at group level;
- Review procedures for initiating "before the event" task force type audits where evidence exists of deteriorating performance which could lead to a major accident.

A wide variety of input and output measures are already employed to measure process safety performance. Plans are in place to report two new measures (one output and one input) at Group level for process safety/integrity management performance. BP have also implemented improvements to Group level audit protocols (to incorporate Process Safety more explicitly) in the annual assurance report process. Regulatory issues (including letters and enforcement notices) are a regular agenda item for COMAH Liaison Group Meetings. Linkages between plant reliability and safety are being addressed by a number of networks from operating companies. The Group's Major Incidents Announcements (MIAs) have been analysed to identify common process safety themes. The Group also regularly shares information on incidents via the Quarterly Safety Bulletins (QSBs). BP operates a system of peer assists and peer reviews to proactively improve performance.

5. Corporate Instructions

BP should review the corporate instructions to major hazard installation managers to identify when it is appropriate to consider shutting down or not restarting an installation. Consideration needs to be given to the COMAH

Regulation 18 duty on the Competent Authority to prohibit use where serious deficiencies exist and this duty also needs to be brought to manager's attention. Managers need to be aware of actions expected of them in the event of serious deficiencies occurring or being identified which have a major accident potential to people or the environment. The managerial and safety culture should enable and support managers in making this legally and financially difficult decision.

Since the incidents BP have developed a standard for Process Safety and Integrity Management. The annual Health, Safety and Environmental assurance process has been reviewed to provide additional assurance on satisfactory implementation of this standard in the business.

6. Competent Authority Findings

BP Group should consider the following Competent Authority findings in particular:

- to achieve more widespread and consistent use of the existing root cause analysis system;
- ROSOV fitment policy and ALARP "gross disproportion" test;
- the role of safety reports;
- resourcing of sufficient numbers of technically competent persons;
- the role of Process Safety Management (PSM) Review;
- strategy for reducing loss of containment incidents (including a pipework inspection and maintenance strategy) akin to the off-shore BP strategy for reducing hydrocarbon releases.

Root cause analysis is acknowledged as the correct approach to incident investigation within BP. BP has provided extensive and widespread training in these techniques over many years and continues to further develop its accident investigators with the introduction of new advanced "master classes". The new Process Safety/Integrity Management Standard requires that all facilities "shall eliminate/control/mitigate the hazards such that residual risks are as low as is reasonably practicable". The specific issue of fitment of ROSOVs is the subject of Draft Guidance from the HSE which BP is currently reviewing in conjunction with UK Trade Organisations. As part of restructuring processes BP companies formally examine the adequacy of manning levels. BP is also doing extensive work around Health, Safety and Environmental competencies and has also introduced a new Competency system. Companies in the Group have introduced a new Process Safety/Integrity Management Standard and new audit protocols have been developed. Guidelines for preparing safety reports were developed at Group level and best practice/shared experience is communicated via the COMAH Liaison Network. The new integrity management measures will provide a better focus for directing strategy towards reducing loss of containment incidents.

7. Current and Future Health, Safety and Environmental Strategy and Priorities at the BP Grangemouth Complex

BP has kept the Competent Authority informed of the strategy to move the Complex to world leading performance in safety, availability and reliability. The following summary of the actions that have been taken has been provided by BP.

The significant set of actions identified by the incident investigations undertaken by both the Competent Authority and BP, and the BP Task Force, have been followed by a clear strategy and set of priorities aimed at continuing and sustaining improvement in the management of health, safety and the environment at the BP Grangemouth Complex. The clear aim was to deliver a step change in health, safety and environmental performance, and to build stakeholder confidence in the Complex's ability to deliver in the future. The programme extends through to 2005, and key aspects are described here.

1. Complex Sustaining Capital Programme

Concurrent with the BP Task Force, the site also conducted a review of its sustaining and health, safety and environmental capital programme and decided to increase overall spend to reduce key vulnerabilities. This included a programme to assess risk associated with corrosion under insulation (CUI), and programmes to assess major site infrastructure systems including "light ends" storage, tankage and power distribution.

The overall programme was reviewed and approved by the Complex Board during 2000.

Sustaining capital investment level is currently running at up to twice the level of benchmark sites in the industry, and will be maintained at a level required to meet the programme timescales.

2. Securing a Future for Grangemouth

During 2001, review of BP Grangemouth's overall business performance identified the clear need for a significant intervention in order to secure the future viability of the site. This transformation programme, called "Securing a Future for Grangemouth", aimed to deliver a step change in business performance as measured by three fundamentals – safety, plant availability, and costs, thus establishing the foundation for delivering acceptable business performance in the future.

The transformation programme laid out a clear vision and set of business targets for the site, and addressed three fundamental areas – organisation, people, and business process. The driving themes for the transformation programme were mapped and aligned to the set of actions identified by the BP Task Force and provided a coherent strategy through which continued progress could be delivered beyond completion of the original BP Task Force action set. Internal independent audit confirmed completion of the original BP Task Force action set at the end of 2001, laying the foundation for subsequent follow-on improvements being embedded in the transformation programme.

During the first quarter of 2002, the health, safety and environmental strategy for the site was reviewed and refreshed. A simple vision was developed for "a Grangemouth where health, safety and the environment is integral to every business decision, and owned deep in the organisation". Two key strategic themes were developed. Firstly, to put clear, user friendly and site wide systems into place. Secondly, to use those systems successfully through effective leadership, deep involvement, and openness. Some systems would be new, others would reflect simplification and integration of existing systems. All however would fit in a recognised framework, provide clear accountabilities and set out clear standards.

3. Organisational Design

The organisational design established at the outset of the "Securing a Future" programme provided the basis for consistency across all business streams on-site, and addressed a key theme identified by the BP Task Force. The fundamental design concept established clearly defined ownership and accountability for specific aspects of the site's business: individual plant operation and availability; Complex wide optimisation; and Complex wide functional support. The organisation was built around four Availability Teams: Monomers; Polymers; Forties Pipeline System and Infrastructure; and the Oil Refinery. The design reintroduced front line supervision, after a period of several years when self-directed teams had been established in areas of the site.

Selection into the organisation against criteria including health, safety and environmental behaviours and technical competence, took place during December 2001 and January 2002. A rigorous management of change process was developed to ensure that the design was fully assessed for possible adverse impact on health, safety and environmental performance. The primary focus of this process was to address the safety critical aspects of the organisational change, including human factors. Integral to the management of change process was a simple competence assurance mechanism resulting in postholders in the new organisation having personal development plans delivered where necessary ahead of the individual taking up the new post.

Organisational networks have been established across key functions, which provide a vehicle for common standards of performance, continuous improvement and assurance.

4. Business Process

Several key business processes have been introduced at site during the transformation programme, which fully align with and address key themes identified by the BP Task Force:

- The development of an integrated site wide Health, Safety and Environmental management system had begun prior to 2000, and has been continued with renewed focus on simplicity and user friendliness;
- During 2001, work began on the development of a comprehensive Grangemouth (business) management system, covering all aspects of the site's

business processes and including the Health, Safety and Environmental management system;
- A formal Process Safety Management system and structure was introduced late in 2000. This is now fully incorporated into the organisation with dedicated resources in place;
- Asset care programmes have been refreshed across all areas as part of the transformation programme;
- A new maintenance management system has been introduced along with supporting business processes.

5. Performance Focus

Fundamental to "Securing a Future" was transparency and relentless focus on the performance of the business, namely safety, availability, and cost performance. Clear targets were established and programmes developed to deliver improvement. Daily performance across a suite of business measures is tracked using a simple "Great Day" aggregate measure, forming the basis for day to day conversations about site performance. 90 day safety improvement plans have been introduced to drive safety performance improvement at a local level, deep in the organisation. These enable local ownership for tangible improvement action and the framework for quarter on quarter site level commitments which together have resulted in a step change in performance at site. A broader and balanced set of KPI's has been developed to effect further improvement.

6. Integrated Audit

During 2002, a fully integrated audit programme was developed and piloted. Site wide implementation is underway in 2003. Set against the Grangemouth Management System, the programme fulfils audit requirements across a range of internal and external standards, enabling more effective assurance and governance at site level.

7. Governance

During the implementation of the transformation programme, the site Health, Safety and Environmental governance model was reviewed as part of the overall management of change process. The resulting governance model has two key governance bodies, the Central Health, Safety and Environmental Committee and the Process Safety Committee, working on behalf of the leadership team. Chaired by a Leadership Team member, these committees provide the vehicle through which site policy, strategy and standards are developed and set, and provide assurance that these are being met. Both site level committees have workforce representation and connection into the organisation through the peer groups. Within each availability area, local workplace Health, Safety and Environment committees and Process Safety committees provide local focus on delivery of continuous improvement.

8. Post Investigation - Legal Action

The investigations that have been described in the previous sections result in a picture of the Complex at the time of the incidents which fell short of the BP Group's high expectations for the management of safety and environmental performance.

It should be noted that good fortune played a large part in minimising the consequences of the three incidents and in fatalities or serious injuries being avoided as a result of the incidents which occurred. However the potential for significantly increased damage to property, increased harm to personnel both on and off-site and increased harm to the environment existed.

Following on from the investigations it was considered that BP at the time were in breach of statutory legal requirements and the Competent Authority considered carefully the grounds for prosecution of BP for breaching safety legislation and for prohibition of continuing operation of the Complex or parts of the Complex.

Following the series of incidents and subsequent investigations a report recommending legal proceedings on indictment was prepared and submitted to the Procurator Fiscal, the Scottish public prosecutor (www.procuratorfiscal.gov.uk). Close liaison with the Procurator Fiscal (William Gallacher) had been a feature from the outset of investigations.

The HSE alleged breaches of health and safety law for the FCCU and MP steam rupture incident. In the power distribution failure incident evidence to prove a breach beyond reasonable doubt required for a criminal law case was not available.

Charges recommended to the Procurator Fiscal by the HSE were:

- COMAH Regulation 4 (alternatively Health & Safety at Work etc. Act 1974 Section 2) for the FCCU major accident; and
- Pressure Systems Safety Regulations 2000 (alternatively Health & Safety at Work etc. Act 1974 Section 3) for the MP steam main major accident.

Alternative charges are a feature of Scottish law.

The Procurator Fiscal and Crown Office served an indictment on BP Grangemouth Oil Refinery Limited for breaches of the Health & Safety at Work etc. Act 1974 Section 2 and on BP Chemicals Limited for breaches of the Heath & Safety at Work etc. Act 1974 Section 3.

Indictment procedures are held before a Sheriff and Jury and have unlimited fine potential due to the serious nature of the offence and the size of the company.

The case was heard on indictment in Falkirk Court in front of Sheriff Albert Sheehan on 18th January 2002. BP Chemicals Limited was fined £250,000 for the steam main offence and BP Grangemouth Oil Refinery Limited was fined £750,000 for the FCCU/Cat Cracker offence. BP was heavily criticised by Sheriff Sheehan for "gross dereliction of duties…"

9. Key Lessons for Major Accident Hazard Sites

Based on the investigative work carried out by the Competent Authority and by BP there are three key lessons that should be learned from the incidents at Grangemouth in relation to corporate governance and one lesson specifically relating to utility systems. The Competent Authority believe that if these lessons are learned it will assist the Major Accident Hazard Industry and individual companies to reduce the number of major accidents that occur in line with the HSE's "Revitalising Health and Safety" Strategy.

Lesson 1 - Major accident hazards should be actively managed to allow control and reduction of risks. Control of major accident hazards requires a specific focus on process safety management over and above conventional safety management.

BP have re-evaluated their major accident hazards and improved mechanisms for the management and control of these hazards in order to reduce the risk involved.

The Competent Authority consider that actively managing major accident hazards is consistent with the stated objective of reducing the number of major accidents that occur and would encourage industry to adopt this approach.

BP have recognised the importance of integrating the principles of process safety management into the operation of major hazard sites such as Grangemouth and have augmented existing process safety management systems by the introduction of a Group-wide standard on Process Safety and Integrity Management.

The Competent Authority consider that for major hazard sites, integrating the principles of process safety management into the site management systems is consistent with the stated objective of reducing the number of major accidents that occur and would encourage industry to adopt this approach.

Specific consideration should be given to adopting robust "management of change" procedures with all changes – including organisational changes – being fully evaluated before implementation to ensure that all potential hazards associated with the change have been identified.

Companies should place a greater emphasis on ensuring that a loss of containment does not occur. The integrity of all systems on a major hazard site is essential in order to avoid leaks and spillages that may result in a major accident occurring. Avoiding a loss of containment is important not only for pressure vessels and other large items of plant and equipment but also for the pipework systems which are often not subjected to the same rigorous levels of inspection and maintenance. A reduction in the number of flanges, the removal of dead-legs, a reduction in vibration and the correct securing and supporting of pipework systems can reduce the likelihood of a loss of containment and hence the probability of a major accident occurring.

The success of initiatives in the off-shore industry aimed at the reduction in the number of loss of containment events should be heeded by the on-shore major hazard industries. Failure mechanisms for pipework are already well established and should be well known leading to the conclusion that prevention of such failures should be manageable.

Lesson 2	-	**Companies should develop key performance indicators (KPI's) for major hazards and ensure process safety performance is monitored and reported against these parameters**.

BP has developed a series of KPI's to complement traditional safety statistics in order to highlight the important areas in relation to the control of major accident hazards.

The Competent Authority consider the development of KPI's for process safety to be consistent with the stated objective of reducing the number of major accidents that occur and would encourage industry to adopt this approach. Conventional indicators of safety performance such as "days away from work" (which are high frequency/low consequence events) do not give a measure of process safety relevant to the control of major accidents (which are low frequency/high consequence events) and may give a false impression of process safety performance.

Companies should benchmark their performance in relation to the control of major accident hazards against industry standards. Companies should be monitoring and taking account of industry trends in relation to improvements in safety technology and safety management systems.

Lesson 3	-	**Disruption to utility supply systems (steam, electricity etc.) on a major hazard site can cause significant problems and have the potential to result in a major accident.**

BP have recognised the important issues raised as a result of the power distribution failure and the MP steam main rupture and have re-evaluated their approach to the control of utility supply systems on-site.

The Competent Authority consider that a number of recent power loss incidents (including the incident at BP) have highlighted that power loss incidents have the potential to result in significant safety risks. The vulnerability, reliability and impact of failures of utility systems on major hazards are issues relevant to the preparation of a COMAH safety report and the Competent Authority will require evidence that these issues have been addressed.

10. Wider Messages for Industry

Although the report is predominantly concerned with the series of incidents that occurred at the BP Grangemouth Complex in 2000 it is being published at a time when the HSE has embarked on the "Revitalising Health and Safety" strategy. This strategy aims to "prevent major incidents with catastrophic consequences occurring in high-hazard industries". The opportunity is therefore also taken to remind industry of its responsibilities with some messages from the HSE.

Message 1 - Major hazard industries should ensure that the knowledge available from previous incidents both within their own organisation and externally are incorporated into current safety management systems.

The Competent Authority wish to re-iterate this message since an incident investigation often identifies causes that have previously been identified and reported but for which no action has been taken. Prevention of some major accidents would therefore have been possible with the correct focus.

The Competent Authority considers that industry should be aware of previous major accident histories within their own company and within their industry sector. The conclusions and recommendations from published accident investigation reports are designed to ensure that information is available to a wider audience. Companies need to monitor and close-out actions from these reports to ensure lessons are learned.

For example valuable lessons can be learned from an analysis of historical accident data. Data from Marsh analysing large property damage losses in the hydrocarbon-chemical industries over a thirty year period is available. The lessons from this historical data centre around process safety management issues and "suggest the necessity for a strong safety commitment from senior management as well as local plant management and the need to employ the best available technology to mitigate risk".

In many companies Corporate memory needs to be improved to ensure that the knowledge gained from the incidents of the past is available and heeded by those who are involved today. Each generation of employees should not have to learn anew by repeating the mistakes of the past.

The Competent Authority encourages operators of other major hazard sites to review this report and to incorporate the lessons into their operations.

Message 2 - Operators should give increased focus to major accident prevention into order to ensure serious business risk is controlled and to ensure effective Corporate Governance.

The failure to comply with the requirements of COMAH and the associated major accident potential for a site should be considered as a significant business risk which needs to be addressed as part of effective corporate governance as discussed in the Turnbull Report. Major accidents can prove to be costly in terms of lost production, clean up, fines imposed by the courts and damage to the company reputation as a result of adverse publicity. Major accidents are intolerable to the public, politicians and the regulators. Guidance on the costs of accidents at work is given in the HSE publication HSG96.

The Turnbull report states that directors should, at least annually, review systems of control including risk management, financial, operational and compliance controls that are the key to the fulfilment of the company's business objectives.

The HSE has prepared guidance for directors in order to help them ensure that the health and safety risks arising from their organisation's activities are properly managed. Directors should be fully aware of their corporate responsibilities in relation to the control of major accident hazards. Failure by a corporate body and the directors of a company to adequately manage health and safety can result in prosecution of the company and the individual directors responsible.

As previously stated the underlying causes of major accidents (technical, managerial and human factors) are well established from analysis of hundreds of major accidents worldwide. Directors have a duty to manage these known factors to prevent major accidents.

Message 3 - The COMAH Safety Regime is a "living process" and should be used as a management tool to assist in process safety management

Regular inspection of plant, equipment and safety management systems along with periodic auditing is an essential requirement in the control and prevention of major accidents. Inspection and auditing must be rigorous and targeted at process safety aspects.

The Competent Authority will require evidence of a comprehensive inspection and auditing programme and that it is being rigorously applied during the inspection regime under the COMAH Regulations. Companies should use the inspection and auditing programmes to verify that the descriptions of equipment and management systems contained within the safety reports for major hazard sites are still valid.

The Cullen Report on the Ladbroke Grove rail incident stated the following in relation to safety cases which is relevant to the COMAH safety case regime.

"While it is clear that the safety case can become over bureaucratic, it has the potential to be a valuable tool, by, for example, bringing about a systematic approach to safety and providing a record of management's commitments to safety. The evidence showed that it *(the safety case)* can be a "living document", part of the direct management of safety".

Companies should use safety reports as a "benchmark" against which to monitor and audit compliance and to ensure that safety standards are being maintained.

The Competent Authority consider that human factors is a relevant COMAH issue and require consideration to be given to human factors issues in process safety management and in COMAH safety reports. The Competent Authority has identified inadequate consideration of human factors issues as one of the main causes for the rejection of COMAH safety reports.

Appendix 1 - Descriptions of Processes / Plants or Systems

A1.1 General

This appendix contains background technical information on the processes/plants and/or systems involved in the three incidents described in Section 3 of the main report.

Two of the incidents (power distribution failure and MP steam main rupture) were associated with **"utility systems"** on the Complex whilst the FCCU fire was associated with a **"process plant"**. An explanation of the importance of this distinction is given below.

Industrial sites such as Grangemouth often refer to two different types of activities:

- **Process plants** (also known as processes, chemical plants, manufacturing facilities, processing facilities, units etc.). The Fluidised Catalytic Cracker Unit (FCCU) which was involved in the incident of 10th June 2000 is an example of a process plant.

  Process plants are the locations where the chemicals (crude oil, petrol, diesel, gas oil etc.) are handled and where either physical processes (such as separations) and/or chemical reactions are carried out. These are often complex installations handling a variety of chemicals in different states (gaseous, liquid or solid) and at varying operating conditions (for example, high or low temperatures and pressures).

  Process plants have to be carefully designed, and then operated, maintained and controlled to ensure that they operate safely since a loss of containment of the chemicals can often result in major safety and environmental consequences. For this reason process plants have many different built-in safety systems designed to prevent accidents, and/or to control and mitigate the effects of accidents should they occur.

  Process plants are normally run by a dedicated team of operators who are trained specifically in the operations of the process plant, have a detailed knowledge of the layout and are trained in emergency procedures. Process plants tend to operate as discrete units during normal situations but tend to rely heavily on the provision of other services (utilities) in order to function.

- **Utility systems** (also known as services, service systems etc.). The medium pressure (MP) steam system and the power distribution system which were involved in the incidents of 27th May and 7th June 2000 respectively are examples of utility systems.

  A "utility system" refers to a basic service (such as electricity, gas, electricity, steam, water, compressed air, nitrogen etc.) which is often provided from a central location such as a power station, water treatment plant etc.

In the case of the Complex the distribution systems for utilities are not under the direct control of, and are not the responsibility of the processing plants. They are maintained by a separate group on-site which in the case of the Complex is the Central Resource Group (CRG). Liaison between processing plants and the CRG is required to ensure the smooth and efficient operation of utility systems and when modifications to utility systems are proposed. The utility systems have to be operated to cope with the changing demands of a number of different process plants on the Complex at any time.

Loss of utility supplies to processing plants can cause significant disruption to process operations (for example loss of steam for heating, water for cooling or electricity for running pumps) and for this reason there are often multiple supplies of utilities or different supply routes in order to minimise the effects of a failure in part of the utility supply system. However in the event of total failure of the utility system then unless dedicated standby facilities are available on a process plant (for example diesel generators to maintain power supplies) it may be necessary to shut down processing facilities in a controlled manner until utility supplies can be restored. In some cases this may lead to processes being interrupted part way through and the requirement to safely shut down the plant may lead to chemicals being routed to flare systems and burnt in order to reduce the potential safety hazard on the process plant. Emergency flaring of chemicals in this manner may lead to "smoky flaring" (black smoke) for a period of time.

Further information is given below to describe in further detail each of the utility systems (Power and MP steam) and the process plant (FCCU) involved in the incidents.

A1.2 Power Distribution Systems

An Introduction to Power Distribution Systems

A large industrial area such as the Complex requires a significant quantity of electricity on a daily basis for a number of different applications – lighting, heating, power for equipment etc.

Electricity generated at power stations which feed into the national grid is available at high voltages (since this is the most efficient means of transporting electricity over large distances) which on arrival at site must then be gradually reduced in voltage to supply the individual requirements of the different users.

The voltage is gradually "stepped down" in electrical sub-stations to provide supplies at different voltages (say 33,000V (33kV) down to 11,000V (11kV) and eventually down to 240V which is the domestic supply voltage).

Electricity is transported in electrical cables which must be designed to the appropriate standards for the voltage to be carried and suitably protected when installed. Cables must be insulated to ensure that electricity does not "leak out" and dissipate into the surroundings. This is a potentially hazardous situation which can result in electrocution if personnel come into contact.

In addition to the protection offered by the insulation additional protection is provided by trips (relays) installed in the electrical sub-stations as circuit breakers.

Circuit breakers such as this operate when they detect unusually high levels of current flowing in the circuits that they are protecting, on the basis that excess current usually indicates that a fault exists. The amount of current flowing is continuously measured by devices called current transformers, which essentially produce a small current that is proportional to the much higher current flowing in the high voltage circuits. The current from the transformers then flows through a device called a protection relay (trip). When this relay senses that the current is too high it sends a signal to the associated circuit breaker to trip and this then cuts off the electricity supply to the distribution system downstream of the protection relay.

Under normal operation the “current” associated with the system will be low. However when there is a fault in the electrical distribution system (caused by loss of insulation, flow of electricity to ground etc.) the current in the system will significantly increase. This will be automatically detected by trips which are pre-set resulting in the safe isolation of the faulty section of the distribution system.

Cables must also be protected from external physical damage by appropriate cladding, identification and route marking etc. since injury/accidents caused by cable strikes on buried underground services are widely reported. Common methods are above ground markers or protective cable tiles which are laid on top of the cable when buried.

The HSE has published guidance on avoiding danger from underground services.

Relay Testing Procedures

Relays must be periodically tested to ensure that they are functional (a procedure known as secondary injection testing). This is essential since a non-functional relay offers no protection. In order to do this the relays are temporarily disconnected from the current transformers. Common practice is to use a proprietary test block for the relay which allows the relay to be disconnected for testing purposes. An alternative if no test block is available is to use temporary plastic inserts which should be removed after the testing has been completed in order to reinstate the protection offered by the relay system.

Failure to remove plastic inserts following testing effectively disconnects the protective trip relay from that part of the system and means that that part of the system can not be isolated. Isolation then has to be provided by other relays located further upstream in the distribution system with the resultant risk that additional sections of the distribution system to that part where the fault is present will also be tripped out.

Power supply systems are covered by the Electricity at Work Regulations (EWR). The HSE has published guidance on safe working practices for electricity.

Power Distribution at the Complex

Electricity is one of the basic utility systems and as such an extensive distribution system is required to distribute power throughout the Complex.

There are a number of different electricity supply sources (Scottish Power, the on-site power station etc.) which feed into a distribution system that supplies power to the users. The supply initially at 275kV is gradually reduced through a number of different steps (33kV, 11kV etc.) suitable to the individual users. A number of different electricity supply cables carrying electricity at different supply voltages cross the Complex to form a site wide distribution system.

In order to minimise the likelihood of power loss to individual facilities or areas of the Complex in the event of a failure in one part of the system a number of different routes are available for the distribution of power throughout the Complex. A series of electrical sub-stations are located throughout the Complex.

Protection is built into the system in the form of automatic trips (relays) installed in the electrical sub-stations which on detection of a fault are designed to isolate the relevant section of the system in order to ensure safety. By tripping out the supply to the relevant faulty section, and by having alternative distribution routes safety can be ensured whilst minimising the disruption caused.

The power distribution failure (27th May 2000) involved a fault which developed on a 33kV feeder cable. Details of the 33kV system are given below.

33kV Feeder Cable

The 33kV feeder cable was a three-phase cable constructed with three internal conductors with 33,000 volts between each conductor and earth. The three phases are traditionally identified by the colours red, yellow and blue. The internal conductors were surrounded by oil-impregnated paper insulation, with an extruded lead sheath over the paper insulation, connected to earth. The sheath itself was covered by earthed steel wire armouring which provided an outer layer of mechanical protection. The wire armouring was then covered by an outer plastic sheath providing protection against corrosion.

The cable was laid at a depth of 750mm alongside other high voltage cables and was partially covered with a reinforced concrete cable tile.

The relay trip facilities were the subject of periodic testing to ensure that they were functional but BP historically did not have proprietary test blocks as described above for the temporary isolation of the relays for testing purposes and the testing procedures followed used the installation of plastic inserts in relays for isolation purposes.

A1.3 Steam Distribution Systems

Steam is another of the basic utility systems and as such an extensive distribution system is required to distribute steam throughout the Complex.

An Introduction to Steam Systems

Steam is an important utility and a useful means of transporting stored energy around a site for use as a heating media in processes and offices. Steam generated in boiler plants can be distributed around site at a variety of pressures and temperature (commonly known as HP – High Pressure steam, MP – Medium Pressure steam, LP - Low Pressure steam etc.) depending on the required use, equipment design specification etc. A common feature however is that all steam (as a gas) is at high temperature relative to the surroundings through which the pipework distribution systems pass and that in order to minimise the loss of heat to the surroundings steam mains must be protected by insulation. Steam in distribution systems also travels at high speeds through the pipework.

If cooling occurs in steam mains, as is inevitable due to the long distances frequently involved, then an amount of hot liquid condensate (hot water) is produced as the gas changes back to a liquid. (This is the process where steam being emitted from a kettle condenses on nearby surfaces when rapidly cooled). Liquid condensate occupies less volume than the equivalent mass of steam (a gas) and its presence can cause problems in steam distribution systems. Conveying liquids at high speeds in gas pipelines is undesirable due to the considerable damage that can be caused by the impact of the liquid on fittings such as instruments, valves and bends.

Steam system pipework is protected by a number of different systems. Safety relief valves are installed along lengths of steam main in order to relieve overpressure of steam in the line and hence protect the steam main from catastrophic failure should the steam supply pressure rise. Safety valves for steam are generally designed and sized to relieve steam but not condensate. The presence of safety relief valves on steam systems relieving to atmosphere is clearly visible due to white plumes of steam that are present. Following a steam release to reduce the pressure the safety valves normally re-seat. Safety valves are designed to relieve the pressure allowing for a maximum rate of steam release. The capacity of a safety relief valve to relieve hot liquid condensate is less than that for steam due to the different characteristics of gases and liquids. Safety relief valves are not designed to vent condensate and under these circumstances can not be guaranteed to provide adequate pressure relief for the pipework system concerned.

Heat loss to the surroundings occurs as steam is distributed through long distances of pipework, through machinery and fittings etc. despite lagging and cladding that is designed to minimise the heat loss. As the temperature falls steam can be condensed to form hot liquid condensate. This must be removed from the steam mains in order to prevent flooding of the pipework and the carryover of liquid into instruments, machines and process areas. An extreme condition known as water hammer results in slugs of liquid being conveyed at high velocity through the steam main pipework carried by the steam. The liquid impacts on valves, bends and instrumentation and can cause sudden and catastrophic damage. Removal of condensate is achieved by the installation of steam traps which are designed to capture and then release the condensate from the steam main in a controlled manner. Detailed calculations must be carried out on steam main layouts to correctly size steam traps and safety valves for condensate removal and pressure relief.

Hot condensate is a valuable resource and its collection and return to the steam raising system minimises the quantity of fresh water and energy required for steam raising at the boilers. It is therefore preferable but not always possible to capture and return condensate by means of a condensate return system. Where it is not possible to capture the condensate this is generally released directly to ground. Whilst this does not give rise to any significant environmental concerns since it is only hot water that is being discharged care must be taken when approaching steam traps due to the potential for contact with hot water and scalding/burning which may occur. Steam traps discharging directly to atmosphere are often clearly visible due to a small quantity of accompanying steam which may also be released.

For steam flowing in pipelines an energy balance is achieved whereby fresh steam being fed into the pipeline system from the boilers replaces the steam being fed to the users. The system is effectively balanced with heat losses from the pipework system being replaced by heat input from the distribution system. Condensate should therefore not build up in the steam system. However in the event of the steam system being isolated or in a “dead leg” situation heat loss to the surroundings will still occur but there will be no heat input from fresh steam. As a result steam will cool and condense resulting in gradual condensate build-up unless it is removed.

The design of steam distribution systems requires detailed knowledge and understanding of the mechanisms by which overpressure may be generated and condensate formed and careful design in order to ensure that the steam traps and safety valves are correctly positioned. Precautions against excessive build up of condensate include careful pipe layout and the removal of condensate from dead-legs and low points in the system.

On-going maintenance of the steam supply system is also required in order to ensure that the system is fully functional. Isolation of either safety valves or steam traps impairs the integrity of the overall steam system and introduces the possibility of overpressure or condensate build-up in the steam system.

Steam systems are covered by the Pressure Systems Safety Regulations 2000. The HSE has produced guidance on the safety of pressure systems

Steam Supply at the Complex

Steam is used in large quantities on the Complex for a variety of different purposes including heating. It is generated for the Complex in the main power station which is situated on the North Side of the Complex. Seven water tube boilers generate the steam which is then distributed throughout the Complex by an extensive steam pipework supply system. Steam is exported from the North Side of the Complex to the South Side of the Complex by pipework systems which run beneath Bo’ness road in two separate culverts carrying **g**eneral **e**lectrical and **mec**hanical services known as the West Gemec and East Gemec culverts. Having two supply routes available ensures that in the event of a problem with one of the distribution routes that steam supply can be maintained to the South Side of the Complex.

The steam is originally generated at a pressure of 1850 psi (125 barg) and then reduced in pressure in stages through a system of turbo-alternators, de-superheaters and pressure let down stations into a system of steam distribution pipework headers which give an MP steam supply system at 14 barg (200 psi).

A 450mm (18") MP steam main runs through the West Gemec tunnel and a 700mm (30") main through the East Gemec tunnel. All the pipework (carbon steel) is insulated /clad to minimise the effects of heat loss.

A manifold arrangement on the South Side enables the supply of steam to the chemical plants to be achieved from either of the supply systems. A number of valves on both the North Side and South Side in the vicinity of the two Gemec culverts are associated with the distribution pipework for the steam to allow isolation of various sections of the system as necessary and to ensure the correct routing of steam through the pipework system.

The portion of the pipework systems which run beneath the road essentially form the bottom portion of a "U" of horizontal length 30 metres and vertical drop approximately 6 metres. The pipework runs aboveground adjacent to the Bo'ness road. The culverts are low points compared to the surroundings and are prone to flooding. Pumps are required to keep the water levels in the culverts under control and to prevent the lagging on the steam mains from becoming wet and hence damaged and ineffective.

A1.4 Fluidised Catalytic Cracker Unit (FCCU)

The BP Grangemouth Fluidised Catalytic Cracker Unit (FCCU or Cat Cracker) operates within the Oil Refinery on the North Side of the Complex. The FCCU converts heavy oils into lighter, more volatile materials suitable for use in motor fuels and as chemical feedstocks. The plant was designed for steady state continuous operation and limited start-up and shutdowns were originally anticipated.

The FCCU handles a variety of flammable materials which will readily ignite and therefore careful consideration is given to the elimination of potential ignition sources on and in the vicinity of plant and equipment containing flammable substances by the appropriate design of electrical equipment and the elimination of hot surfaces by insulation of pipework and vessel surfaces.

Prevention of a loss of containment of the chemicals from the process vessels and pipework is a fundamental requirement of the design, operation and maintenance of the FCCU in order to minimise the likelihood of a major accident

In its current configuration the FCCU can process approximately 128 tonnes/hour of "wax" fed from the Vapour Distillation Unit located elsewhere in the Oil Refinery.

Process Description

The FCCU comprises two main sections:

- the "**front end"** where "cracking" is carried out in the reactor/catalyst section. Cracking is the process whereby long chain hydrocarbon molecules (large molecules) are broken down into shorter chain molecules (smaller molecules); and
- the "**back end"** (or "**light ends"**) where separation of cracked materials is achieved by passing cracked materials through a series of columns. This process is also known as fractionation.

The FCCU unit has a total inventory of approximately 120 tonnes of flammable materials with most of the inventory being contained within the fractionator train and various separation and process vessels taking the overheads from the fractionators. Due to the inventory of materials the FCCU meets the definition of a "top tier" installation under the COMAH Regulations and therefore a safety report is required to be prepared.

A "simplified" description of FCCU operations is given below. FCCU operations are complex and involve many different recycle and heat recovery systems within the processes described below.

"Front End" – Reactor/Catalyst Section

Heavy oils and steam are fed into a "riser" where they contact an upflowing stream of hot catalyst particles (zeolite). The oils are "cracked" (i.e. broken down) into smaller more volatile compounds and coke (basically carbon) is deposited onto the catalyst particles. There is a significant heat loss from this part of the reaction. The mixture of hydrocarbon gases, steam and catalyst pass from the "riser" to the cyclones where the catalyst is separated from the gases. The catalyst drops into the stripping section of the reactor where residual hydrocarbons are stripped off the catalyst by steam. The catalyst then flows to the Regenerator where the carbon is burnt off by a stream of air and the carbon is oxidised to give carbon monoxide (CO), which is then further oxidised to give carbon dioxide in the new CO-boiler. The overall coke oxidation process is highly exothermic and produces adequate heat to counteract the heat loss in the cracking reaction, and to provide a source of heat for the columns in the "back end" section of the plant

The "front end" of the FCCU process is represented schematically in the figure below.

Figure A

FCCU Front End

"Back End" – "Light Ends"/Fractionation

From the cyclones and the Reactor the hydrocarbon gases and steam pass to the "light ends" section consisting of a number of fractionation columns. The purpose of this section is to separate the newly formed reactor products into various distillation fractions such as fuel gas, LPG and components for blending into motor spirit, diesel, gas oil and fuel oil. A number of different columns are present in this section for the separation of individual products.

Main fractionating column (E1)
The Main Fractionator operates at high temperature (about 500^{o}C), low pressure (0.4 barg) and separates the incoming feed from the "front end" section of the plant into a number of different product streams including gasoline, light gas oil, heavy gas oil and decanted oils. The overhead vapours which come off the top of the fractionating column are partially condensed, the liquid collected in a reflux drum, the gases compressed and cooled and the condensed liquids are combined with the liquids in the reflux drum. The wet gases are routed via a compressor into the Vapour Recovery Unit which consists of a number of additional columns identified below.
Absorber/stripper column (E4)
The overhead product from the Main Fractionator is contacted with a stream of wash oil. The unabsorbed gases pass from the top of the column into the Oil Refinery fuel gas system or to the flare system. The liquid from the base of the column is pumped to the next column.
Debutaniser column (E5)
The column which operates at about 12 barg and 190^{o}C takes feed from E4. The LPG components (propane/butane) are distilled off the top of the column as a mixture and fed into the Depropaniser column (E7) – see below. The heavier material (Debutaniser bottoms) which is similar to petrol is removed from the base of the column and routed into the Re-run column (E6).
Re-run column (E6)
Debutaniser bottoms are fed into the rerun column via a heat exchanger (C25) before being "flashed" across a control valve. *("flashing" refers to the instantaneous change of state from liquid to gas that occurs when liquid is fed through a control valve which drops the pressure of the liquid and the temperature of the liquid on the downstream side of the control valve is then greater than the boiling point of the liquid at that new pressure).* In the Re-run column the feed is separated into light and heavy gasoline products and a residue which is recycled from the base of the tower. This is a low pressure column operating typically at about 2 barg.
Depropaniser column (E7)
The feed from the Debutaniser column (E5) is separated and used as either chemical feedstocks or blended into LPG products from other parts of the Complex. This column is also operated at around 12 barg.

BP has classified the whole of the Vapour Recovery Unit (VRU) ("back end" of the FCCU) as Zone 2 for electrical classification purposes with a few Zone 1 areas. There are no Zone 0 areas. The electrical equipment is appropriately certified for use in such areas. *(Zone 2 indicates a zone in which a flammable atmosphere is not likely to occur in normal operation and if it does occur only exist for a short time. Zone 1 indicates a zone in which a flammable atmosphere is likely to occur for a short period of time during normal operation. Zone 0 indicates a zone in which a flammable atmosphere is likely to be continuously present or present for long periods).*

The "back end" of the FCCU process is represented schematically in the figure below.

Figure B

FCCU Back End

Plant Control

The plant is controlled by a "distributed control system" (DCS) located in the Central Control Building (CCB) sited 400m to the south east of the plant. Significant manual intervention is also required on the plant particularly during start up and shut down of the plant.

Plant History

Since it was designed, constructed and commissioned in 1951 various modifications have been carried out on the plant. The original FCCU was designed to process approximately 60 tonnes/hour.

1974	The unit was changed to incorporate "riser cracking", where the reaction takes place in the reactor riser rather than in the main reactor vessel itself. This allowed the plant to take advantage of more active catalysts.
1987	The unit was modified further to increase its throughput to the present capacity (approximately128 tonnes/hr). This project included modification of the pipeline between the Debutaniser (E5) and Re-run (E6) columns with the provision of a preheater for the E6 column.
1989	The plant was re-instrumented with a DCS system as part of a process instrumentation project.
1996	A Stage 1 revamp project was carried out to improve the environmental performance of the unit in response to new legislation covering particulate emissions. This involved the installation of 3rd and 4th stage cyclones to the Regenerator for enhanced catalyst recovery and the installation of a carbon monoxide (CO) boiler for energy conservation and associated improved steam generation capacity. As part of this project the drainage of the unit was improved and improvements and repairs to fire resistant insulation on the structural steel also took place.

1998	A Stage 2 revamp project was undertaken in order to enable the unit to address future feedstock requirements (lower quality feed/heavier feedstock). This required major changes to the reaction section of the unit, including a new reactor and riser assembly, new air blowers and extensive modifications to the waste heat recovery systems and the main fractionator overhead system. The Stage 2 revamp project also installed remote isolation valves in those sections of the plant where significant modifications were introduced. At the same time improvements to the plant's relief systems were also carried out as part of an Oil Refinery Relief Project. At the time of the Stage 2 revamp a Stage 3 revamp was envisaged for 2003 which would have resulted in extensive modification and improvements to the Fractionation section. Many proposed changes were deferred for later consideration and possible inclusion in the Stage 3 revamp project. At this stage significant changes to the inventory isolation systems for the VRU were expected to take place.

Overall the "front end" section of the FCCU had been significantly revamped since commissioning (especially in 1998) but the "back end" however had not been subject to large-scale modifications and was largely the original design/installation with the exception of the pre-heater which had been installed on the E5/E6 transfer line in 1987.

Figure C

Columns

Appendix 2 - Previous HSE and SEPA Involvement

A2.1 Overall Responsibility

The Complex is subject to many different legislative requirements across the full range of its activities for both conventional safety, process safety and the environment.

Until the COMAH Regulations came into force on 1st April 1999, the HSE and SEPA operated completely separate inspection regimes. From 1st April 1999 the HSE and SEPA jointly form the Competent Authority as defined under the COMAH Regulations. A Memorandum of Understanding defines the responsibilities of the two bodies. Under the terms of the agreement SEPA were involved in the Competent Authority investigations that took place following the incidents but it was agreed that the HSE would take the lead as safety issues were predominant.

A2.2 HSE – History of Involvement

The HSE has been the primary regulatory authority at the Complex for health and safety legislation for many years and has a long history of involvement on-site under different legislative banners ranging from the Factories Act 1961, through the Health & Safety at Work etc. Act 1974 and the Control of Industrial Major Accident Hazards (CIMAH) 1984 Regulations to the Control of Major Accident Hazard Regulations (COMAH) 1999.

The CIMAH Regulations 1984 came into affect following a series of major accidents in Europe, including the Flixborough major accident in 1974 in Britain. This led to the Advisory Committee on Major Hazards (ACMH) reporting to the UK parliament in the late 1970's. The CIMAH Regulations evolved from the ACMH and the Seveso I Directive from the EC. *(The Directive followed the major accident at the ICMESA plant in Italy in 1976 which involved the accidental production and release of a dioxin as an unwanted by-product from a runaway chemical reaction. This led to widespread contamination of the surrounding area. This major accident was the catalyst for improving safety legislation across the European Community.*)

The HSE also inspects and enforces "conventional" health and safety issues such as workplace transport, falls from height, confined spaces, asbestos etc which are generally covered under the Health & Safety at Work etc. Act 1974.

Primary regulatory responsibility within the HSE for the Complex lies within Land Division and the Hazardous Installations Directorate (HID) of the HSE. HID Land Division is concerned primarily with on-shore chemical processing facilities and the implementation of the COMAH Regulations across the Complex.

The HSE and health and safety legislation is a "reserved" matter for the Westminster Parliament. Following Scottish devolution however SEPA reports to the Scottish Ministers and Executive.

Since the formation of the Scottish Executive the HSE in Scotland has liaised directly with the Scottish Executive. A framework to guide the working relationship between the HSE and the Scottish Executive has been developed in the form of a Concordat. The objective of the Concordat is to ensure that the roles and responsibilities of the two organisations in the new constitutional structure are effectively translated into practical working arrangements between the two organisations.

Ministers from both the Scottish Assembly and Westminster, and MPs and MSPs, expressed concern at the major accidents and BP's performance. The HSE and SEPA gave regular briefings to them throughout the post-incident investigation phase.

Due to the range and extent of the hazards presented by the Complex there was a regular dialogue between the HSE and BP prior to the series of incidents which occurred and the HSE were present on-site on a regular basis. The Complex is complicated to regulate and involvement on-site from the HSE/SEPA prior to the series of incidents was already found to be increasing. Additional resource was necessary to carry out both the pro-active (for example, a new inspection strategy and plan had been developed to handle major accident topics) and the reactive regulatory activities required (for example, involvement in incident investigations).

A2.3 COMAH

The COMAH Regulations are a "permissioning regime" that is designed to ensure that for sites with a major accident potential that high standards are achieved. In this case the "COMAH permissioning regime" requires the company to document in advance the hazards, risks and measures to eliminate or control them (in the form of a safety report). The Competent Authority has a duty to examine the safety report and report the results of the examination to the operator.

A requirement of the COMAH Regulations is that a major hazard site such as the Complex is required to prepare a series of safety reports for the installations present on-site to demonstrate safe and environmentally sound operation during the life cycle of facilities processing or storing dangerous substances.

The COMAH safety report is required to identify the potential for major accidents and describe the measures in place for preventing such accidents and limiting the consequences of any which do occur. The safety report is evidence that an operator has carefully scrutinised the preventative and control measures.

These safety reports (which are submitted to the Competent Authority for assessment and intended to be placed onto a public register) are a public statement by the company of the mechanisms that are in place on-site for the prevention of major accidents. Details to be provided in safety reports include not only technical measures but also the safety management systems that are in place.

The key requirement of a safety report is to demonstrate that the all measures necessary to prevent major accidents and to limit the consequences to people and the environment of any that do occur have been taken. The safety report provides the

Competent Authority with a comprehensive description of the establishment, its surroundings, the associated risks and the control measures in place to enable verification of safety management systems by inspection over a 5 year period.

The safety reports comprised a three level report – BP Group, Grangemouth establishment and 28 top tier installation reports, and were submitted by BP in February 2000 as legally required. Initial examination by the Competent Authority identified significant weaknesses, which BP agreed to revise and resubmit, with an agreed resubmission timescale plan.

The failure of safety reports to meet the required standard did not necessarily equate with an unsafe site. If the examination had identified serious deficiencies in the safety report the Competent Authority had a duty to prohibit operations under COMAH Regulation 18. The problem was genuine difficulty in meeting the higher standards of "demonstration" evidence (that is demonstrate in writing that all measures necessary to prevent or minimise major accidents are in place) which COMAH required compared to the previous CIMAH safety regime.

BP was not alone in the on-shore major hazard industry in having such difficulties with safety reports. Some of the simpler BP COMAH "top tier" sites safety reports did pass examination by the Competent Authority. The problem was the complexity of the multi-installation safety reports.

The Competent Authority examination of the resubmitted reports resulted in the issue of an improvement notice on 31st May 2001, with a compliance date of 1st May 2002. Similar improvement notices were also issued to other operators.

Further discussion took place with BP leading to a meeting at the headquarters of BP in London (Britannic House) on 23rd November 2001 which agreed a way forward to enable BP safety reports to meet the required standard. Under the provisions of the Health & Safety at Work etc. Act 1974 BP formally requested a further extension to the compliance date in order to allow a phased re-submission of the safety reports. The Competent Authority extended the improvement notice until the end of July 2003, with the first safety reports being required to be re-submitted at the end of June 2002.

If a major accident occurs (as defined under the COMAH Regulations) the Competent Authority has a duty to investigate the circumstances surrounding the incident and to produce a public report so that lessons can be learned. COMAH Regulation 19 clearly identifies the inspection and investigation duties of the Competent Authority.

Parallels can be seen between the COMAH safety report regime for the major hazard industries and the issues raised during Lord Cullen's enquiry into the Ladbroke Grove rail incident. Lessons can be learned in terms of industry regulation, safety leadership and the safety report regime.

A2.4 HSE – Current Inspection Regime at Grangemouth

The Complex is regulated by inspectors from the HSE - Hazardous Installations Directorate (HID) – Land Division, based in Edinburgh.

HSE Edinburgh
Belford House
59 Belford Road
Edinburgh
EH4 3UE

HID uses the Chemical & Downstream Oil Industry Forum (CDOIF) and the Refinery Issues Group (RIG) to develop intelligence and communicate issues within Land Division, to other regulators and with the industry and employee representatives.

The Refinery Issues Group (RIG)/Refinery Sector assists and provides guidance for the direction of inspection methodology for refineries such as Grangemouth.

The RIG consists of an HSE peer group of HM Principal Inspectors and technical specialists who provide a:

- Coordinated review of the inspection plans across all the main refineries in the UK. Arising from the Lord Cullen Ladbroke Grove railway investigation report and the HSE prior role investigation reports into BP Grangemouth, Conoco and CSG COMAH major accidents in 2000/2001 a commitment has been made to review the inspection strategy and inspection methods for refineries and the most complex “top tier” multi installation sites, and consider if any changes are necessary to meet the COMAH Regulation 19 duty on the Competent Authority to have an adequate system of inspection;

- Coordinated approach to major hazard installations e.g. HF Alkylation: PLPG etc. Sub-groups have been formed to analyse HF Alkylation units and Fluidised Catalytic Cracker Units.

For BP Grangemouth, and certain other large multi-site companies such as Transco (formerly British Gas), and Calor Gas, the HSE operates a Lead Unit system (previously known as the HSE Lead Unit Principal Inspector system). For these companies the HSE Lead Unit Coordinating Inspector ensures consistent approach to inspection of these companies, and ensures impact at senior management levels.

A team of HSE Inspectors report to an HSE Principal Inspector with overall responsibility for the Complex. Under the COMAH Regulations there is a duty on the competent authority to “organise an adequate system of inspections of establishments or other measures of control appropriate to the type of establishment concerned”. Accordingly the HSE team carries out a programme of routine scheduled inspection visits of the Complex and facilities and investigations into incidents, working to an inspection plan.

The strategy underpinning the inspection plan recognised that risk controls in refinery operations could be improved and listed around 30 topics for inspection. A major thrust of the strategy was to target senior BP management to improve their management controls and the HSE Principal Inspector had discussed the strategy with the Complex Director and with Trade Union safety representatives prior to the incidents occurring, thus raising awareness in advance of inspection.

The Complex is subject to a wide range of legislative compliance requirements for which the HSE is responsible as the regulatory authority. Legislation relevant to the investigations at the time of the incidents was:

- Health & Safety at Work etc. Act 1974;
- Management of Health and Safety at Work Regulations 1999;
- Control of Major Accident Hazards (COMAH) 1999;
- Control of Industrial Major Accident Hazards (CIMAH) 1984.

  CIMAH/COMAH are relevant to all three incidents. At the time of the incidents not all the COMAH safety reports had been submitted or accepted by the Competent Authority and therefore the Complex was subject to both the requirements of CIMAH and COMAH.

- Pressure Systems Safety Regulations 2000 (PSSR)
  Relevant to the MP steam main rupture incident;
- Construction Design and Management Regulations 1994 (CDM)
  Relevant to the power distribution failure incident;
- Electricity at Work Regulations 1989 (EWR)
  Relevant to the power distribution failure incident.

Enforcement

The HSC (Health and Safety Commission) enforcement policy statement forms the basis for enforcement decisions. Enforcement strategy encompasses verbal advice, written recommendations to achieve action, enforcement notices (improvement and prohibition) and prosecutions. Notices and prosecution are known as formal enforcement. Prohibition notices are intended to ensure that the process or activity is not continued until adequate controls are in place. Improvement notices are designed to gain improvements in health and safety law compliance within fixed timescales. Prosecution may result in fines on companies for breaching health and safety law.

In addition to the HSE policy there is a practical enforcement management model (EMM), which assists enforcement decisions to ensure consistency, proportionality and that the appropriate enforcement decision is made (See www.hse.gov.uk/enforce/emm.pdf).

A recent history of regulatory involvement and enforcement action taken by the HSE on-site is given below.

Previous Incidents

Between July 1999 and June 2000 seven separate incidents occurred at BP Grangemouth each with significant off-site implications. These were investigated by the HSE and are summarised below:

- 27th July 1999 - 33kV Interconnector Trip
  A commissioning error on a new interconnector led to site wide loss of electricity supply. This subsequently resulted in loss of steam, shutdowns of plants and significant flaring.
- 20th November 1999 - FCCU upset during start-up. ("torch oil explosion")
  Whilst attempting to restart the FCCU from an abnormal state an overpressure event occurred in the ducting.
- 28th December 1999 - Demineralised Water
  An ion exchange bed collapsed due to high pressure drop leading to an effluent excursion.
- 20th January 2000 - Multiple steam boiler trips
  A cascade trip of steam boilers resulted in Complex wide shutdowns and fire damage to a boiler.
- 29th May 2000 - Power distribution failure
- 7th June 2000 - MP steam main rupture
- 10th June 2000 - FCCU fire

Previous Enforcement Actions for the BP Oil Grangemouth Refinery Limited

Three enforcement actions have been taken for the BP Oil Grangemouth Refinery Limited since 1988.

- In a prosecution in 1988, the Oil Refinery was fined £250,000 for a fatal incident in connection with a flare line and £500,000 for a fatal incident following an explosion in a hydrocracker.
- December 1994 - The Company was prosecuted for a fire in a crude oil distillation unit and fined £50,000.
- August 1996 - There was an unsuccessful prosecution over asbestos.

Improvement Notices issued to the BP Oil Grangemouth Refinery Limited

A number of improvement notices have been issued to BP Oil Grangemouth Refinery Limited since 1998.

- October 1998 - Three improvement notices were issued relating to:
  - Monitoring jetty loading operations following an incident (this was an EC reportable unignited propylene release);
  - Maintenance of jetty loading equipment;
  - Adequacy of training for jetty loading operations.
- December 1999 - A system to identify major hazards arising from abnormal operations following the torch oil explosion in November 1999.

- March 2000 - Pressurised LPG storage – the improvement notice was issued on a very complex ALARP issue. Initially BP appealed to an Employment Tribunal before withdrawing the appeal and presenting alternative options for compliance to the Competent Authority which were accepted. The improvement notice was formally extended until May 2003. BP complied by the due date.
- July 2000 - Asbestos control resulting from a fire on the FCCU.

Previous Enforcement Actions for BP Chemicals Limited, Grangemouth

Two enforcement actions have been taken for BP Chemicals Limited, Grangemouth since 1999.

- July 1999 - Prosecution for asbestos.
- September 2000 - Prosecution following a finger amputation.

A2.5 Post – Incident Review of HSE Involvement

Following the series of incidents a “Level 1” Major Accident Investigation was instigated by the HSE.

As part of the “Level 1” Major Accident Investigation, it is standard HSE practice to investigate the “prior role” at the Complex to check if HSE/HID procedures were adequately followed, and if any lessons can be learned. The investigation leader was the Head of Land Division Unit 3 based in Liverpool to give independence from the unit in Edinburgh which routinely inspects the Complex.

The investigation concluded that the inspection team had delivered an inspection programme broadly in line with the HID requirements but it was limited by the resources available (this had previously been identified and steps taken to resolve HSE Inspector resource). The Refineries Industry Group (RIG), an HSE group, who meet to share experience on inspection activity at refineries, had previously expressed concern over the inconsistency of strategy for the refinery industry and work was underway to increase the impact of inspection across the refinery industry.

The BP Group and Grangemouth inspection strategy and plan was found to be in line with other refinery inspection resourcing and systems and was considered an adequate system of inspection under COMAH Regulation 19.

It was recognised in HID that refineries and petrochemical complexes are amongst the most complex and challenging inspection systems for a regulator to deliver impact. For this reason allied with Lord Cullen’s report into the Ladbroke Grove rail crash, which examined the safety inspection regime, HID took the opportunity to review COMAH Regulation 19 inspection systems via an Inspection Working Group of RIG.

A2.6 Current HSE National Initiatives

"Revitalising Health and Safety" Strategy

The "Revitalising Health and Safety" strategy document from the HSE sets a goal to "prevent major incidents with catastrophic consequences occurring in high-hazard industries" and sets a target of "a 20% reduction in RIDDOR dangerous occurrences and COMAH Regulation 21 major accidents (accidents of sufficient seriousness to require notification to the European Commission)" by 2004.

Loss of Containment/Pipework Initiative

A pipework maintenance and loss of containment initiative for on-shore facilities (mirroring the HSE/Industry offshore hydrocarbon release reduction project) was started in April 2002.

Occupied Buildings National Project

Concerns over the standards of occupied buildings on major hazards sites were raised first in the UK following the Flixborough (Nypro UK) major explosion accident (1st June 1974) and were also a major issue in the major accident at Hickson & Welch Ltd, Castleford, Yorkshire (21st September 1992).

CIA Guidelines were first published in 1979 (*An approach to the categorisation of process plant hazard and control building design*).

The complexity of the issues, the potential costs of resolution and the need for development of a risk assessment methodology resulted in a time lag until 26th June 2001 when further CIA guidelines were issued with the agreement of the HSE.

Under the "Revitalising Health and Safety" strategy a target has been set for "all occupied buildings to comply with Chemical Industry Association guidance on the design of occupied buildings for chemical manufacturing sites" by March 2006.

Competent Authority Steering Group

Competent Authority tripartite steering group (HSE/EA/SEPA) meetings have been regularly held since implementation of the COMAH Regulations. A number of important national projects have been compiled under the umbrella of the single implementation project (SIP).

Examples include – Lead Unit / Industry sectors work planning; joint enforcement policy; major accident investigation policy; emergency planning strategy; domino strategy; national security.

In addition in Scotland there has been a Competent Authority (HSE/SEPA) working group operating prior to the implementation date of the regulations, to give practical effect to the formal Memorandum of Understanding between the two organisations. Examples include agreements on inspection methodologies and priorities, and ways to ensure consistency of approach between the two parts of the Competent Authority.

Human Factors Team Initiatives

The HID Human Factors team was set up in 1999 to focus on an area recognised to represent significant opportunities to improve industry importance. The Human Factors Team, whose experience includes a mix of psychology, ergonomics and industrial safety management; is a "one-stop-shop" for the directorate involved in:

- Direct support for field teams in inspections and enforcement;
- Training, operational policy and guidance for HSE Inspectors;
- External promotion and publications;
- COMAH safety report assessment.

Areas where there has been particular demand for the Human Factors Team's support have included:

- Organisational change and demanning;
- Ergonomics in the design of safety-critical systems, such as alarms;
- Safety culture;
- Competence;
- Management of fatigue.

The team also support the HSE's Field Operations Directorate, particularly the Railways Inspectorate.

A2.7 Scottish Environment Protection Agency (SEPA)

The Scottish Environment Protection Agency (SEPA) is the public body responsible for environmental protection in Scotland.

The main aim of SEPA is "to provide an efficient and integrated environmental protection system for Scotland which will both improve the environment and contribute to the Government's goal of sustainable development".

More detail about SEPA can be found on the website www.sepa.org.uk.

SEPA similar to the HSE have a long history of involvement at BP Grangemouth. The regulatory framework for the environment relevant to the Complex at the time of the incidents was Integrated Pollution Control under the Environmental Protection Act 1990.

At the time of the incidents SEPA had the lead responsibility to control discharges (to land, air and water) from the larger and more complex "prescribed", "scheduled" or "Part A" processes through Integrated Pollution Control (IPC) authorisations, of which there were around 200 in force in Scotland. Regular reviews of IPC authorisations ensure continual improvement in environmental performance, either through changes in management systems or the installation of new technologies as they become available.

Following investigations carried out by SEPA in the aftermath of the incidents no significant environmental impact was identified.

The EC Directive 96/61/EC on Integrated Pollution and Control (IPPC) is being implemented under the Pollution Prevention and Control Act 1999. Under the Act the existing IPC regime is being replaced by a new Pollution Prevention and Control (PPC) regime. SEPA have the responsibility for the implementation of PPC in Scotland.

The requirements of the Directive are based on the IPC regime. However there are a number of differences:

- A wider definition of emission, to include noise, vibration, heat and energy as well as substances;
- A requirement to take raw material use into account;
- A requirement to consider the prevention of incidents;
- A requirement to consider waste minimisation;
- A requirement to consider energy efficiency;
- Requirements to include contaminated land, site restoration and permit surrenders;
- A new pollution emissions register;
- Assessment of installations rather than individual processes;
- Use of Best Available Techniques (BAT).

SEPA is also the regulatory authority charged with implementing the requirements of the Radioactive Substances Act 1993. This Act requires registration for the use of radioactive materials, and authorisation for the storage and disposal of radioactive wastes. The purpose of this Act is to protect the environment by controlling the use of radioactive substances, including the generation of waste and proper disposal of any such waste. BP hold valid registrations for use and keeping of closed radioactive sources at the Complex. Most of the registered sources on-site are used for non-intrusive measurement of levels within vessels.

Appendix 3 – BP Investigations

A3.1 Getting HSE Right (GHSER)

"Getting HSE Right (GHSER)" is BP's Health, Safety and Environmental Management System Framework and sets out expectations for delivery of health, safety and environmental performance.

BP's pledge is to demonstrate respect for the natural environment and to work to achieve the goals of no accidents, no harm to people and no damage to the environment.

One element of the HSE investigation into the series of incidents at the Complex included a comparison against BP's expectations as defined in "Getting HSE Right (GHSER)".

"Getting HSE Right – a guide for BP managers" describes the BP Health, Safety and Environment Management System Framework and the Key Processes which support the Health, Safety and Environmental Expectations to be adopted by all BP managers. They are the boundaries within which all BP managers must operate. The guide is available in full and can be downloaded from the BP website (www.bp.com).

There are thirteen elements to the BP Health, Safety and Environmental Management Systems Framework

1. Leadership and accountability
2. Risk assessment and management
3. People, training and behaviours
4. Working with contractors and others
5. Facilities, design and construction
6. Operations and maintenance
7. Management of change
8. Information and documentation
9. Customers and products
10. Community and stakeholder awareness
11. Crisis and emergency management
12. Incidents, analysis and prevention
13. Assessment, assurance and improvement

In order to be compliant with and to achieve the overall stated objectives of the BP Group strategy the requirements of "Getting HSE Right (GHSER)" must be translated by the Complex across the different Business Streams and Central Resource Groups and into local arrangements.

A3.2 BP Incident Investigation

In response to each of the incidents BP carried out their own independent investigations which were lead by BP senior managers with appropriate experience based at other BP sites throughout the world. BP followed in-house procedures which required an investigation of incidents of this nature to be carried out and followed internal guidelines for nature and scope of the investigations.

Additional expertise was draughted into the investigation teams either from within the BP organisation or externally if appropriate expertise was not available within (for example an independent specialist in condensation induced water hammer was contracted to provide specialist advice in the MP steam main rupture incident).

Although the focus of the BP incident investigations was different from that of the HSE investigations there was close cooperation between the incident investigation teams and a sharing of information. There was generally a close agreement between the findings of the different investigation teams.

In response to the findings of the BP incident investigation teams the Complex carried out the following actions for each of the incidents.

Power Distribution Failure

- BP operating teams conducted appropriate risk assessments before re-establishing power circuits and re-starting plants;
- BP set up a new Power Systems team, responsible for power generation, power distribution and power systems development across the whole of the Complex. The work was previously carried out by a number of separate groups.

MP Steam Main Rupture

- BP repaired all the damage immediately;
- BP launched an extensive inspection and pressure testing programme to ensure the integrity of the entire steam system on the South Side of the Complex;
- BP checked the design, installation and operation of steam traps around the culverts before recommissioning;
- BP set about improving the pumping and condensate draining arrangements in the Power Station, to prevent future flooding of the culverts,
- BP reviewed their procedures for the safe operation and maintenance of steam lines and implemented a full training programme for staff. Including a procedure for inspections following steam system upsets.

FCCU Fire

- BP operations and inspection teams checked all plants to verify that all pipework support complied with BP engineering standards;

- BP issued a new emergency response site wide procedure to address handling asbestos and ceramic fibres during emergencies;
- BP decided that the FCCU would remain shut down until the Complex had completed a full review of all future options.

Further details of BP's response to the incidents can be found from the BP website (www.bp.com).

A3.3 Process and Operations Task Force Audit Team

The number and nature of the incidents that had occurred within a short period of time raised concerns internally, from the Competent Authority and the general public over the standards that were currently being applied to safety across the whole Complex.

In addition to the three BP incident investigation teams described above BP also set up a BP Task Force of experts from outside the Complex in order to complete a fundamental process and operations review of each facility including utilities areas.

The purpose of the BP Task Force was to provide enhanced assurance of safe operation and environmental performance.

The BP Task Force was commissioned on 12th June (Two days after the FCCU incident) and began its work on 16th June 2000. At this time some of the units on-site were shut down following the incidents whilst others remained operational.

Following the series of incidents the first objective of the BP Task Force was to complete an initial survey of the units on-site that were still operational to confirm that they were suitable for continued operation. This was followed by a fundamental process and operations review of each facility including utilities and areas associated with but outside the immediate vicinity of the facility (known as outside battery limits or OSBL).

The BP Task Force used an audit protocol derived from a number of BP documents and relied upon a combination of the audit protocol, their own experience, the information received and a variety of aide memoire lists in carrying out their investigations.

The following topics were reviewed for each operating area:

- Start-up procedures;
- Normal operating procedures;
- Emergency procedures;
- Competency of operating teams including procedures for on-going training and re-certification;
- Mechanical integrity;
- Instrument integrity;
- Electrical system integrity;
- Control system testing;
- Access, lighting and housekeeping standards;
- Existing risk assessment processes (HAZOP, materials of construction, unit start-ups, work permitting);
- Contractor management;
- Recommendations from prior and current incident investigation teams.

The BP Task Force was the largest ever assembled in BP. It involved approximately 30 experts including senior managers from both inside and outside BP (UOP Limited, Eutech etc.) and was lead by a Senior Manager from the USA. The teams included expertise in the areas of safety, mechanical, process, instruments and electrical. Specialist skills from internal or external to the company were seconded onto the team as considered necessary by the BP Task Force team leader.

The only personnel from the Complex involved on the BP Task Force were statutory workforce Trade Union safety representatives.

The review of the Complex was comprehensive and in-depth. All areas of the Complex were fully audited including all the Operational Units, the Central Resource Groups (HS&E/OSG – Operations Support Group) and processes and procedures. In addition the Grangemouth Leadership Team was interviewed and the recent major incidents were also reviewed.

In order to ensure that high priority items could be quickly addressed management and other key personnel received verbal feedback on the initial findings immediately after the audits had taken place. Audit development lists were then compiled and subjected to quality and consistency checks before being forwarded on a weekly basis to the Grangemouth Leadership Team. Actionees and target dates were agreed between the BP Task Force team leader and the Manufacturing Manager before the completed development lists were issued as final. Four man years of work was completed in eight weeks.

All unit and functional area development lists were reviewed at a BP Task Force workshop where they were refined into Complex wide themes. The themes were then presented to the Grangemouth Leadership Team and reviewed by a safety expert from outside BP before being submitted to the Complex Director.

The BP Task Force made a number of recommendations using a priority system ranging from:

- Immediate/prior to start-up (A) items; These items had to be completed and verified by the Manufacturing Manager prior to re-commissioning/start-up;
- Medium term (B) items. These items may be completed after re-commissioning but a proposed target date was set and agreed between the BP Task Force and the Manufacturing Manager who was to subsequently verify completion to the Complex Director by the due date.

Observations were also made and recorded by the BP Task Force where appropriate.

The BP Task Force approach was welcomed by the HSE and complemented the investigations being carried out by the HSE. The sharing of views and information throughout was a welcome feature and reduced the need for an independent HSE audit of the Complex.

A3.4 Summary of the Themes from Task Force Findings

The BP Task Force completed an initial survey of the units continuing to operate and concluded that each unit could safely continue to operate. All other facilities were then fully reviewed.

In the case of units that were shut down at the time of the audit any necessary corrective actions were implemented before units were restarted.

The review identified a number of areas within the Complex where standards were below BP's high expectations but recognised that since the formation of the new Grangemouth Leadership Team in April 2000 standards across the Complex had already begun to be enhanced. However the BP Task Force identified a number of additional recommendations in order to further enhance standards and reduce the probability of a further major incident.

The BP Task Force covered recommendations that were Complex wide, unit specific and covered functional areas.

Complex wide recommendations covered the following general areas;

- Organisational alignment;
- Accountability and assurance for process safety;
- Management of change;
- Inconsistent standards;
- Ownership (full responsibility for all operations, maintenance and development);
- Maintenance and reliability;
- Action tracking;
- Competency assurance;
- Health, safety and environmental assurance;
- Behaviour.

Unit specific recommendations covered the following areas;

- Olefins;
- Polyethylene;
- Polypropylene;
- GTU/Benzene and Ethanol;
- Applied Technology;
- Forties Pipeline Services;
- Oil Refinery;
- Infrastructure (Utilities and distribution, power distribution, power station, logistics etc.).

Recommendations covered the following functional areas;

- Operations Support Group (OSG);
- Commercial;
- Shift managers;
- Human resources;
- Health, safety and the environment.

Further details of the BP Task Force can be found from the BP website (www.bp.com).

A3.5 Study into Root Causes of Accidents

Background

Prior to the series of incidents that occurred in May-June 2000 BP had in place a number of systems for recording information relating to health, safety and environmental incidents.

The Total Loss Control (TLC) database is used within the Complex as the primary means of first raising and then subsequently tracking and recording all incidents (both near misses and those resulting in some form of loss) that occur on the Complex. The system has only been in general use since August 1999 with much of the historical data having been compiled from data previously stored in a number of different database systems.

In addition incidents that have resulted in a serious or major loss/injury are normally subjected to a formal inquiry resulting in the publication of an Incident Report which is reviewed by a Local or Factory Committee of Enquiry. Both the immediate and root causes of the incident are reviewed and appropriate recommendations prepared to avoid any future repetition of the incident. Near miss and minor incidents do not normally require formal investigation but the facility exists when entering the information onto the TLC database to assign immediate and root causes to the incident. A number of pre-determined immediate and root causes are available for selection.

An assessment of both the actual and the potential severity of the incident are required.

Analysis of the recorded incident information is carried out in order to determine the root causes of the incident. This is done in accordance with the BP Comprehensive List of Causes (CLC) approach methodology.

Overall the system should allow data to be recorded and trends to be identified so that lessons can be learned and action taken to ensure that a repetition of incidents is avoided. A consistent approach to the recording and analysis of the incidents is required in order for the system to be effective in fulfilling these requirements. The selection of the immediate and root causes criteria is particularly important if trends are to be identified.

Investigation

Following the series of incidents that took place initial investigations by BP and the Competent Authority identified similar incidents that had occurred previously and several questions therefore arose. Whether the existing system for recording information relating to health, safety and environmental incidents was appropriate? Whether data was being captured/recorded in a consistent format ? Whether suitable analysis was being carried out, lessons learned and actions being taken based on the information gathered that should prevent incidents from recurring ?

In response BP appointed independent consultants as part of a project to back-track through the existing data to determine whether there were any connections and common causes between the incidents and to independently review the effectiveness of the current systems for recording and analysing incidents.

In response a series of independent reports were prepared which looked at a number of different areas:

- A detailed analysis of data extracted from BP's Total Loss Control (TLC) database. This report covered a detailed analysis of all the incidents that had been recorded over the previous 5 years (from 1st January 1995 to 30th June 2000). The primary purpose was to identify if there were any common and increasing trends in the root causes of incidents and the severity. In addition the analysis also reviewed the structure and adequacy of the TLC database as a means of recording incident data;
- A detailed analysis of significant incident reports. A selection of significant incident reports over a twelve month period were reviewed for consistency of approach towards incident investigation, classification, analysis and reporting;
- A detailed analysis of the FCCU incidents since spring 1998. The analysis included a comparison with other FCCU incidents reported worldwide;
- Suggestions for improvements to health, safety and environmental performance at Grangemouth.

As a result of the independent review it was concluded that overall BP Grangemouth has an excellent tool in the TLC database – but not one without faults. A number of issues were identified for the TLC system in relation to data capture, recording and analysis and consequently recommendations were made to BP for improvements.

As a result of the review of the significant incident reports and the FCCU incidents a number of issues were identified in relation to the use and application of risk tools and the management of health, safety and the environment in general at the Complex.

Consequently recommendations were made to BP for areas requiring improvement.

Appendix 4 – Published Guidance

Contents

Alarm Handling

- CHIS6 - HSE Information Sheet: Chemicals Sheet No 6 – Better alarm handling
  To download see www.hse.gov.uk/pubns/chis6.pdf

- EEMUA Guidance - Alarm systems, a guide to design, management and procurement. No 191.
  Engineering Equipment and Materials Users Association 1999
  ISBN 0-8593-1076-0

  The EEMUA guidelines, which the HSE contributes to and recommends, suggest that of the total number of alarms present the split between emergency: high priority: low priority should be 5:15 and 80% respectively.
  Note for the Power Plant the split was found to be 10:70:20

Asbestos

- For further guidance on asbestos and related issues see www.hse.gov.uk/asbestos/index.htm and www.hse.gov.uk/pubns/asbindex.htm

- HSG189/1 - Controlled asbestos stripping techniques for work requiring a licence.
  HSE Books 1999
  ISBN 0-7176-1666-5

- L27 – The control of asbestos at work: Control of Asbestos at Work Regulations 1987 – Approved Code of Practice.
  HSE Books 1999
  ISBN 0-7176-1673-8

- L28 - Work with asbestos insulation, asbestos coating and asbestos insulating board: Control of Asbestos at Work Regulations 1987 - Approved Code of Practice.
  HSE Books 1999
  ISBN 0-7176-1674-6

- INDG223 - Managing asbestos in workplace premises.
  HSE Books 2001
  ISBN 0-7176-1697-5

COMAH

- HSG191 - Emergency Planning for Major Accidents: Control of Major Accident Hazards Regulations 1999.
  HSE Books 1999
  ISBN 0-7176-1695-9
  See also www.hse.gov.uk/hid/land/comah/level3/5c9aa42.htm

- HSG190 – Preparing Safety Reports: Control of Major Accident Hazards Regulations 1999.
  HSE Books 1999
  ISBN 0-7176-1687-8
  See also www.hse.gov.uk/hid/land/comah/level3/5c9aa17.htm

- L111 - A Guide to the Control of Major Accident Hazards Regulations 1999: Guidance on Regulations.
  HSE Books 1999
  ISBN 0-7176-1604-5

- COMAH Safety Report Assessment Manual (SRAM).
  See www.hse.gov.uk/hid/land/comah2/index.htm

- For further details on published guidance on the COMAH legislation see website at
  www.hse.gov.uk/pubns/comah1.htm

- For guidance on the assessment of the technical aspects of COMAH safety reports see www.hse.gov.uk/hid/land/comah/level3/index.htm

Competent Authority

- For more information on how the Competent Authority functions see www.hse.gov.uk/comah/index.htm

Construction (Design and Management) Regulations 1994

- HSG224 - Managing health and safety in construction: Construction (Design and Management) Regulations 1994: Approved code of practice and guidance.
  HSE Books 2001
  ISBN 0-7176-2139-1

  For general information on health and safety in construction see:
- HSG150 – Health and safety in construction
  HSE Books 2001
  ISBN 0-7176-2106-5

Corporate Governance/Directors Responsibilities

- Turnbull Report – "Internal Control: Guidance for Directors on the Combined Code" published by the Institute of Chartered Accountants for England and Wales, September 1999
  ISBN 1-84152-010-1

  This is a practical guide that will ensure that the board of a company is aware of the significant risks faced by their company and the procedures in place to manage them. Executive management is responsible for managing risks through maintaining an effective system of internal control, and the board as a whole is responsible for reporting it.

- See also The Institute of Chartered Accountants website at www.icaew.co.uk for further guidance to directors on the Combined Code on Corporate Governance. See www.icaew.co.uk/internalcontrol.

- INDG343 - Director's responsibilities for health and safety.
  HSE Books 2001
  ISBN 0-7176-2080-8
  To download see www.hse.gov.uk/pubns/indg343.pdf

- HSG96 – The costs of accidents at work
  HSE Books 1997
  ISBN 0-7176-1343-7

Electricity

- HSG85 – Electricity at work: Safe working practices.
  HSE Books 1993
  ISBN 0-7176-0442-X
  See also www.hse.gov.uk/hid/land/comah/level3/5c84120.htm

Electricity at Work Regulations (EWR) 1989

- HSR25 - Memorandum of guidance on the Electricity at Work Regulations 1989: Guidance on Regulations.
  HSE Books 1989
  ISBN 0-7176-1602-9

Emergency Isolation

- CHIS2 - HSE Information Sheet: Chemicals Sheet No 2 - Emergency isolation of process plant in the chemical industry.
  To download see www.hse.gov.uk/pubns/chis2.pdf

The guidance recommends that isolation should be affected from the control room, with alarms provided on plant and in the control room.

- See also www.hse.gov.uk/hid/land/comah/level3/5c7177c.htm for further information on isolation and a list of previous major accidents where isolation was relevant.

- See also www.hse.gov.uk/hid/land/comah/level3/5c724c1.htm for information on the safe isolation of plant and equipment prepared by the Oil Industry Advisory Committee (OIAC).

Emergency Planning

- HSG191 - Emergency Planning for Major Accidents: Control of Major Accident Hazards Regulations 1999.
  HSE Books 1999
  ISBN 0-7176-1695-9
  See also www.hse.gov.uk/hid/land/comah/level3/5c9aa42.htm

- For general information see The UK Emergency Planning Society at www.emergplansoc.org.uk and The Society of Industrial Emergency Services Officers (SIESO) at www.sieso.org.uk

Environment

- Guidance on the interpretation of major accidents to the environment for the purposes of the COMAH Regulations 1999.
  ISBN 0-11-753501-X

  For general information see the following:

  - See European Environment Agency at www.eea.eu.int
  - See Environment Agency at www.environment-agency.gov.uk
  - See Scottish Environment Protection Agency at www.sepa.org.uk

General Information on the Chemical and Oil Industry

- For general information see the following:

- European Chemical Industry Council – CEFIC at www.cefic.org

- Chemical Industries Association – CIA at www.cia.org.uk and also "Sustaining the UK chemical industry" which is available directly from the CIA.

- CONCAWE at www.concawe.be
  See downloadable report – "The Seveso 2 directive and the oil industry" and statistical summaries of reported incidents

- See also "Large Property Damage Losses in the Hydrocarbon - Chemical Industries – A Thirty-Year review. Trends and Analysis", Nineteenth Edition, February 2001. Published by Marsh Risk Consulting.

- American Petroleum Institute – API – at http://api-ec.api.org

- For information on the Responsible Care programme see www.chemical-industry.org.uk

- Institution of Chemical Engineers (IChemE) at www.icheme.org

- "Lessons from Longford (The Esso Gas Plant Explosion)" – Andrew Hopkins. Published by CCH Australia Ltd. Books.
  ISBN 1-86468-4224.

Health and Safety at Work etc. Act 1974

- L1 - A Guide to the Health & Safety at Work etc. Act 1974.
  ISBN 0-7176-0441-1
  See also www.hse.gov.uk/hid/land/comah/level3/5c845d4.htm

Health and Safety Executive

- Prioritising the work of the Health and Safety Commission
  HSE Discussion Document DDE17.
  To download document see www.hse.gov.uk/consult/disdocs/dde17.htm

- Revitalising Health and Safety Strategy Document
  For further information see www.hse.gov.uk/revitalising/what_is/index.htm

- Further details on HSE HID – Land Division are available via the website – www.hse.gov.uk/hid/ which also contains details of the strategic plan for HID for the period 2001-2004.

- Health and Safety Commission Strategic Plan for 2001-2004.
  See http://www.hse.gov.uk/aboutus/plans/hscplans/plan0104.htm

- HSC Enforcement policy statement.
  To download see www.hse.gov.uk/pubns/hsc15.pdf

- The Concordat between the HSE and SEPA can be located at
  www.hse.gov.uk/scotland/scordat.htm

Human Factors

- HSG48 – Reducing error and influencing behaviour.
  HSE Books 1999
  ISBN 0-7176-2452-8
  See also www.hse.gov.uk/hid/land/comah/level3/5c72542.htm

Inspection

- INDG178 - Written schemes of examination. Pressure Systems Safety Regulations 2000
  HSE Books 2002-10-11
  ISBN 0-7176-2269-X

  See also www.hse.gov.uk/hid/land/comah/level3/5c99293.htm

Ladbroke Grove Rail Incident – Lord Cullen Report

- For further information on the general issues arising from the Internal Inquiry into events leading up to the Ladbroke Grove rail incident see www.hse.gov.uk/railways/paddrail/issues.htm

- The train collision at Ladbroke Grove 5 October 1999 – A report of the investigation.
  HSE Books 2000
  ISBN 0-7176-1918-4
  The full report is located at www.hse.gov.uk/railways/paddrail/ladbroke.pdf

- The Ladbroke Grove Rail Inquiry Part 1
  HSE Books 2001
  ISBN 0-7176-2056-5
  The full report is available at http://www.hse.gov.uk/railways/paddrail/lgri1.pdf

- The Ladbroke Grove Rail Inquiry Part 2
  HSE Books 2001
  ISBN 0-7176-2107-3
  The full report is available at http://www.hse.gov.uk/railways/paddrail/lgri2.pdf

Legal Issues

- See the Crown Office and Procurator Fiscal Service at www.crownoffice.gov.uk

Loss of Containment

- For further details of the offshore release project see www.hse.gov.uk/hid/osd/hsr2001

Major Accidents

There have been a number of major incidents in the UK that are relevant to the incidents at BP Grangemouth. These have been investigated by the HSE and public reports have been published. Brief details are given below.

- The Fires and Explosion at BP Oil (Grangemouth) Refinery Ltd: A report of the investigations by the Health & Safety Executive into the fires and explosion at Grangemouth and Dalmeny, Scotland, 13 March, 22 March and 11 June 1987.
  HSE Books 1989
  ISBN: 0-11-885493-3

  See also www.hse.gov.uk/hid/land/comah/level3/5a591a0.htm, www.hse.gov.uk/hid/land/comah/level3/5c99976.htm and www.hse.gov.uk/hid/land/comah/level3/5c99518.htm

- The Fire at Hickson & Welch Limited. A report of the investigation by the Health & Safety Executive into the fatal fire at Hickson & Welch Limited, Castleford on 21 September 1992.
  HSE Books 1994
  ISBN: 0-71-760-702-X

  See also www.hse.gov.uk/hid/land/comah/level3/5a59323.htm

- The Chemical Release and Fire at the Associated Octel Company Limited: A report of the investigation by the Health & Safety Executive into the Chemical Release and Fire at the Associated Octel Company, Ellesmere Port on 1 and 2 February 1994.
  HSE Books 1996
  ISBN: 0-7176-0830-1.

  See also www.hse.gov.uk/hid/land/comah/level3/5a58dc3.htm

- Texaco Refinery, Milford Haven, 24 July 1994: A report of the investigation by the Health & Safety Executive into the explosion and fires on the Pembroke Cracking Company Plant at the Texaco Refinery, Milford Haven on 14 July 1994.

HSE Books 1997
ISBN 0-7176-1413-1

See also www.hse.gov.uk/hid/land/comah/level3/5a58dee.htm

- **BNFL Sellafield**
  The HSE team inspection of the control and supervision of the operations at BNFL's Sellafield plant. See www.hse.gov.uk/nsd/team.htm

- **UKAEA Dounreay**
  Safety Audit of Dounreay 1998 – Final Report 2001
  See www.hse.gov.uk/nsd/auditfin.pdf

Management of Health and Safety at Work Regulations 1999

- L21 - Management of health and safety at work: Management of Health and Safety at Work Regulations 1999 – Approved code of practice and guidance.
  HSE Books
  ISBN: 0-7176-2488-9.

Occupied Buildings

- Guidance for the location and design of occupied building on chemical manufacturing sites
  Chemical Industries Association (CIA)
  ISBN 1-85897-077-6

Permissioning Regimes

- Memorandum of Understanding between HSE and SEPA
  See www.hse.gov.uk/policy/sepamou.htm

- HSE Policy on permisioning regimes
  See www.hse.gov.uk/enforce/permissioning.pdf

- Information on Major Accidents notified to the European Commission by the Competent Authority for April 1999/March 2000 can be obtained from
  www.hse.gov.uk/hid/land/comah/careport.htm

- Regulating higher hazards: Exploring the issues.
  Principles underlying the legal frameworks, as exemplified by the offshore, chemical, rail and nuclear regimes
  HSE Discussion Document DDE 15
  To download document www.hse.gov.uk/consult/disdocs/dde15a.pdf

Permit-to-Work

- INDG98 – Permit to work systems.
  HSE Books 1997
  ISBN 0-7176-1331-3
  See also www.hse.gov.uk/pubns/indg98.pdf

Pressure Systems Safety Regulations 2000 (PSSR)

- L122 - Safety of Pressure Systems. Pressure Systems Safety Regulations 2000 - Approved Code of Practice.
  HSE Books 2000
  ISBN 0-7176-1767-X
  See also www.hse.gov.uk/hid/land/comah/level3/5c9e96a.htm

- INDG261 - Pressure Systems – Safety and you.
  HSE Books 2001
  ISBN 0-7176-1562-6
  See www.hse.gov.uk/pubns/indg261.pdf

RIDDOR

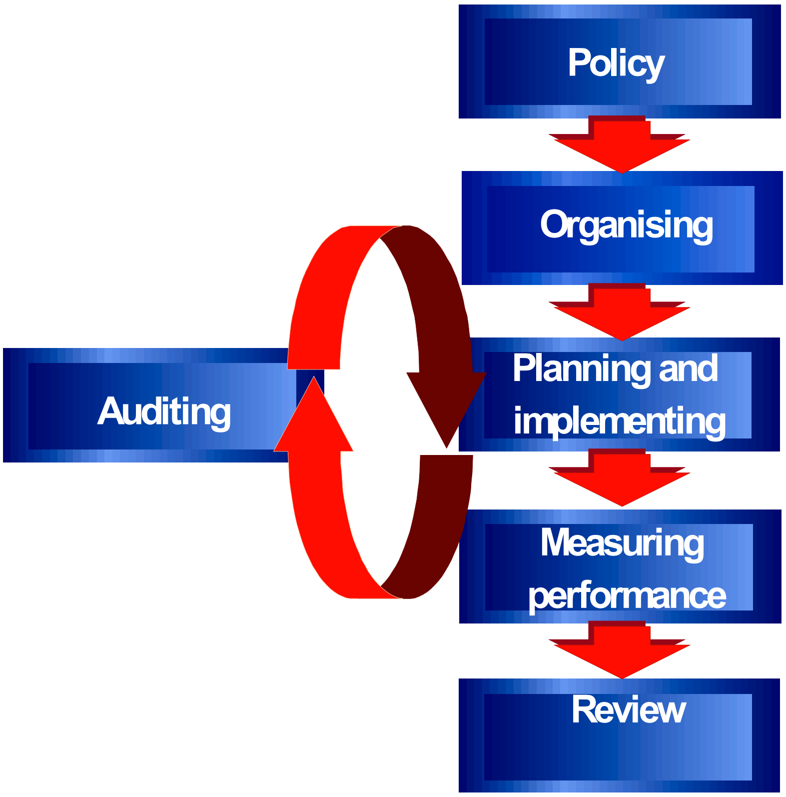
- L73 - A guide to the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995.
  HSE Books 1999
  ISBN 0-7176-2431-5

- HSE31 - RIDDOR explained. Reporting of Injuries, Diseases and Dangerous Occurrences Regulations/ Leaflet.
  HSE Books 1999
  ISBN 0-7176-2441-2

Safety Management

- HSG65 – Successful Health and Safety Management
  HSE Books 1997
  ISBN 0-7176-1276-7
  See also www.hse.gov.uk/hid/land/comah/level3/5c72bcf.htm

  Introduces POPMAR model for successful health and safety management



- INDG275 - Managing Health and Safety: Five steps to success.
  HSE Books 1998

- Essentials of health and safety at work
  HSE Books 1995
  ISBN 0-7176-0838-7

- HSG217 - Involving employees in health and safety – Forming partnerships in the chemical industry
  HSE Books 2001
  ISBN 0-7176-2053-0
  See also www.hse.gov.uk/press/e01127.htm

Seveso II – Major Accidents

- European Process Safety Centre (EPSC) at www.epsc.org.
  Information on the Seveso II Directive (96/82/EC) and the Major Accident Reporting System (MARS) from the EU Major Accidents Hazards Bureau can be accessed via the EPSC website.

- Information on Major Accidents notified to the European Commission by the Competent Authority for April 1999/March 2000 can be obtained from www.hse.gov.uk/hid/land/comah/careport.htm

- See also the European Union online website at www.europa.eu.int

- The "Implementing Seveso II Conference", 6-8 November 2000 is available at www.hse.gov.uk/hid/seveso2 and gives details on a wide range of topics including permissioning regimes and demonstrations.

Technical Papers

- Catastrophic Water Hammer in a Steam Dead Leg – C.Galante (HSE), S.Pointer (HSE) - Loss Prevention Bulletin, IChemE, Issue 167, October 2002.
- "Preventing Major Accidents with catastrophic consequences – a UK goal", G.Adderley, V.Partington, A.McNab and A.Blackmore, HSE, Bootle, Merseyside. 17th Annual Center for Chemical Process Safety (CCPS) International Conference and Workshop – Risk, Reliability and Security, October 8-11, 2002, Jacksonville, Florida.

Tolerability of Risk/Risk Assessment and ALARP

- Reducing Risks – Protecting People (R2P2)
  HSE discussion document DDE11
  Documents available from www.hse.gov.uk/consult/disdocs/dde11.htm

- See also www.hse.gov.uk/dst/alarp1.htm

Underground Services

- HSG47 - Avoiding danger from underground services
  HSE Books 2000
  ISBN 0-7176-1744-0

Utilities

- For general information on the "Reliability of Utilities" see www.hse.gov.uk/hid/land/comah/level3/5c9923d.htm

- For information on the Chemstar Ltd Explosion/Fire see

www.hse.gov.uk/hid/land/comah/level3/5c99a78.htm and also report published by Health and Safety Executive, "The explosion and fire at Chemstar Limited, 6 September, 1981"
ISBN 0-11-883-666-8

- See also "Process Utility Systems", Broughton, 1993, IChemE.

Glossary

Alarm Flooding

Alarm flooding is a condition where alarms appear on the control panels at a rate faster than the operator can comprehend or deal with. Alarm flooding prevents the operator from determining the cause of the process upset or process emergency and therefore limits the scope for effective and quick emergency response.

Alarm system design and alarm "flooding" of operators trying to deal with excessive numbers of alarms and control rooms was an issue in the Texaco Milford Haven Refinery explosion and fire in 1994 which injured 26 people and caused around £48 million in damages and production losses.

ALARP (as low as reasonably practicable)

This is the level to which risks should be controlled. Thus, determining that risks have been reduced to ALARP involves an assessment of the **risk** to be avoided, of the **sacrifice** (in money, time and trouble) involved in taking measures to avoid that risk, and a **comparison** of the two.

This process can involve varying degrees of rigour which will depend on the nature of the hazard, the extent of the risk and the control measures to be adopted. The more systematic the approach, the more rigorous and more transparent it is to the regulator and other interested parties. However, duty-holders (and the regulator) should not be overburdened if such rigour is not warranted. The greater the initial level of risk under consideration, the greater the degree of rigour the HSE requires of the arguments purporting to show that those risks have been reduced ALARP.

ALARP "gross disproportion" test – In any assessment as to whether risks have been reduced ALARP, measures to reduce risk can be ruled out only if the sacrifice involved in taking them would be grossly disproportionate to the benefits of the risk reduction.

For further information on ALARP see website – www.hse.gov.uk/dst/alarp1.htm

Cable Tiles

Cable tiles are lengths of reinforced concrete tiles designed to protect underlying cables and act as depth markers.

Competence

Health and safety competence is the combination of knowledge, skills and experience that ensures roles are fulfilled and tasks completed with due regard to the hazards involved and the risk control measures necessary.

Competent Authority

This is a joint inspection and enforcement body consisting of the HSE and either SEPA (in Scotland), or the EA (in England and Wales).

Condensation Induced Water Hammer

"Condensation induced water hammer" is a rapid condensation event. It could also be aptly termed a rapid steam bubble collapse. It occurs when a steam pocket becomes totally entrapped in sub-cooled condensate. As the trapped steam gives up its heat to the surrounding condensate and pipe walls, the steam changes from a vapour to liquid state. As a liquid, the volume formerly occupied by the steam shrinks by a factor ranging from several hundred to over a thousand, depending on the saturated steam pressure. Likewise, the pressure in the void drops to the saturated vapour pressure of the surrounding condensate. (For example, the saturated vapour pressure of condensate at ambient temperature is less than 1 psia). This leaves a low pressure void in the space formally occupied by the steam. The surrounding condensate still under steam pressure will rush in to fill the void. The resulting collision of condensate generates an over-pressurisation that reverberates throughout the section of pipeline filled with condensate. Since condensate is virtually incompressible, in a collision, it does not give.

The specific factors that influence the severity of condensation induced water hammer are:

- Steam pressure;
- The degree of condensate sub-cooling;
- The pressure of non-condensibles left over in the void;
- The size of the void.

(Kirsner: Heating, Power & Air Conditioning Journal: January 1999)".

Construction, Design and Management Regulations 1994 (CDM)

These Regulations are intended to protect the health and safety of people working in construction, and others who may be affected by their activities, by ensuring good management of construction projects, from concept to completion and eventual demolition. Everyone in the construction supply chain is included.

Control of Industrial Major Accident Hazard Regulations 1984 (CIMAH)

The CIMAH Regulations applied to the Complex prior to being superseded by the COMAH Regulations and were designed to prevent or mitigate the effects of major accidents both on people and the environment.

Control of Major Accident Hazards Regulations 1999 (COMAH)

These Regulations superseded the CIMAH Regulations in 1999 and extended the scope and requirements in line with the Seveso II Directive. Major accident hazard sites as defined under the COMAH Regulations (COMAH sites) are required to prepare and submit a safety report to the Competent Authority for assessment which should contain certain information as specified by the regulations in order to allow the Competent Authority to assess the overall safety of the site.

Control of Major Accident Hazards Regulations 1999 (COMAH) – Regulation 4

Regulation 4 requires that "*Every operator shall take all measures necessary to prevent major accidents and limit their consequences to persons and the environment*".

Control of Major Accident Hazards Regulations 1999 (COMAH) - Regulation 18

Regulation 18 requires the Competent Authority to prohibit operation if serious deficiencies with major accident potential are found.
"The competent authority shall prohibit the operation or bringing into operation of any establishment or installation or any part thereof where the measures taken by the operator for the prevention and mitigation of major accidents are seriously deficient."

Control of Major Accident Hazards Regulations 1999 (COMAH) - Regulation 19

Regulation 19 of the COMAH Regulations clearly identifies the inspection and investigation duties of the Competent Authority and states:

(1) "The competent authority shall organise an adequate system of inspections of establishments or other measures of control appropriate to the type of establishment concerned;

(2) The inspections or control measures referred to in paragraph (1) shall not be dependent upon the receipt of any report submitted by the operator and they shall be sufficient for a planned and systematic examination of the systems being employed at the establishment, whether of a technical, organisational or managerial nature;

- *a) that the operator can demonstrate that he has taken appropriate measures to prevent major accidents;*
- *b) that the operator can demonstrate that he has provided appropriate means for limiting the consequences of major accidents both inside and outside the establishment;*
- *c) that the information contained in any report sent to the competent authority by the operator of the establishment adequately reflects the conditions in the establishment; and*

d) that the information has been supplied to the public pursuant to regulation 14.

(3) A system of inspection referred to in paragraph (1) shall meet the following conditions –

a) there shall be a programme of inspections for all establishments;

b) unless such a programme is based upon a systematic appraisal of major accident hazards of the particular establishment concerned, the programme shall, in the case of establishments to which regulations 7 to 14 apply, entail at least one on-site inspection made on behalf of the competent authority every 12 months;

c) following each inspection, a report shall be prepared by the competent authority; and

d) where necessary, matters shall be pursued with the operator within a reasonable period following the inspection.

(4) Where the competent authority or the Executive has been informed of a major accident at an establishment the competent authority shall –

a) obtain from the operator of the establishment –

i) information as respects the circumstances of the accident, the dangerous substances involved, the data available for assessing the effects of the accident on persons and the environment, the emergency measures taken and the steps envisaged to alleviate the medium and long-term effects of the accident and to prevent any recurrence of it, and

ii) such other information in the operator's possession as will enable the competent authority to notify the European Commission pursuant to regulation 21(1);

b) ensure that any urgent, medium and long-term measures which may prove necessary are taken;

c) make a full analysis of the technical, organisational and managerial aspects of the major accident and collect, by inspection, investigation or other appropriate means, the information necessary for that purpose;

d) take appropriate action to ensure that the operator takes any necessary remedial measures;

e) make recommendations on future preventative measures."

Cracking

A process by which molecules with many carbon atoms are broken down into smaller molecules with fewer carbon atoms.

DCS – Distributed Control System

An electronic process control system where the control of a unit is split between user interfaces (which may be remote from the unit) and the electronic control equipment, which is typically located on the process unit.

Dead-leg

A section of pipe where there is normally no flow and which is filled with stagnant process fluid.

Electricity at Work Regulations (EWR) 1989

These Regulations impose duties on persons in respect of electrical systems, electrical equipment and conductors and in respect of work activities on or near electrical equipment in order to ensure, as far as is reasonably practicable, that there is no danger of death or personal injury.

Environmental Protection Act/Integrated Pollution Control

Under the IPC Regulations sites are required to prepare and submit IPC applications to SEPA for assessment. These IPC applications should contain certain information as specified by the regulations in order to allow the SEPA to assess the environmental performance of the facilities on-site. Following submission of a successful IPC application SEPA will then issue an IPC authorisation. IPC authorisations include the approved discharge points and the quantities and compositions of the authorised emissions. The authorisation may also contain an improvement programme for the company to follow with, for example, specified dates for the installation of new equipment or the preparation of a technical report.

Flare

Flare stacks are used to burn-off materials that are generated on-site but which can not be re-used or reclaimed. Under normal operating conditions a bright orange flame can be seen coming from a flare stack. However if the combustion conditions are not optimised then dark smoke can be seen being released from the flare stack.

FCCU – Fluidised Catalytic Cracker Unit

A refinery unit using a widely-used process for the conversion of the heaviest components of crude oil into motor fuels.

Grangemouth Petrochemical Complex Major Incident Control Committee

The Grangemouth Petrochemical Complex Major Incident Control Committee (MICC) was set up in the late 1960's and has successfully developed an integrated emergency management plan which consists of Procedures for Dealing with a Major Incident at Grangemouth (the MICC Procedures) and Falkirk Council's statutory COMAH Off-site Contingency Plan for the mitigation of a major industrial accident at Grangemouth. The MICC Procedures are based on a mutual aid scheme between the petroleum, chemical and related industries together in partnership with Falkirk Council, and the emergency services, the Health Board, the Water Authority and the COMAH Competent Authority.

The MICC provides a link between the on-site emergency plans of the establishments in the Grangemouth area (Avecia, BP, Syngenta, Calor Gas etc.) and the statutory off-site plans drawn up by Falkirk Council. It provides resources as necessary and in the event of an incident provides communications between the companies, the public authorities and the general public. It includes technical experts and representatives from local major hazard sites, police and emergency services, the Local Authority, public health and the utility companies.

Health & Safety at Work etc. Act 1974 (HSWA)

The HSWA lays down a framework of duties for ensuring health and safety. The Act imposes general duties on employers towards employees and others, including members of the public off-site, to ensure that they are protected from the risks arising from the employers' activities.

Health & Safety at Work etc. Act – Section 3

Section 3 of the Act places a duty on employers to ensure, so far as is reasonably practicable, that people who are not employed by them, but who may be affected by the way they conduct their business, are not exposed to risks to their health and safety.

Human Factors

Human factors discovers and applies information about human behaviour, abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable, and effective human use.

IMT – Incident Management Team

A BP Grangemouth multi-disciplinary team established in accordance with emergency procedures to advise and manage the emergency response to an incident.

Level 1 Investigation

A "Level 1" investigation refers to an investigation carried out when there is high level of interest amongst the local population, politicians etc. but where there have been no fatalities. "Level 2" investigations are appropriate when fatalities have resulted. "Level 0" investigations are appropriate when there has been a "near miss". This was the terminology used in HSE/HID Major Incident Investigation Procedures at the time of the incidents, but has now been superseded by another categorisation approach.

Logistics Facilities

Logistics refers to storage and distribution facilities such as warehouses, loading areas etc.

Major Accident

An occurrence (including in particular, a major emission, fire or explosion) resulting from uncontrolled developments in the course of the operation of any establishment and leading to serious danger to human health or the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances.

Major Accident Hazard Sites

These designated sites process or store more than specified quantities of certain dangerous substances and have the potential to cause significant on-site and off-site effects to employees, members of the public and the wider environment including the possibility of causing multiple fatalities. The quantities stored at Grangemouth are in excess of the Top Tier thresholds as defined under the COMAH Regulations and therefore the Complex is subject to the full requirements of the COMAH Regulations.

Management of Health and Safety at Work Regulations 1999

These Regulations are aimed at improving health and safety management, and make more explicit what is required of employers under the Health & Safety at Work etc. Act 1974. They lay down a framework of duties requiring a systematic approach to the management of health and safety, based on risk assessment.

Permit-to-Work

A permit-to-work system is a formal written system used to control certain types of work that are potentially hazardous. A permit-to-work is a document which specifies the work to be done and the precautions to be taken. Permits-to-work form an essential part of safe systems of work for many maintenance activities. They allow work to start only after safe procedures have been defined and they provide a clear record that all foreseeable hazards have been considered.

Pressure Systems Safety Regulations 2000 (PSSR)

These Regulations deal with the stored energy hazards associated with the containment of fluids under pressure, in pressure equipment and systems – for example boilers – used in the workplace. The aim of the PSSR is to prevent serious injury from the hazard of stored energy as a result of the failure of a pressure system or one of its components.

Process Safety Management

Process safety management is concerned with the management of safety hazards arising from process operations and is distinct from the management of conventional safety (slips, trips, falls etc). Process safety management requires detailed knowledge of the chemical and process hazards associated with the operations of the plant in order to ensure that the correct focus and resource is applied to the control of the potential major hazards.

Remotely Operated Shut-Off Valve (ROSOV)

A valve which allows an item of plant or equipment to be isolated automatically from a safe location without the necessity for manual intervention.

The inability to quickly isolate hazardous substances inventory in the event of a major accident was an issue in the Associated Octel Company major accident (1st and 2nd February 1994).

For new installations ROSOVs should normally be fitted unless there are good technical reasons why they are not appropriate. For existing installations, the decision needs to be based on ALARP/cost benefit analysis.

RIDDOR

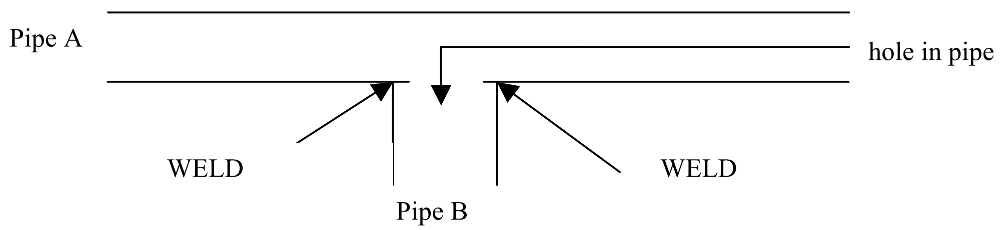
The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 places a legal duty on employers, the self-employed and those in control of premises to report some work-related accidents, diseases and dangerous occurrences to the relevant enforcing authority for their work activity. This can be either the HSE or one of the Local Authorities.

The law requires the following work-related incidents to be reported:

- deaths;
- major injuries;
- over 3-day injuries: - where an employee or self-employed person has an accident and the person is away from work or unable to work normally for more than 3 days;
- injuries to members of the public where they are taken to hospital;
- work-related diseases; and
- dangerous occurrences: - where something happens that does not result in a reportable injury but which could have done.

Set-on Tee-Piece

A tee-piece which is formed by welding one pipe over a hole made in another. In this case the tee-piece is formed by the pipes themselves with the joining weld being at the junction of the tee-piece. This is distinct from a forged weld-reducing tee-piece where the junction is in the forged fitting and is at a distance from the welds between the fitting and the adjoining pipes.



Seveso II Directive

The Seveso II Directive has two aims. Firstly the prevention of major accident hazards involving dangerous substances and secondly (since accidents do occur) the limitation of the consequences of such accidents not only for man (health and safety aspects) but also for the environment. The requirements of the Directive are in corporated into UK legislation by the COMAH Regulations.

Steam Trap

A device installed in steam distribution systems which removes hot condensate from the steam main in order to protect the steam main from condensate build-up. Discharge of hot condensate from a steam trap may be directly to the environment or into a condensate collection system if appropriate. Different types of steam trap are available for installation.

TLC – The Total Loss Control system

A computer based system for recording and ranking incidents and near-misses on the BP Grangemouth Complex and for tracking actions resulting from such incidents and near-misses.

Top Tier/Lower Tier

The COMAH Regulations operate at two levels depending on the quantities of dangerous substances at an establishment. Schedules of specific “named substances” and “general categories” are presented in the Regulations.

Establishments which have quantities of dangerous substances exceeding the top tier thresholds (either individually or following application of the COMAH aggregation rules) are known as “top tier” COMAH sites. “Top tier” status requires the operator to:

- Notify the Competent Authority;
- Prepare a Major Accident prevention Policy (MAPP);

- Submit a written safety report;
- Prepare an on-site emergency plan and to provide sufficient information for an off-site emergency plan to be prepared;
- Make information available to the public.

Establishments which have quantities of dangerous substances exceeding the lower tier thresholds (either individually or following application of the COMAH aggregation rules) but not the top tier thresholds are known as "lower tier" COMAH sites. "Lower tier" status requires the operator to:-

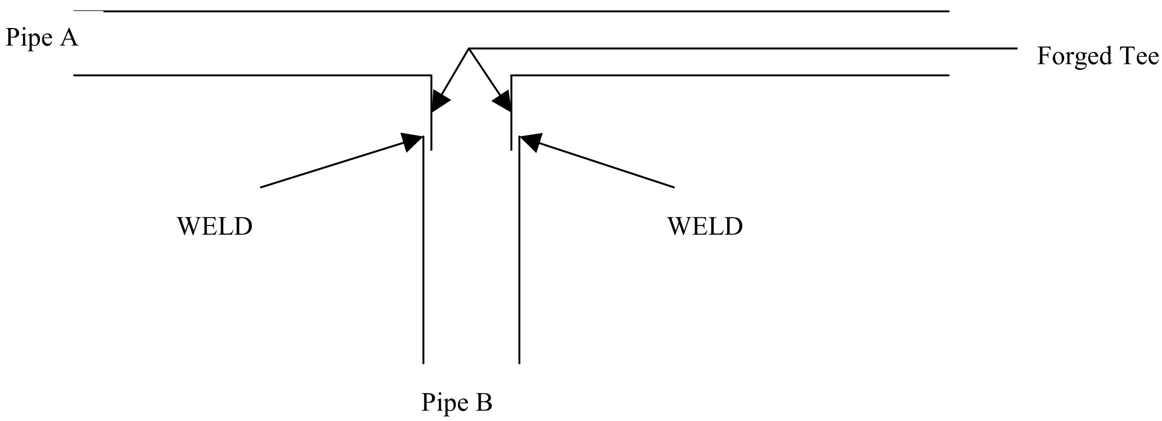
- Notify the Competent Authority;
- Prepare a Major Accident prevention Policy (MAPP);

Water Hammer

When a column of flowing fluid is suddenly stopped, a pounding of the line commonly known as water hammer is usually produced.

Weld–Reducing Tee-Piece

A forged tee-piece where the joining pipes are each welded to the fitting but where the forged fitting forms the actual tee-piece.



Vapour Cloud Explosion

A cloud of vapours which when ignited can not expand freely results a significant overpressure and explosion.

In general terms explosions tend to be more serious since they have the potential to cause fatalities more readily than fires due to the short duration energy release which gives no time for evasive action to be taken by personnel. In the event of a fire, escape is often possible due to the time taken for the spread of the fire to occur.

VRU – Vapour Recovery Unit

The section of the FCCU where the light hydrocarbon gases produced by the cracking process are compressed and separated into different product streams.

ACRONYMS

ACMH	-	Advisory Committee on Major Hazards
AGI	-	Above Ground Installation
ALARP	-	As Low As Reasonably Practicable
API	-	American Petroleum Institute
AWE	-	Atomic Weapons Establishment
barg	-	Unit of pressure (1barg = normal atmospheric pressure)
BNFL	-	British Nuclear Fuels Limited
CA	-	Competent Authority
CCB	-	Central Control Building
CDM	-	Construction (Design and Management) Regulations
CDU	-	Crude Distillation Unit
CEFIC	-	European Chemical Industry Council
CIA	-	Chemical Industries Association
CIMAH	-	Control of Industrial Major Accident Hazards 1984
CHP	-	Combined Heat and Power Plant
CLC	-	Comprehensive List of Causes analysis methodology
CO	-	Carbon Monoxide
COMAH	-	Control of Major Accident Hazards Regulations 1999
CONCAWE	-	Oil Companies' European Organisation
CRG	-	Central Resources Group
CSG	-	Cleansing Service Group Ltd (CSG), Sandhurst, Gloucester
CUI	-	Corrosion Under Insulation
DAFWFC	-	Days away from work case frequencies
DCS	-	Distributed Control System
E4	-	Ethanol Plant
EA	-	Environment Agency
EC	-	European Commission
EEMUA	-	Engineering Equipment and Materials Users Association
EMM	-	Enforcement Management Model
EPSC	-	European Process Safety Centre
EU	-	European Union
EWR	-	Electricity at Work Regulations 1989
FCCU	-	Fluidised Catalytic Cracker Unit
FPS	-	Forties Pipeline System
FPSI	-	Forties Pipeline System and Infrastructure Availability Team
G4	-	Ethylene Cracker
Gemec	-	General electrical and mechanical services culverts
GHSER	-	Getting Health, Safety and the Environment Right
GLT	-	Grangemouth Leadership Team
HAZOP	-	Hazard and Operability Study
HF	-	Hydrogen Fluoride
HID	-	Hazardous Installations Directorate
HP Steam	-	High Pressure Steam
HR	-	Human Resources
HS&E	-	BP Health, Safety and Environment Group
HSC	-	Health and Safety Committee
HSE	-	Health and Safety Executive

HSG	-	Health and Safety Guide
HSL	-	Health and Safety Laboratories
HSWA	-	Health & Safety at Work etc. Act 1974
IChemE	-	Institution of Chemical Engineers
IMT	-	Incident Management Team
IPC	-	Integrated Pollution Control
IPPC	-	Integrated Pollution Prevention Control
KPI	-	Key Performance Indicator
kV	-	Kilovolt
LPG	-	Liquefied Petroleum Gas
LP Steam	-	Low Pressure Steam
MAH	-	Major Accident Hazard
MAPP	-	Major Accident Prevention Policy
MARS	-	Major Accident Reporting System
MATTE	-	Major Accident to the Environment
MIA	-	Major Incidents Announcements
MICC	-	Grangemouth Petrochemical Complex Major Incident Control Committee
MIRAIM	-	Major Accident Investigation Procedure
MMR	-	Maintenance, Management and Reliability
MP	-	Member of Parliament
MP Steam	-	Medium Pressure Steam
MSP	-	Member of the Scottish Parliament
OIAC	-	Oil Industry Advisory Committee (OIAC)
OSBL	-	Outside Battery Limits
OSG	-	Operations Support Group
PCC	-	Pembroke Cracking Company Plant
PHSER	-	Project Health, Safety and Environment Review
PLPG	-	Pressurised Liquefied Petroleum Gas
PMP	-	Plant Modification Proposal
POPMAR	-	**P**olicy **O**rganising **P**lanning and implementing **M**easuring performance **A**uditing **R**eview
PPC	-	Pollution Prevention Control
psi	-	Pounds per square inch (unit of pressure). Normal atmospheric pressure = 14.7 psig
PSM	-	Process Safety Management
PSSR	-	Pressure Systems Safety Regulations 2000
PTFE	-	PolyTetraFluoroEthylene
PTW	-	Permit-to-Work System
QRA	-	Quantified Risk Assessment
QSB	-	Quarterly Safety Bulletin
R2P2	-	Reducing Risks Protecting People
RIDDOR	-	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995
RIG	-	Refineries Industry Group
ROSOV	-	Remotely Operated Shut-Off Valve.

SEPA	**-**	Scottish Environment Protection Agency
SIESO	-	Society of Industrial Emergency Services Officers
SIP	-	Single Implementation Project
SMS	-	Safety Management System
SRAM	-	Safety Report Assessment Manual
TCR	-	Thermal Control Room
TLC	-	Total Loss Control
UKAEA	-	United Kingdom Atomic Energy Authority
UPS	-	Uninterruptible Power Supply
USA	-	United States of America
V	-	Volt
VCE	-	Vapour Cloud Explosion
VRU	-	Vapour Recovery Unit

Figure 1 – Power Distribution Grid

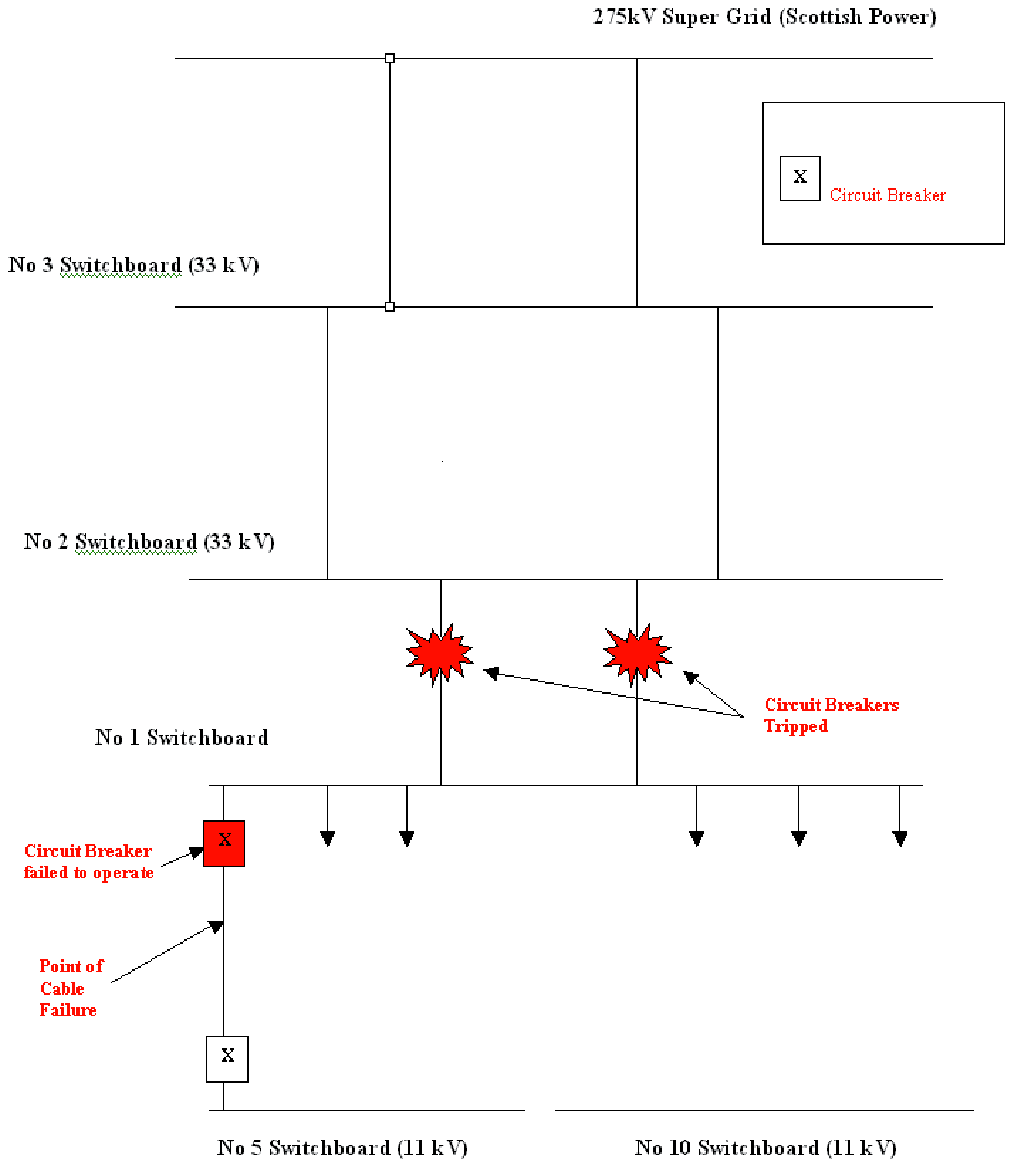
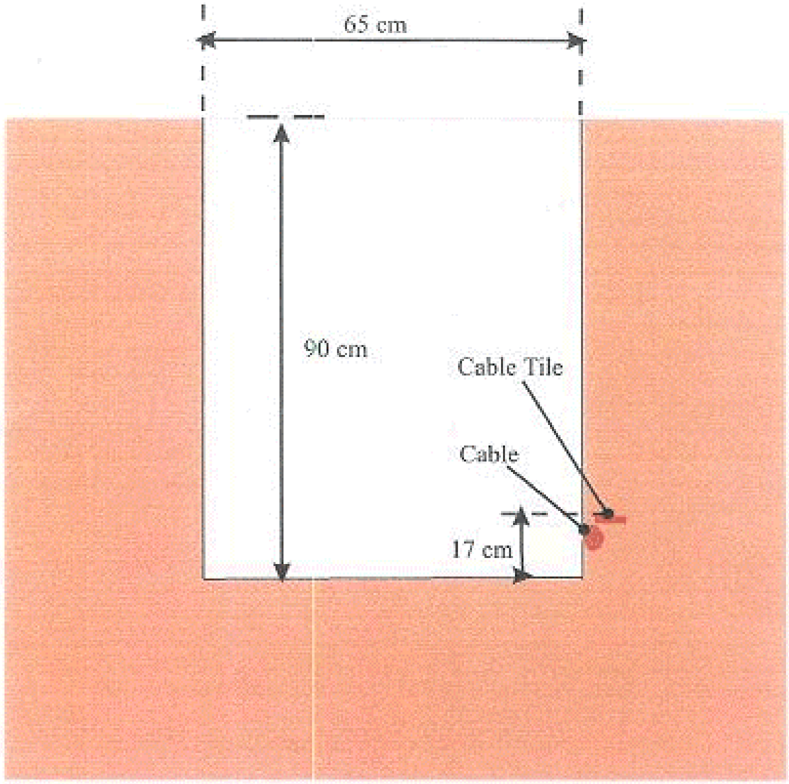
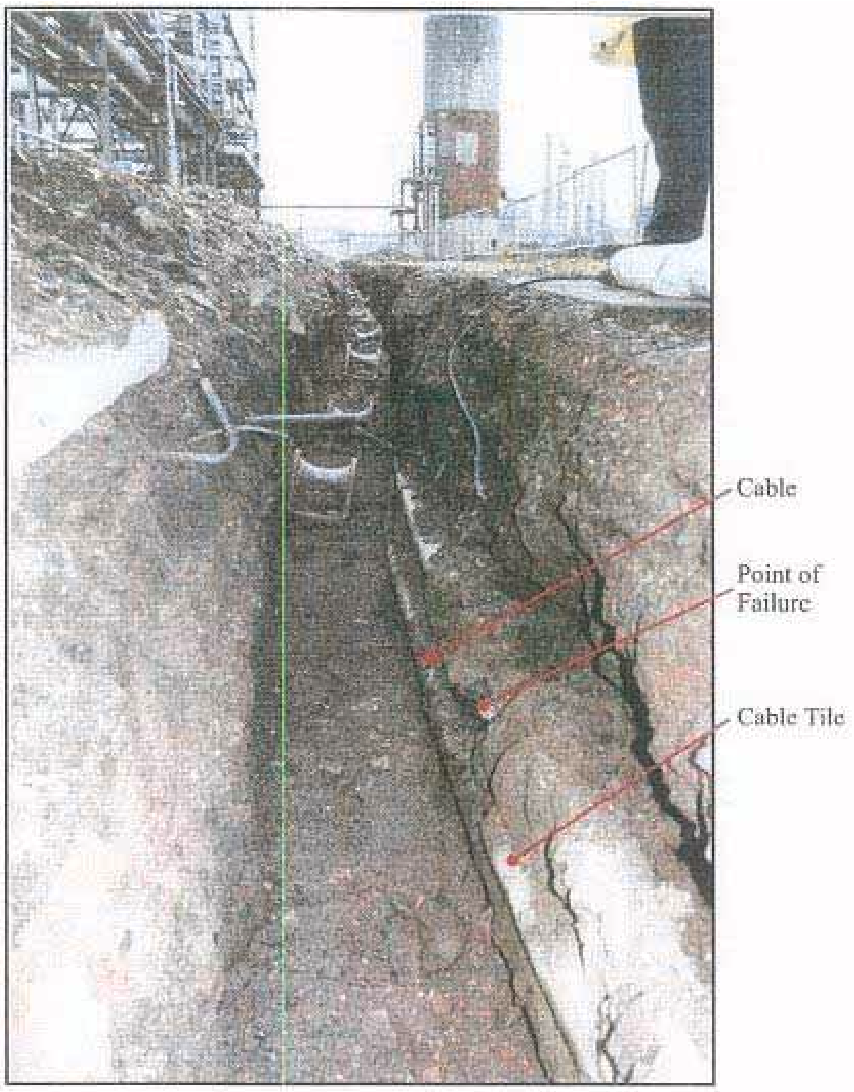


Figure 2 – Trench Diagram



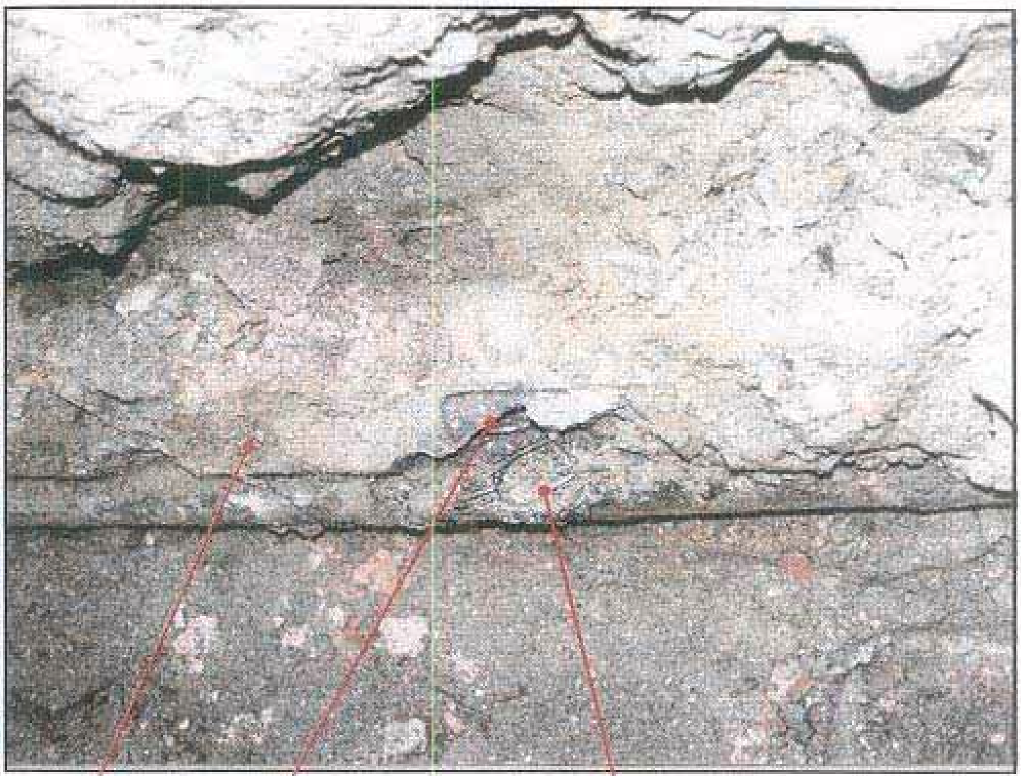
Elevation of Trench Showing Cable Just Inside Side Wall

Figure 3 – Trench Photo



Cable Trench Showing Damaged Cable and Offset Cable Tiles

Figure 4 – Trench Photo



The Damaged Section of Cable and Cable Tile

Figure 5 – Damage Photo

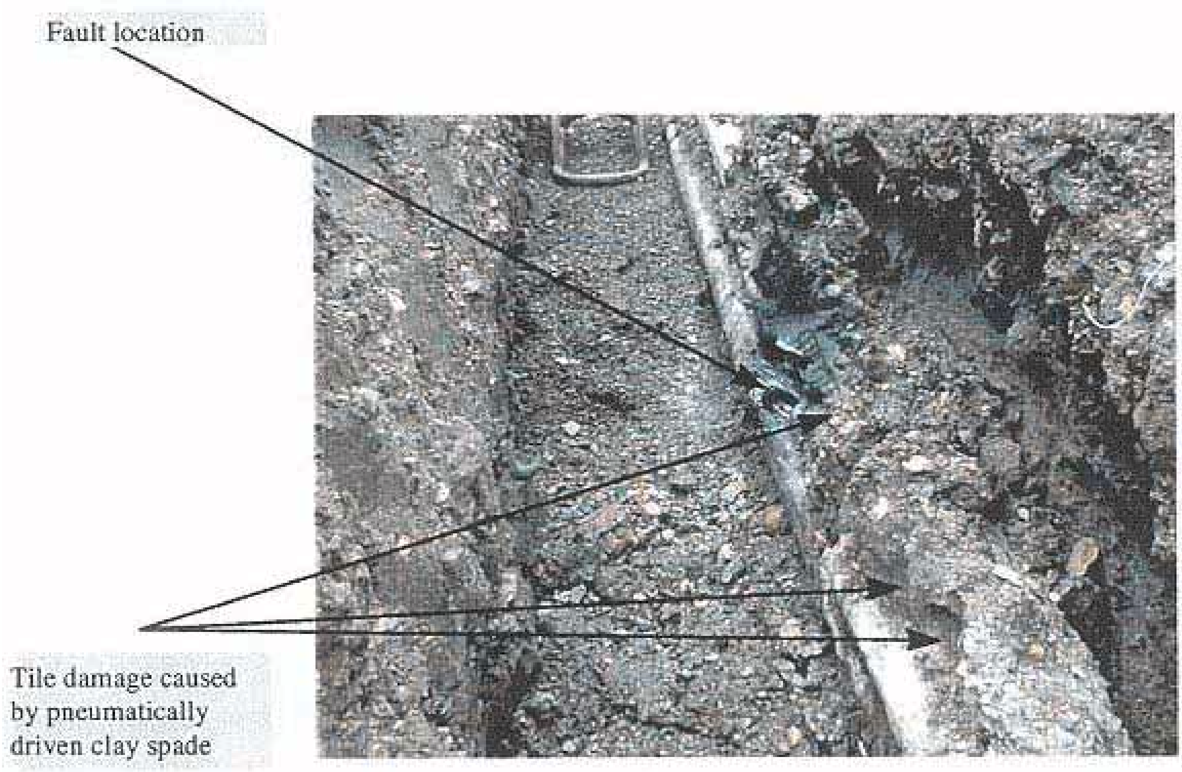
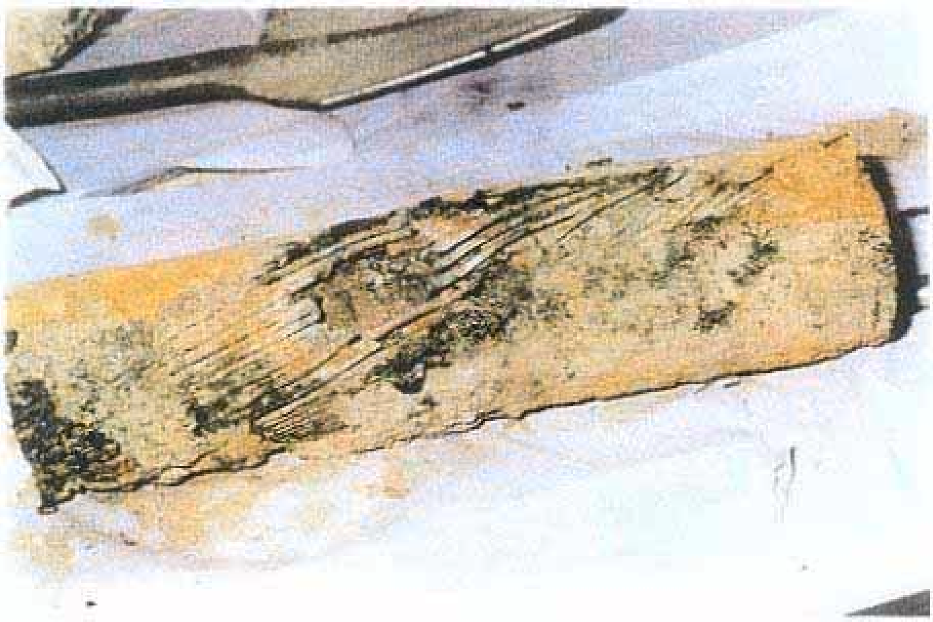
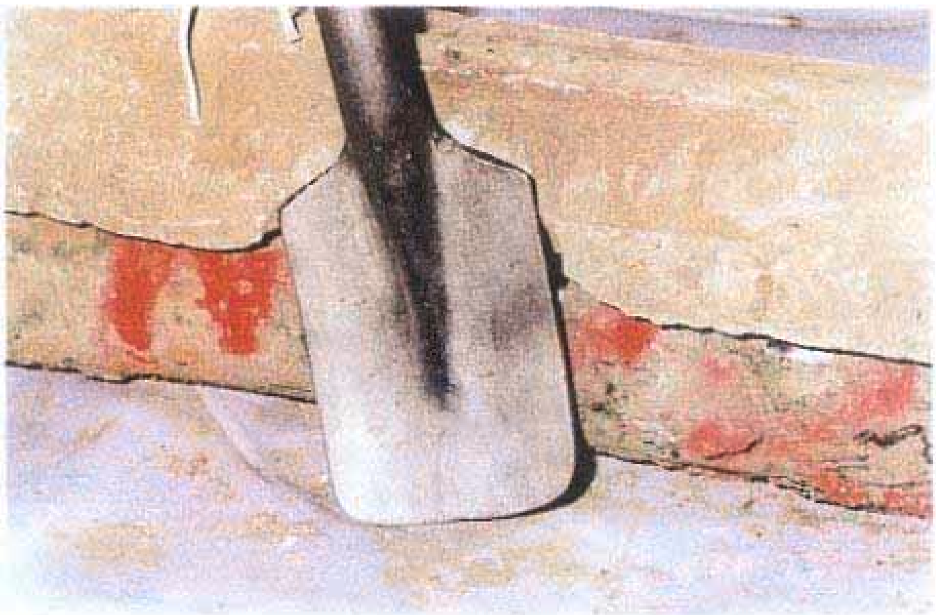


Figure 6 – Cable Photo



- Section of damaged cable prior to examination

Figure 7 – Clayspade Photo



- Small pneumatic clay spade fitted to the damage site of Photograph

Figure 7 – Panel **Photo**

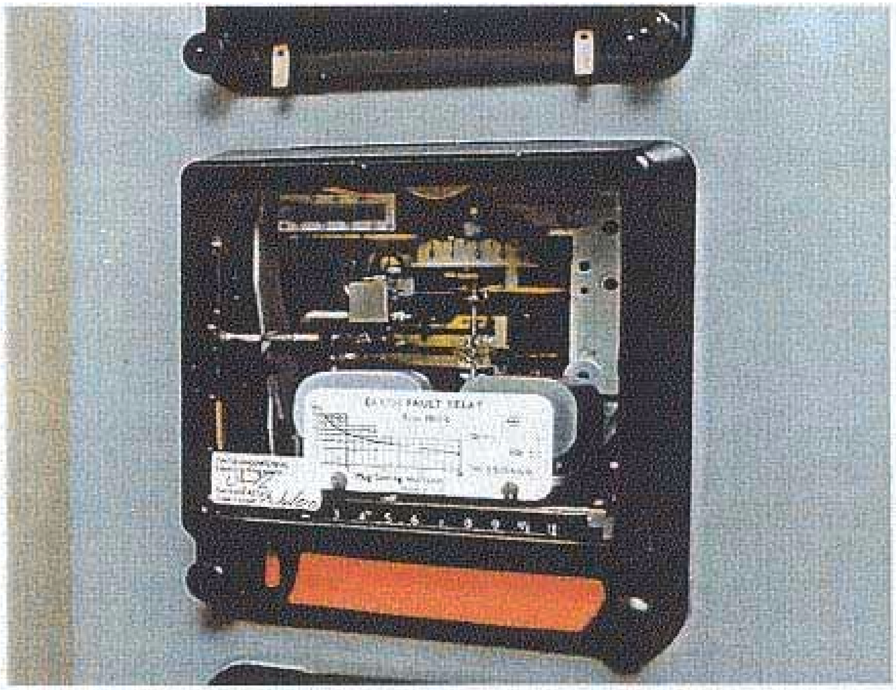


Figure 9 – Plastic panel Inserts

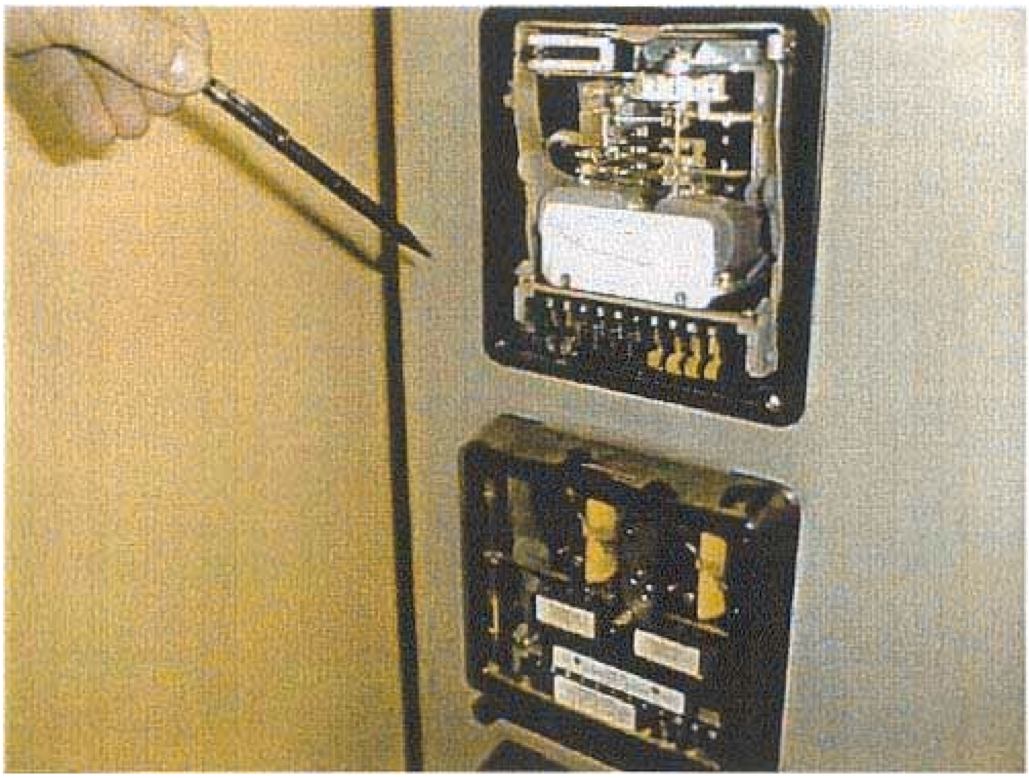


Figure 10 – Steam Distribution System

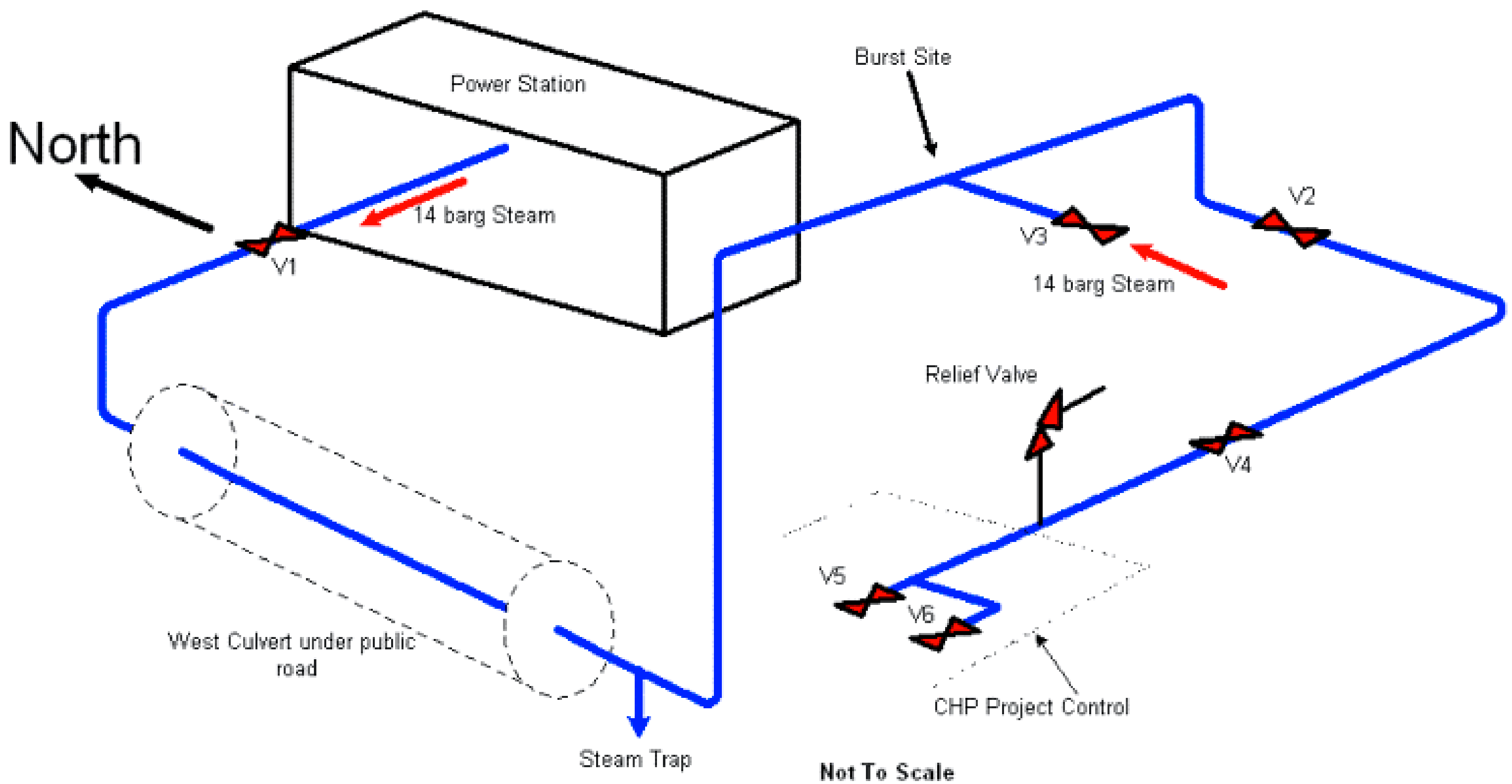


Figure 11 – Rupture Photo

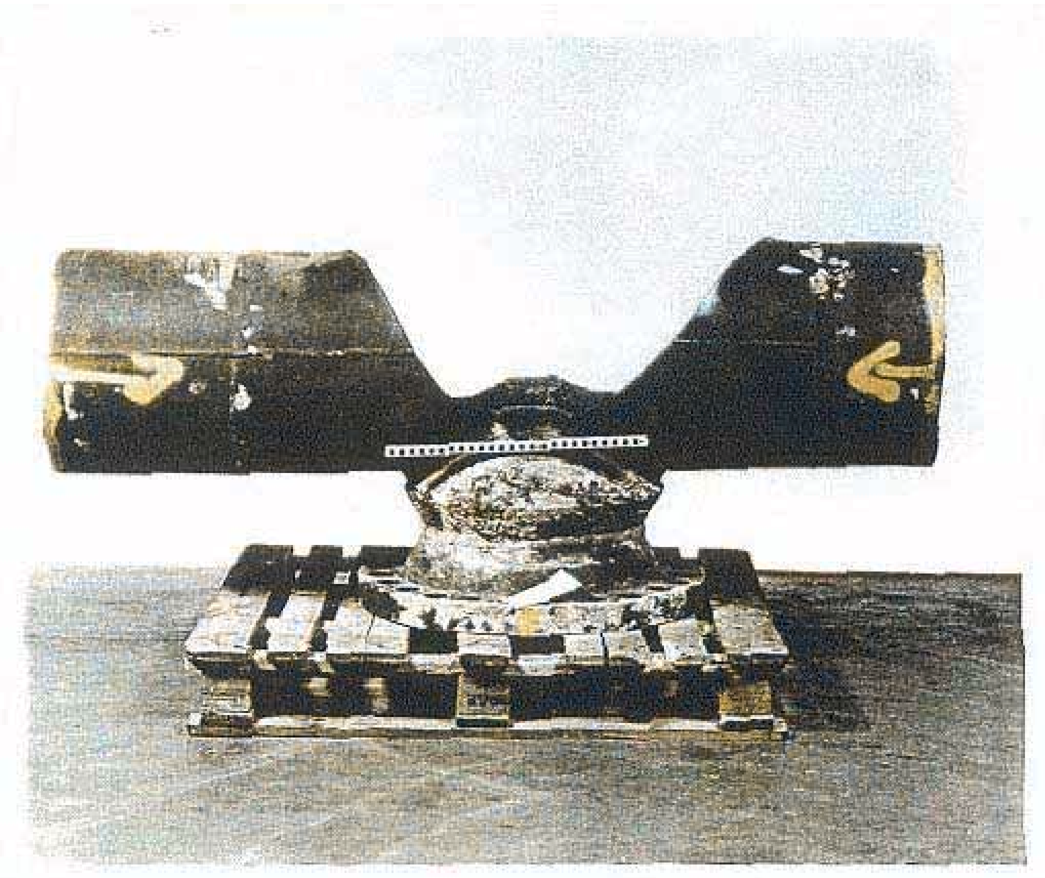


Figure 12 – Steam Main Photo

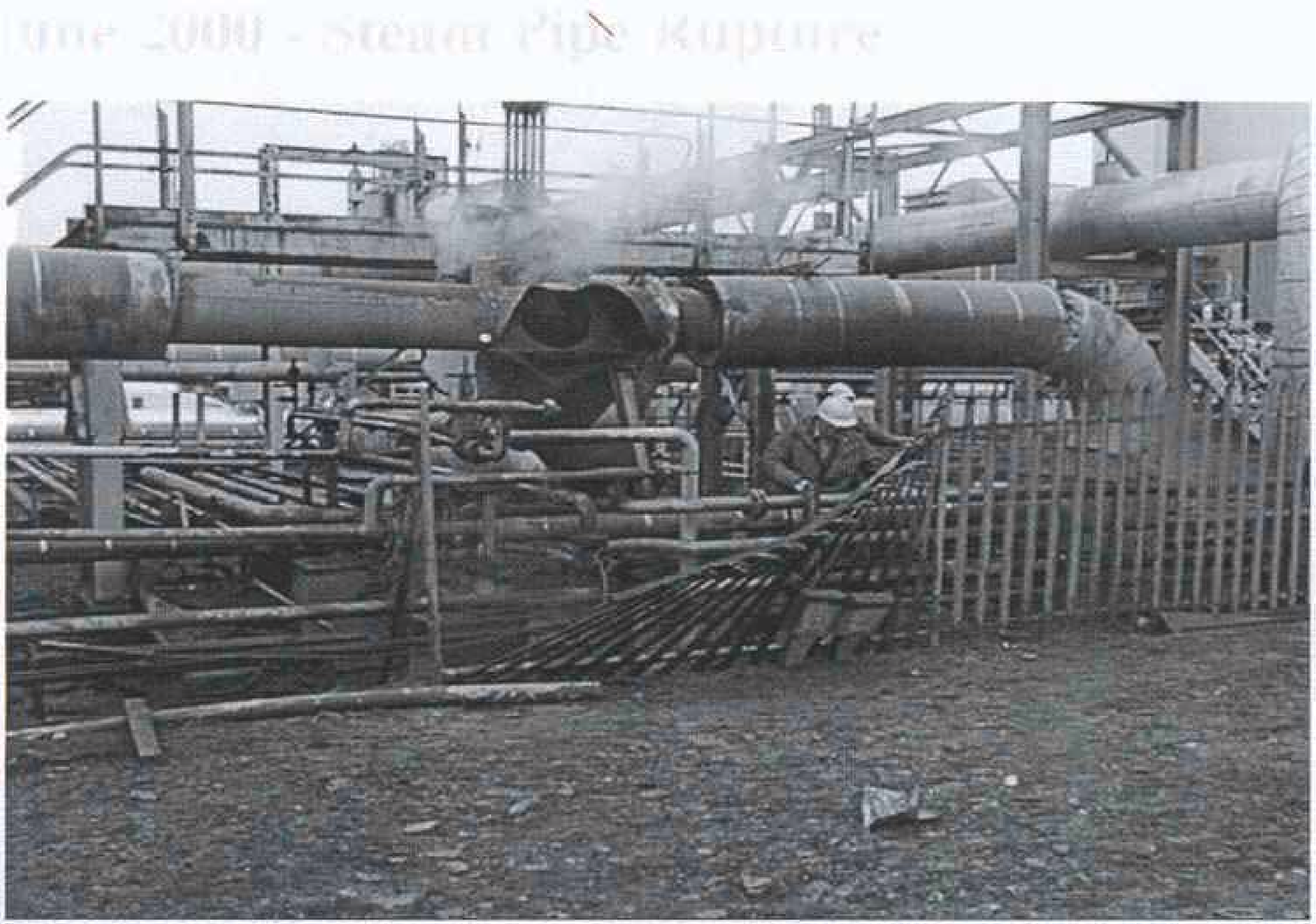


Figure 13 – Rupture Photo

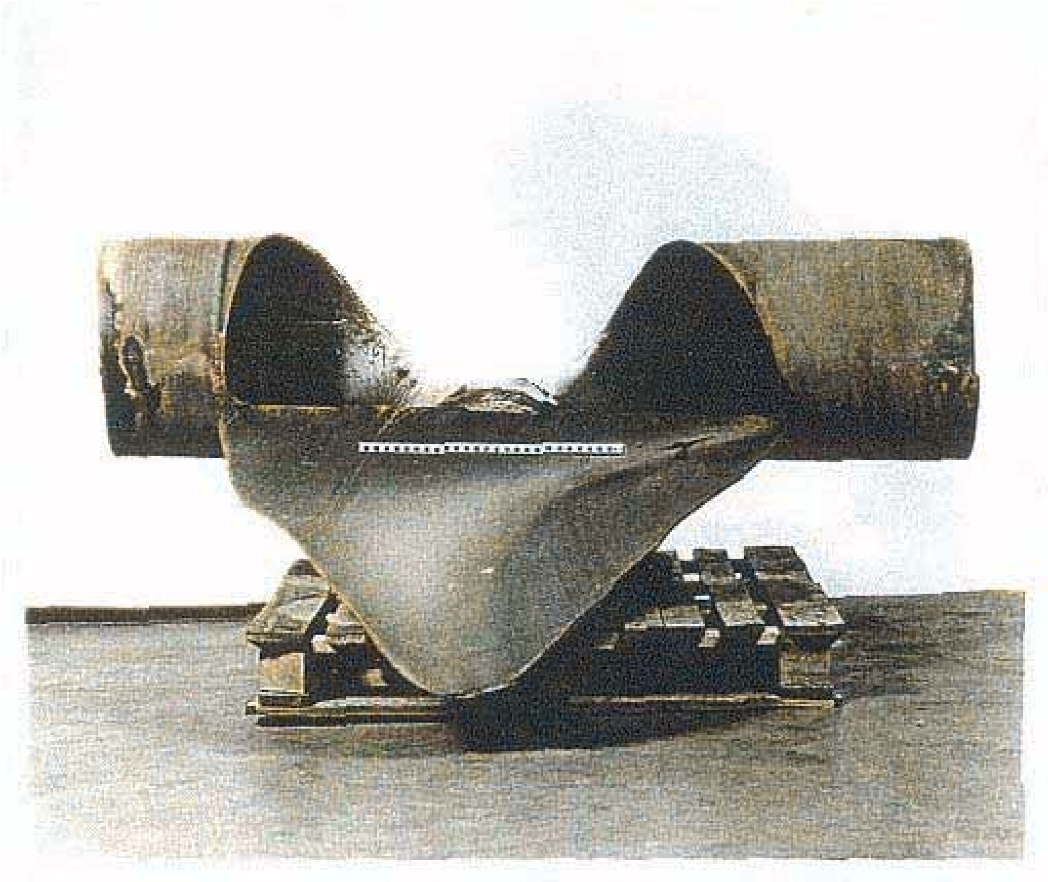


Figure 14 – Culvert Diagram

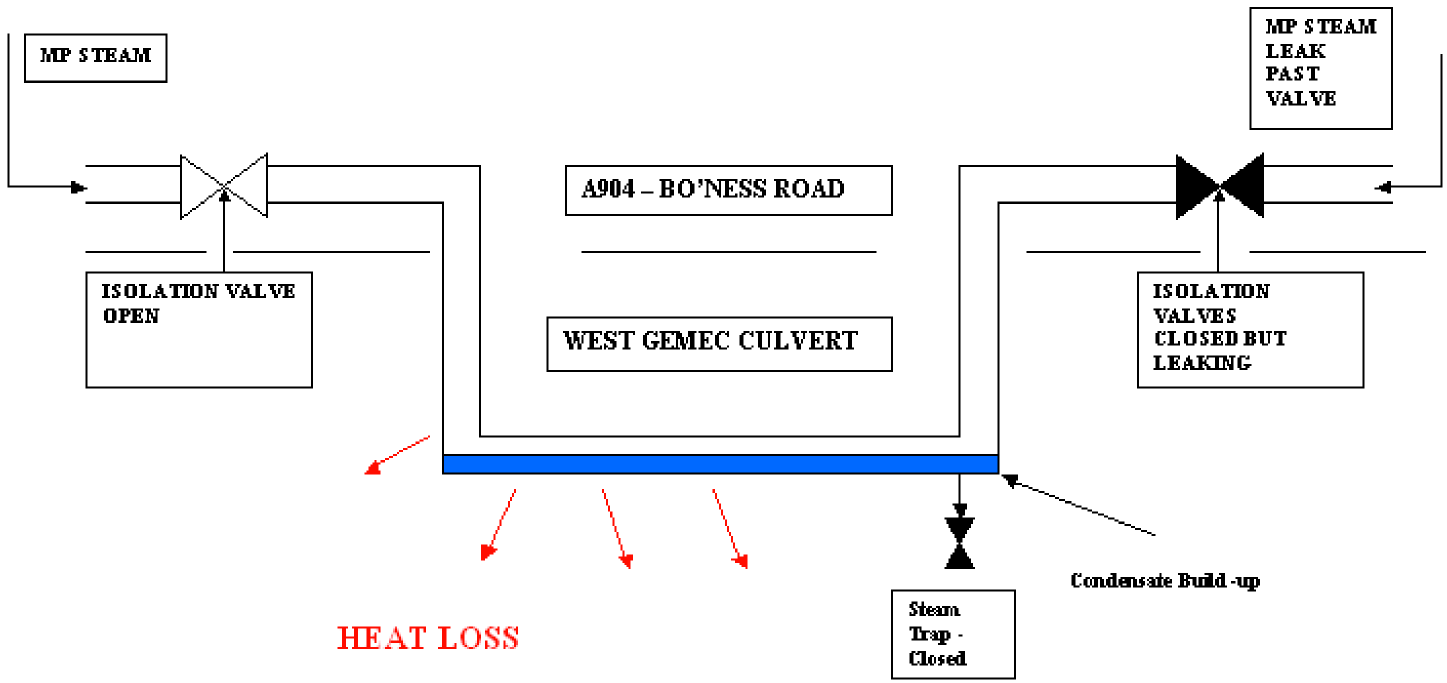


Figure 15 – Culvert Diagram

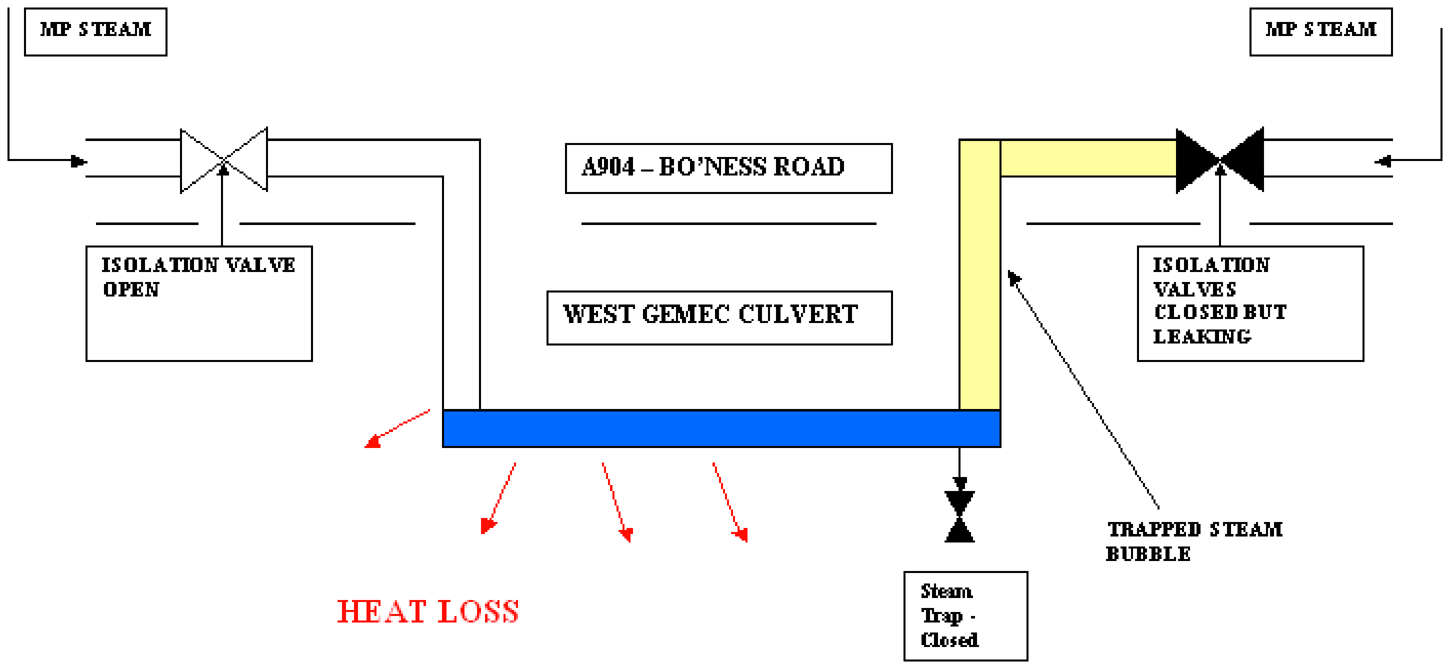


Figure 16 – Culvert Diagram

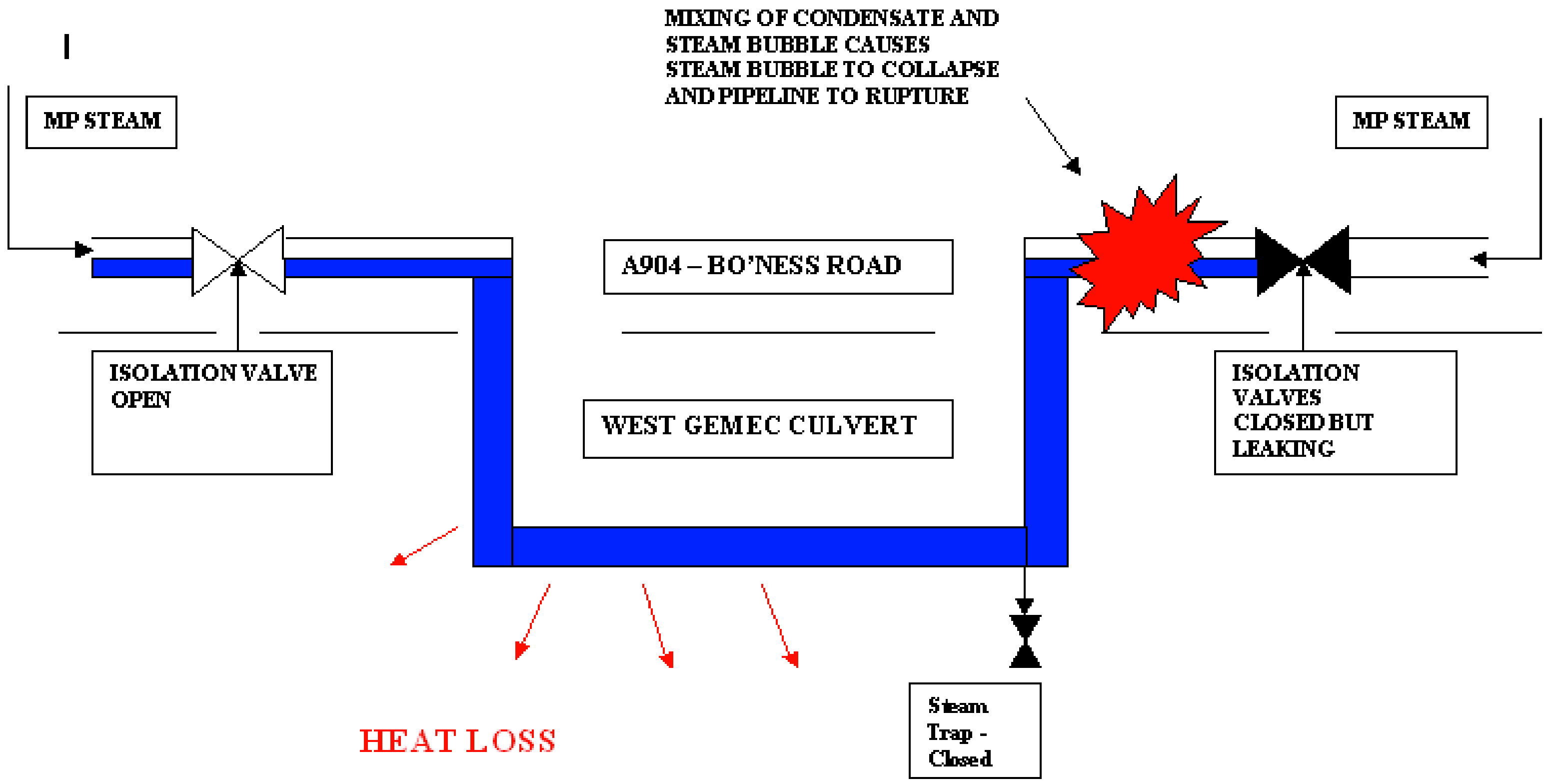


Figure 17 – Pipework (1)

Figure 18 – Pipework (2)

Figure 19 – HSL (1)

Figure 20 – HSL (2)

Figure 21 – HSL (3)

Figure 22 – Damage (1)

Figure 23 – Damage (2)

Figure 24 – Damage (3)

Figure 25 – Damage (4)

Figure 26 – Damage (5)

Figure 27 – Damage (6)

Figure A – FCCU Front End

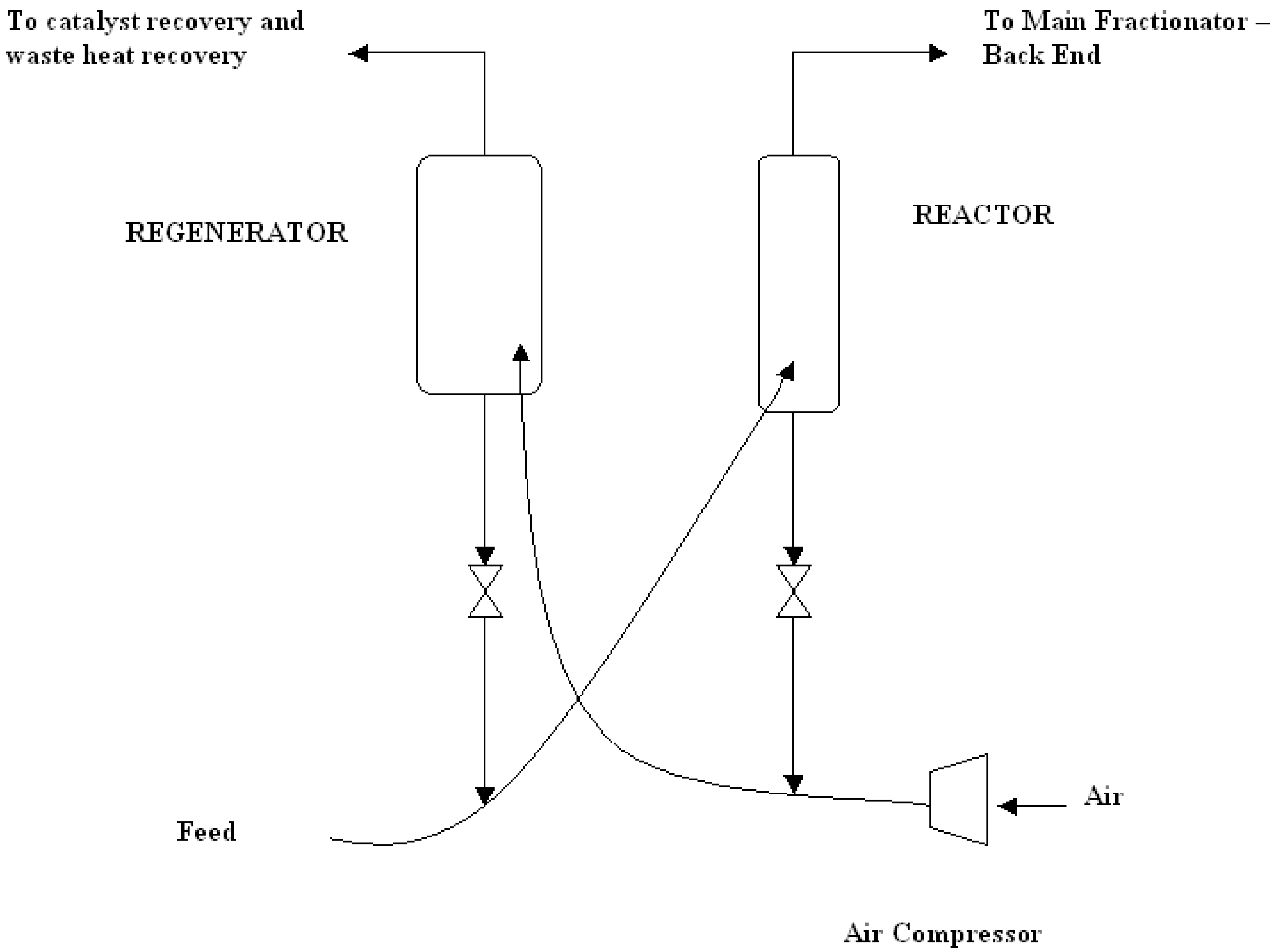


Figure B - FCCU Back End

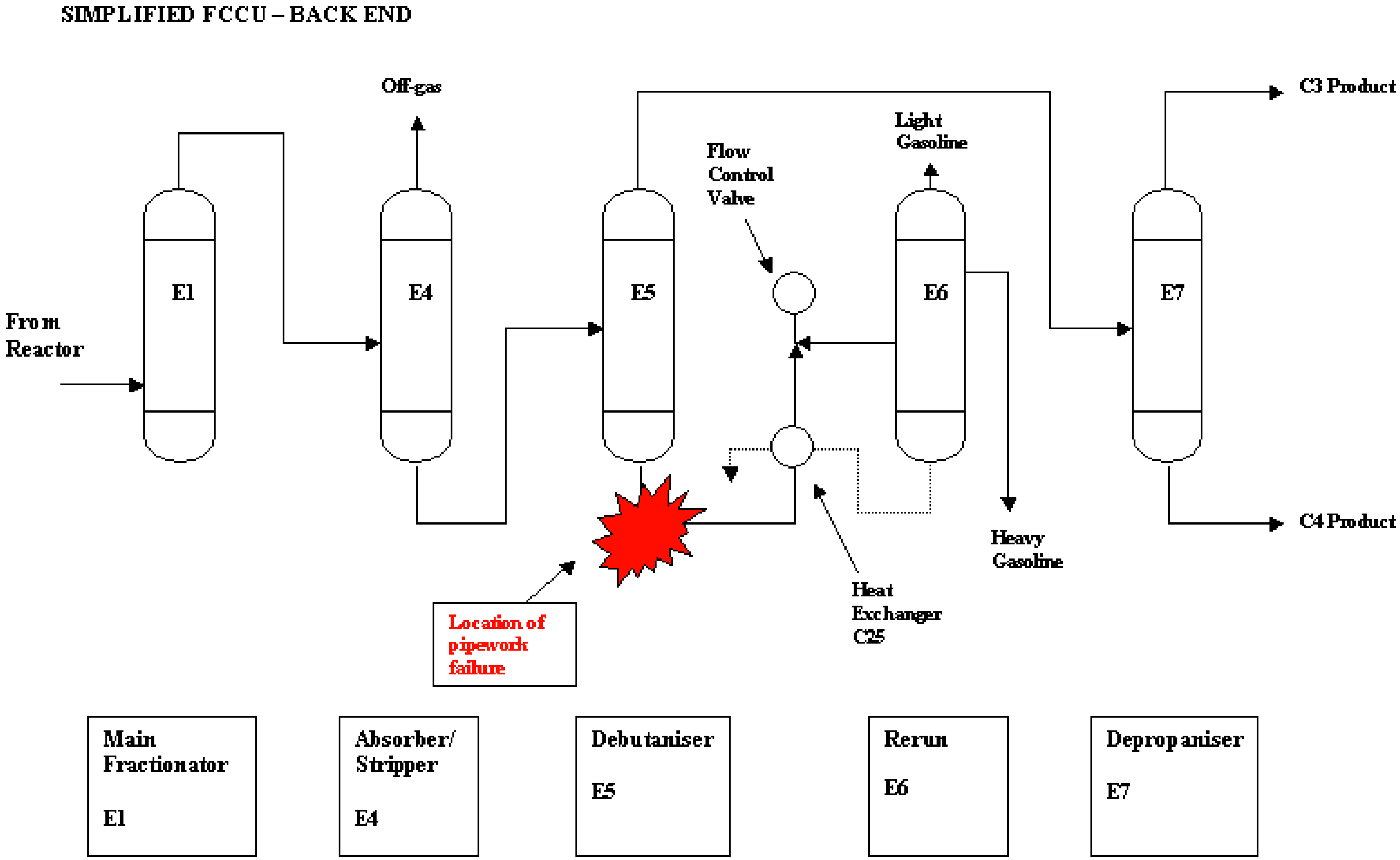


Figure – Columns