

Lessons from the Longford Gas Explosion and Fire

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ABSTRACT

Europe is currently introducing the Seveso II Directive which will require companies to implement an advanced safety management system and to demonstrate that major hazards are well controlled. A major accident occurred recently in Australia to a company that was implementing a system broadly equivalent to the Seveso II requirements. The way that this accident occurred and how safeguards were bypassed is an important lesson to learn.

On 25 September 1998, a vessel in the Esso Longford Gas Plant, Victoria, Australia, fractured releasing hydrocarbon vapours and liquid. A major fire followed. Two Esso employees were killed and eight others were injured. Supplies of natural gas to domestic and industrial users were halted for between 9-19 days. The State of Victoria, which is highly dependent on natural gas, suffered substantial disruption to the economy. The Government ordered a Royal Commission to investigate the causes of the incident. DNV acted as technical adviser and the authors of this paper were members of the Royal Commission technical investigation team.

The main lessons to be drawn from Longford relevant to loss prevention are, in the opinion of the authors, as follows:

1. Safety Management System - incomplete implementation
2. Knowledge Stewardship - insufficient on old plant
3. Management of Change - organisational change not scrutinised
4. Audit and Review - inadequate attention to detail

1. INTRODUCTION

This paper presents some key features of the accident, as determined by the Royal Commission, and comment on possible implications for those implementing the requirements of Regulatory Authorities.

DNV's role was to act as technical adviser to the Royal Commission throughout its investigation, and therefore is in a position to offer some insights. The authors regard it as a serious professional duty to ensure that key findings are shared with others responsible for process plants. Litigation is underway and DNV is careful where relevant only to quote from the public record of the Royal Commission. *This is made clear in this paper by the use of italic typeface for direct quotations.*

Finally, in any inquiry there tends to be a focus in black and white terms on those things that were wrong or deficient. However, there is much that was right with the Esso facility, and perhaps shades of grey on others. The most powerful lesson from Longford, in the author's opinion, is that a well-run facility, with a world-class safety management system can still experience a major event. This paper will outline how omissions or deficiencies could overcome the other safeguards in place.

2. THE PROCESS

At Longford, Esso Australia operates three gas plants to process gas flowing from wells in the Bass Strait. It also operates a Crude Oil Stabilisation Plant (CSP) to process oil flowing from other wells in the Bass Strait. The gas plants are known as Gas Plant 1 (GP1), Gas Plant 2 (GP2) and Gas Plant 3 (GP3). They are numbered in the order in which they were built, starting with GP1, which commenced production in March 1969.

The incoming natural gas had liquid condensate removed in the slugcatchers while gases heavier than methane (ethane, propane, etc) were removed by absorption into an oil stream. The lean oil circulation process flow diagram (see Figure 1) clearly shows the oil circulating. For clarity the gas and condensate streams are not included. In broad terms the process passes chilled natural gas containing condensate (ethane, propane and butane) into the Absorber vessels and in counter-current flow absorbs the condensate in Lean Oil at a temperature of about -20°C . The saturated Lean Oil leaving the Absorbers is termed Rich Oil.

Rich Oil is passed, after flashing (Rich Oil Flash Tank) and heat exchange, to the ROD (Rich Oil De-ethaniser). This is a fractionation tower where methane is removed at the top and heavier components collect in the bottom and are recirculated by means of a reboiler, GP905, the item that failed in this accident.

The bottoms Rich Oil stream passes through another heat exchanger, GP922 (that was leaking on the day of the accident), to the ROF (Rich Oil Fractionator) where final fractionation of the Rich Oil occurs, regenerating the Lean Oil in the bottoms. This Lean Oil is passed to fired heaters and then through a series of other exchangers providing heat energy to the process, before returning to the Absorber in a closed loop.

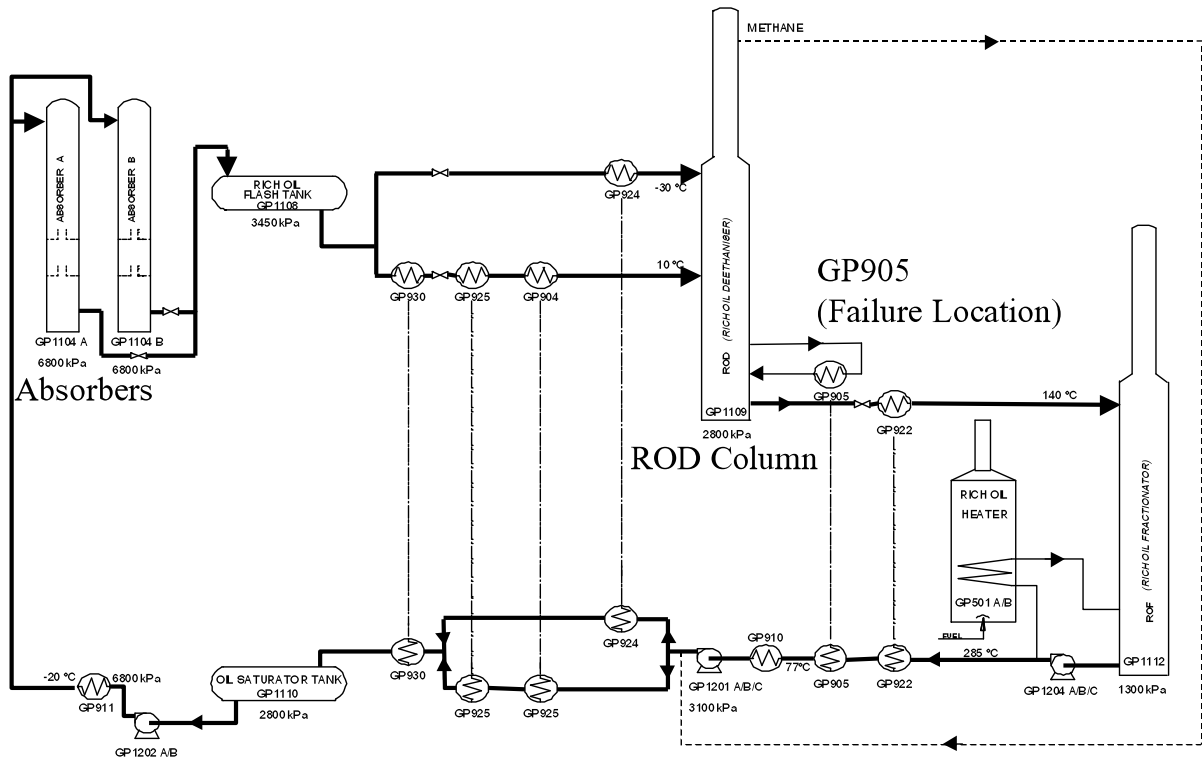


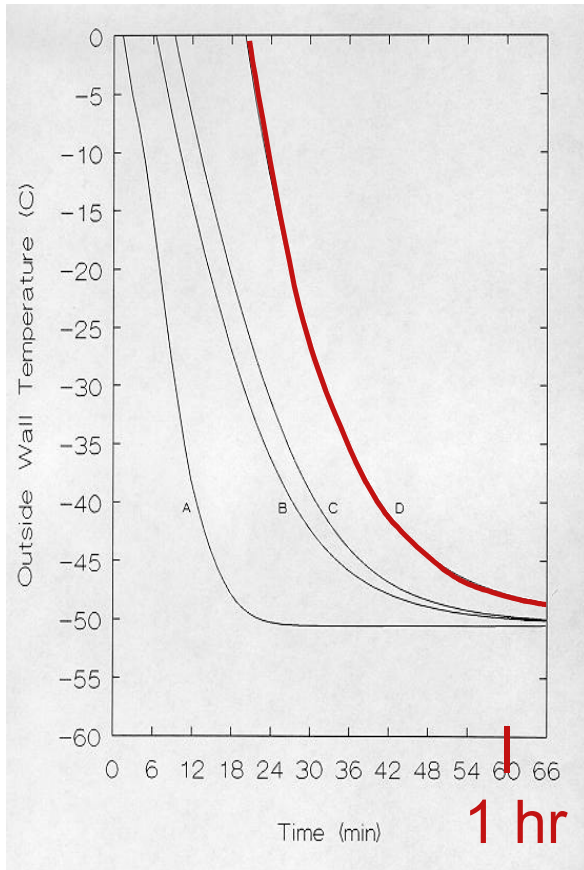
Figure 1 PFD for GP1's Absorber Oil Recirculation Loop

3. BACKGROUND TO ACCIDENT

3.1. Precursors

There were a number of precursors to the failure of GP905. The actual sequence of events and the high degree of interconnections and interactions, meant that post-event analysis was difficult, underlining the diagnosis problem which must have been faced by the operators.

There was an upset in the ROD distillation column. This caused the ROD to carry over liquid through the vapour line to the discharge from the GP1201 pumps. *It appears that the ROD did carry over liquid (or condensable vapour), possibly due to internal flooding. Liquid carryover occurred.* This additional flow to the Oil Saturator Tank caused the level to rise.



A consequence of the rise in the level of the Oil Saturator Tank was that LRC2 closed the valve regulating the flow from the GP1201 pumps. This reduction in flow would have caused LFSD8 (a low flow shutdown trip to protect the pumps) to shut down the GP1201 pumps.

Lean oil circulation stopped when the GP1202 pump shut down.

Following the cessation of lean oil flow, the condensate flowing from the absorbers through the rich oil system was flashing to lower and lower temperatures with the result that there was a drop in temperature in the Rich Oil Flash Tank and the ROD system.

Simulations indicate that the temperature reached as low as -48°C in this section of the plant.

Figure 2 Simulation Results Graph

Both GP905 and GP922 exhibited signs of extreme coldness by the formation of ice on the uninsulated parts of their exteriors and on the pipework to and from them. A decision was made to shut down GP1 shortly after 11.00 am.

One of the vessels involved was GP905. The reduction in temperature of that vessel caused the embrittlement of its steel shell. When hot lean oil was re-introduced into the vessel it ruptured by way of brittle fracture at its eastern end, releasing a volume of hydrocarbon vapour which travelled towards the area of the fired heaters where it ignited, causing an explosion and fire. (see Figure 3)

3.2. Organisational Background

The Longford site, like most others in the process industry, had been the subject of several manpower reviews over the years to maintain its efficiency and competitiveness.

The Commission highlighted... *Two structural changes to operations management occurred at Longford, which were relevant to the matters under investigation. These changes were the relocation of engineers from Longford to*

Melbourne and the redefinition of the role and responsibilities of supervisors and operators.

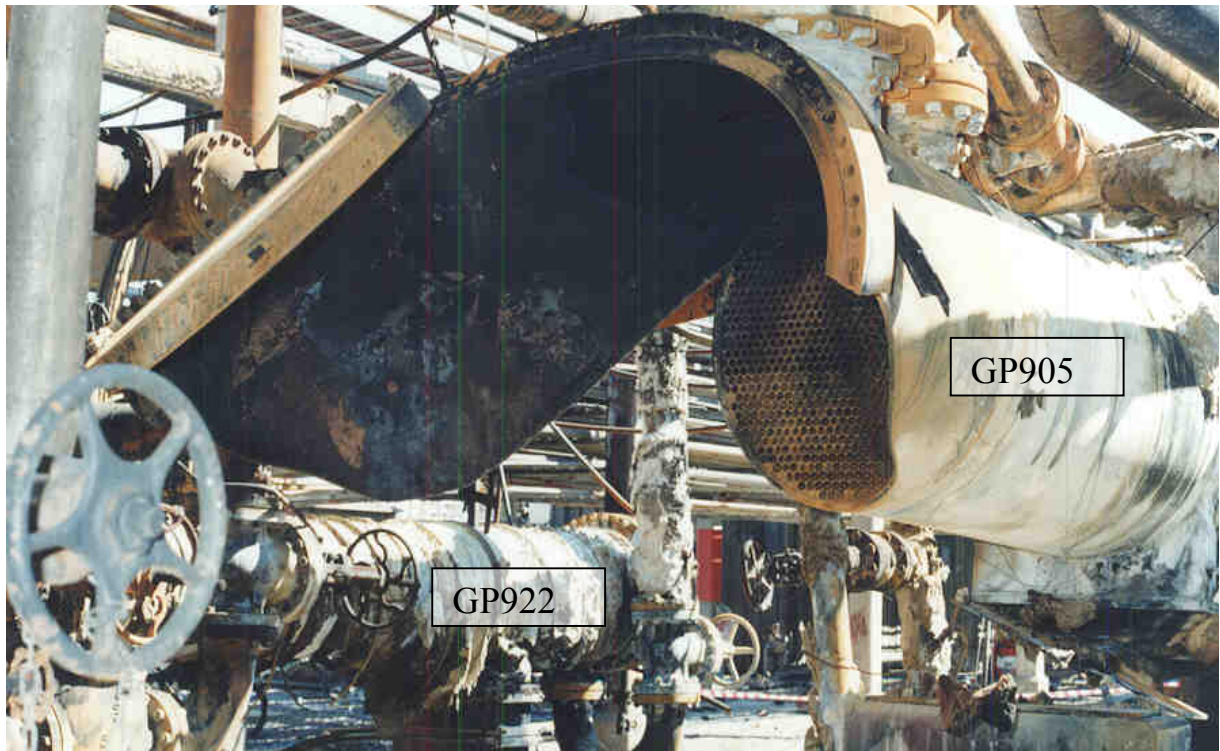


Figure 3 Failed End of GP905

The effect of shifting engineers to Melbourne was to lessen, in the Commission's view, the ready availability of specialist engineering knowledge (e.g. materials and process) on the site, as opposed to operations knowledge, which remained local. Esso anticipated these changes and made alternative arrangements to ensure engineering knowledge accessibility. Engineers typically undertook both a "surveillance" role and a "project" role. To assist with the former, Esso introduced a process data transmitting system (PIDAS) that allowed Melbourne-based engineers real-time access to process variables. Esso also retained a corporate aeroplane to make travel to the site easier.

The other matter, the reorganisation of supervisors meant that... *the primary role of the shift supervisors had become largely administrative, since, by agreement with the four unions represented at Longford, the responsibility for effective plant operation had been transferred to the operators.*

Maintenance staffing was also reviewed and reduced.... *Following these changes the number of supervisors and associated staff at the Longford plant fell from 25 in 1993 to 17 in 1998. Over the same period, there was also a reduction in the number of maintenance staff from 67 to 58.*

Whilst criticism has been directed at Esso's reduction of its maintenance staff at Longford and its allocation of priority to work order requests, the Commission finds that Esso's standards, practices and procedures with regard to these matters did not cause or contribute to the occurrence of the explosion, fire or failure of gas supply.

3.3. Staffing and Equipment Issues

No plant operates all the time with its entire staff present and all its equipment functioning perfectly. Systems are designed to have replacement staff available and / or technical solutions for malfunctioning equipment. Some relevant personnel substitutions or breakdowns on the day included:

- On the day of the accident, the plant manager was at Long Island Point participating in a work safety presentation.
- The position of Operations Superintendent was vacant, and the person acting as Operations Superintendent was on holiday.
- The person substituting for the Acting Superintendent was away ill.
- The Commission identified 4 other staff involved in the accident who were relieving or acting for others.
- The day crew for the shift was all on training at the time when extra manpower was requested.

3.4. The Metallurgy of the Failure

The exchanger, though not rated for the low temperature, did not fail due to the low temperature alone. Following leaks from a nearby exchanger (GP922) *the decision was made to re-introduce lean oil flow into GP922 to try and stop the leak.*

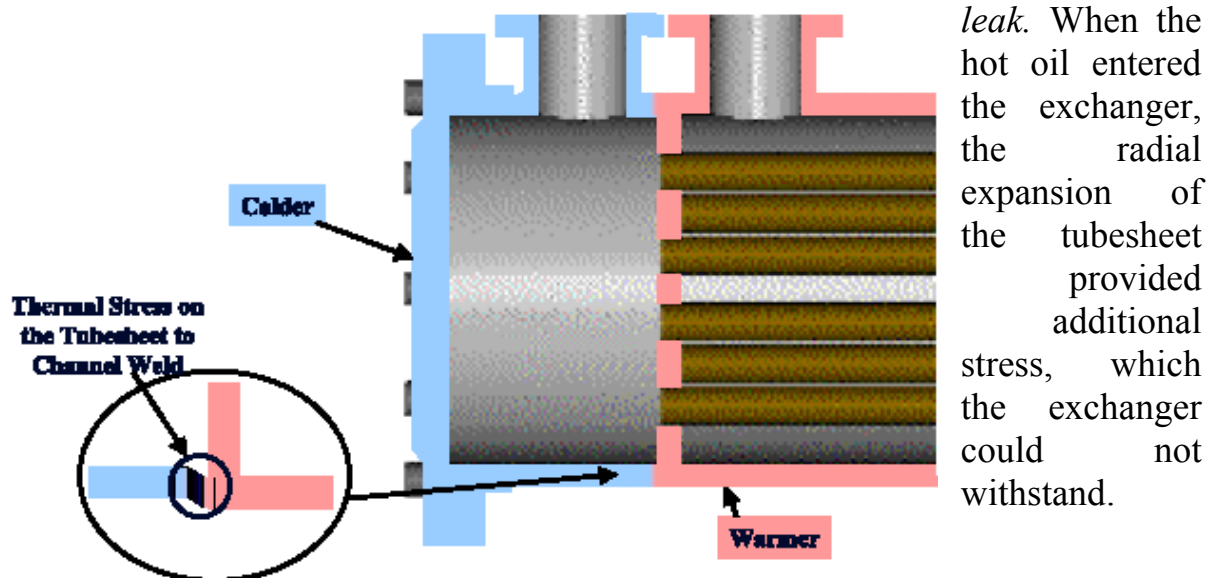


Figure 4 Thermal Stress Model

A catastrophic end failure occurred to exchanger GP905. Essentially the whole end was ripped open (see Figure 3) and the contents of the exchanger, the ROD

column, and all its interconnections were rapidly released. Metallurgical analysis showed... *The featured surface and ligaments indicate that the crack propagated slowly while it was in the weld. It is concluded that the failure in the channel was fast brittle fracture.*

4. THE EVENT

The south-south easterly drift of the vapour cloud from the ROD/ROF area was towards the general direction of the gas-fired heaters, located approximately 170 metres away at the southern boundary of the plant. It would have taken in the order of 30-60 seconds for the cloud to drift this distance.

The burn pattern of the cloud, the eyewitness descriptions of the movement of the flame front and the lack of any significant overpressure damage, all support the conclusion that the front edge of the cloud ignited once it reached the fired heaters.

After the initial release at 12:26 and vapour cloud fire that caused the deaths and injuries, the flame front travelled back to the source. A prolonged fire ensued in this area. Unfortunately, this was beneath a critical pipe-rack junction called "King's Cross". The flames impinging on this pipe rack led to three other rapid releases of large flammable inventories over a 30 minute period, from 13:00 to 13:32. These were termed explosions in the press, but more accurately were fireballs resulting from large pipe ruptures.

A major problem for the Esso operating staff was to isolate the many pipes passing through this critical junction of pipe racks. The GP905 exchanger was 5 m to 10 m from this junction. The total isolation of the pipes feeding the fire required nearly 2½ days. This was due to major interconnections between the 3 gas plants. The Commission reported... *Geoff Evans, a [Country Fire Authority] operations manager, was concerned about the ad hoc nature of the isolation of fuel sources. At 2.30 pm on Saturday, 26 September, he had a discussion with Mick Brack, an Esso acting operations superintendent. He asked Brack for a detailed plan of the plant's pipework to assist the IMT (Incident Management Team) in identifying which valves should be isolated to stop the flow of fuel to the fires. Brack said that he did not have a plan available and that in any event, the Longford plant was a hybrid, having had its original design modified on a number of occasions, so that a plan, even if one could be located, might not have been of much assistance.*

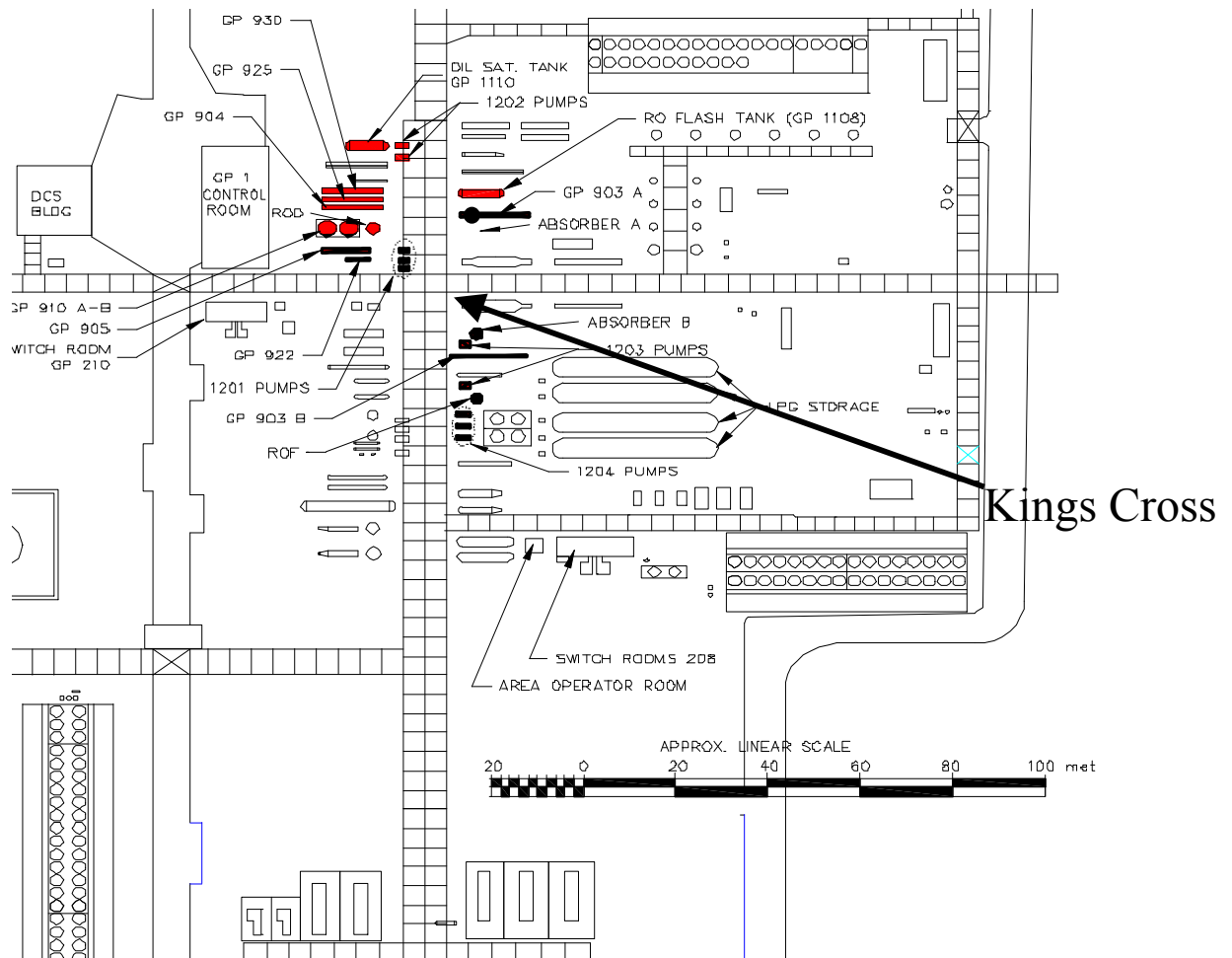


Figure 5 Plot Plan around GP905 and King's Cross Junction

Regarding the source of fuel for the fire, the Commission concluded that the local inventory was only sufficient to fuel the fire ... *for up to two hours following the initial release, indicating that the fire was ultimately fed from sources outside GP1. The ESD system in GP1 was designed only to isolate the Longford plant from the major offshore pipelines, and the feed to the gas transmission line. It did not activate any isolation valves, apart from a valve on the dehydrators, within GP1. The consequence was that the entire volume of hydrocarbons contained within GP1 vessels and interconnecting piping existed as an uncontrolled source of fuel for the fires emanating from GP905 and GP922. ... This weakness was recognised by a 1994 Periodic Risk Assessment (PRA) of GP1, but it appears that no action was taken to correct the situation.*

Had the supply of flammable materials been isolated within minutes after GP905 ruptured, it is unlikely that any of the pipes in the piperacks would have failed as they did ... The availability of these further sources to fuel the fire completely changed the dimension and scale of the accident.

5. ESSO'S SAFETY MANAGEMENT SYSTEM

Following an oil spill from the oil tanker Exxon Valdez in 1989 and against the background of a number of other disasters arising from the hazardous activities of companies other than the Exxon Corporation and its affiliates, Exxon developed a framework for the safe and environmentally sound operation of its various undertakings. The framework was called Operations Integrity Management Framework (OIMF). Exxon Company International had developed an 11 element management system guidelines:

Element 1 – Management leadership, commitment and accountability;

Element 2 – Risk assessment and management;

Element 3 – Facilities design and construction;

Element 4 – Information/documentation;

Element 5 – Personnel and training;

Element 6 – Operations and maintenance;

Element 7 – Management of change;

Element 8 – Third party services;

Element 9 – Incident investigation and analysis;

Element 10 – Community awareness and emergency preparedness;

Element 11 – Operations integrity assessment and improvement.

These combined with OIMF led to the Operations Integrity Management System (OIMS). OIMS is widely regarded in safety management circles as being of world-class standard. It embodies many of the most modern concepts of safety management systems and has been extensively copied by another major oil company; an indication that it has wide credibility.

The Commission investigated deeply the implementation of the OIMS system at Longford and in its view established several omissions or deficiencies in implementation. The authors of this paper suggest, to the degree that they accept the Commission's findings, that readers might well recognise similarities in their own facilities to those described here. This is vital knowledge to share amongst the industry.

Briefly the Commission outlined its assessment of omissions or deficiencies as follows. The Operator, Esso Australia, did not agree with all these findings during the presentation of evidence, therefore the authors have used only the words of the Commission itself.

5.1. Training

... the accident on 25 September itself demonstrated the primary deficiency in Esso's training. That deficiency lay in the failure of its training programmes, however implemented, to impart or refresh the knowledge required to operate GP1 safely in the conditions which existed on the day.

At no relevant time did any programme include training with respect to the hazards associated with the loss of lean oil flow, the hazards associated with the uncontrolled flow of condensate into the rich oil stream from the absorbers, the critical operating temperatures for GP922 and GP905, the circumstances in which brittle fracture might occur or the procedures for the shutdown or start up of GP1.

5.2. Operating Instructions

An example of Esso's failure to implement OIMS is apparent from the state of the Longford Plant Operating Procedures Manual, which contained the operating procedures for GP1 and was located in the GP1 control room. It was a controlled document and was identified by the OIMS Systems Manual as part of OIMS. The manual did not comply with the guidelines in critical respects. It did not contain any reference to the loss of lean oil flow and contained no procedures to deal with such an event. Nor did it contain any reference to GP1 shutdown or start up procedures or the safe operating temperatures for GP905 and GP922.

5.3. Operator Knowledge

The deficiencies in operator training and operating procedures were reflected in the evidence of what the operators and supervisors actually did on 25 September 1998 ... The collective experience of those present at GP922 on 25 September 1998 was more than 200 years at Longford and yet no one recognised the hazards associated with the plant conditions which culminated in the explosion and fire.

The operations manager at Esso ... agreed that the instruction given to operators "failed in arming them to recognise the significance of cold temperatures ... there was clearly a lack of knowledge or understanding of cold temperatures." He said he had no idea, before the accident, that a loss of lean oil flow for any length of time would be a hazard.

5.4. OIMS Self Assessment

Element 11 of the ECI Guidelines, which were translated into Esso's OIMS Systems Manual, required a "process that measures the degree to which expectations are met" and regarded that requirement as essential "to improve operations integrity and maintain accountability".

An external assessment was carried out by a team ... in March and April 1998. A report of the assessment was prepared and sent to [Esso]. The report noted that the assessment team had concluded that Esso had successfully applied OIMS and had a high level of management involvement and participation, presumably in that process.

These (and other) observations of the assessment team appear inconsistent with the Commission's findings concerning the failure of Esso to implement its own systems, particularly in relation to risk identification, analysis and management, training, operating procedures, documentation, data and communications. The Commission can only conclude that the methodology employed by the assessment team was flawed in that the team failed to identify significant deficiencies in the extent to which "individual EAL Management Systems" conformed to the guidelines, particularly in relation to GP1, and were implemented.

5.5. Risk Assessment

With the introduction of OIMS in the early 1990's, there was a requirement for the carrying out of HAZOP studies as part of the design process for new plant. OIMS also contained provision for retrospective HAZOP studies on existing plant, should they be called for. Retrospective HAZOP studies were conducted for GP2 in September 1994, for GP3 in November 1994 and for the CSP in December 1995.

Esso recognised the particular significance of a HAZOP study for GP1, given the age of the plant, the modifications made to its initial design and the changes to design standards since the plant was built. These reasons grew stronger with the passage of time. Indeed, a HAZOP study for GP1 was planned to take place in 1995 and the cost of such a study was included by Esso in successive budgets during the years 1995 to 1998.

The HAZOP study planned for GP1 never took place ... In the end, no satisfactory reason was given in evidence for its deferral or abandonment.

The Commission was convinced of the value of a HAZOP ... it is inconceivable that a HAZOP study of GP1 would not have revealed factors which contributed to the accident which occurred on 25 September 1998. It would, for example have revealed the consequences associated with loss of lean oil flow and would have identified the procedures to be adopted in order to avoid dangerously low temperatures.

5.6. Relocation of Plant Engineers

Until 1991, engineers were stationed at Sale and worked at the Longford plant daily. In 1992, Esso relocated all its plant engineers to Melbourne as part of a restructuring of the company. The change appears to have had a lasting impact on operational practices at the Longford plant. The physical isolation of engineers from the plant deprived operations personnel of engineering expertise and knowledge which previously they gained through interaction and involvement with engineers on site. Moreover, the engineers themselves no longer gained an intimate knowledge of plant activities.

The Commission concluded strongly...*There were no experienced engineers on site at the time of the accident on 25 September 1998. Such changes required a risk assessment in the Commission's interpretation of Esso's Management of Change System... Again, no such assessment was carried out.*

5.7. Incident Reporting and Analysis

A prior, unrelated incident, occurred on 28 August 1998, which led to many similar characteristics associated with the loss of Lean Oil circulation in GP1. This was not investigated. *Had the incident on 28 August 1998 been reported as it should have been, the danger of equipment becoming subject to dangerously low temperatures upon the loss of lean oil flow for any length of time would, in all probability, have become known as would the steps available to avert the danger. The failure to report this incident thus stands as another example of a failure in Esso's implementation of its management systems.*

5.8. Overall Assessment of Management System

Evidence was given that OIMS was a world class system and complied with world's best practice. Whilst this may be true of the expectations and guidelines upon which the system was based, the same cannot be said of the operation of the system in practice. Even the best management system is defective if it is not effectively implemented. The system must be capable of being understood by those expected to implement it.

Esso's OIMS, together with all the supporting manuals, comprised a complex management system. It was repetitive, circular, and contained unnecessary cross-referencing. Much of its language was impenetrable.

The Commission gained the distinct impression that there was a tendency for the administration of OIMS to take on a life of its own, divorced from operations in the field.

However, the fundamental shortcoming was in the implementation of OIMS, as seen in the inadequate state of knowledge of Esso personnel of the hazards associated with loss of lean oil circulation in GP1 and of the actions which could be taken to mitigate such hazards.

Reliance placed by Esso on its OIMS for the safe operation of the plant was misplaced. The accident on 25 September 1998 demonstrated in itself, that important components of Esso's system of management were either defective or not implemented.

6. IMPLICATIONS FOR COMPANIES

The main lessons to be drawn from Longford relevant to meeting the needs of regulatory authorities are, in the opinion of the authors, as follows:

1. Safety Management System – incomplete implementation.
2. Knowledge Stewardship – insufficient on old plant.
3. Management of Change – organisational change not scrutinised.
4. Audit and Review – inadequate attention to detail.

6.1. Safety Management System

A Safety Management System must be implemented fully. It is better to implement all of the safety management system adequately than selected parts excellently and others not at all (CCPS, 1989). The Commission accepted that OIMS was a world-class SMS, but queried its fullness in implementation. Clearly large parts had been implemented well, but those parts that had not been were the cause of the disaster.

Risk Assessment must be founded on good Hazard Identification. No HAZOP had been done for GP1 and thus the risk assessment that was carried out had omissions and limited scope. Many older plants have never been properly HAZOPed and other companies should assess the implications of this omission.

6.2. Knowledge Stewardship

Knowledge and Competence are vital. Whilst very extensive operations knowledge was locally available, the Commission significantly queried the absence of local process and materials engineering skills. This recalls the Flixborough disaster finding that a key mechanical engineering post was vacant and thus a temporary modification was not mechanically checked. Esso made arrangements involving IT linkages and easy travel arrangements to enable process and engineering surveillance of the Longford site. The Commission concluded that these arrangements were not adequate. Downsizing, re-engineering, right-sizing are all important means to remain competitive, but the effect of these on competence should be risk assessed (Management of Change). This is of particular importance to older plants where documentation is often not as good as for modern plants.

Training and Operating Instructions. These need to be tightly linked to a detailed hazard identification and risk assessment. This is the key means to communicate fundamental process and materials knowledge to operating staff. Operating instructions should be linked to specific safety implications.

6.3. Audit and Review

A Safety Management System once implemented must be rigorously audited. This requires an active and challenging Corporate function and also that the regulator does their job effectively. Regulations will not prevent accidents if the safety case so developed remains a collection of paper – active systems must verify it is being implemented and continuously maintained and updated (the “living Safety Case concept”). This activity is not trivial and should be

budgeted. Both these suggestions are a challenge to current thinking. Many Corporate Safety Groups have been seriously downsized with operating assets given much greater autonomy. Similarly, many Regulators (for example some EU regulators implementing Seveso 1) did not actively regulate the industry. They took the view that the development of a safety case was in its own right an adequate regulatory achievement. Development of a safety case goes some way to managing safety but must be rigorously implemented to ensure that required standards are met.

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