Incident

# Lessons from Longford – 20 years on

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## Introduction

"Detective Inspector Bill Willis here. I hear you are a systems engineer" – the phone call every design engineer dreads! Thankfully one of my designs hadn't failed; instead this phone call started the most sobering, challenging and life-changing nine months of my career. Ten days previously there had been an explosion and fire at Esso's gas plant at Longford, about 200km east of Melbourne, Australia. Peter Wilson and John Lowery had died, eight had been injured and Melbourne had lost its supply of natural gas. I was seconded as a technical expert initially to the coronial enquiry and then to the Longford Royal Commission when it took over the investigation a few weeks later.

Although the immediate consequences were clear, the technical cause and detailed events leading to the explosion were not. During my several weeks on the Longford site, testing instruments and supervising demolition, I met and worked with many of the survivors. I was shocked by the devastating impact the accident had on them and on the close-knit rural community of which they were part. The supervisor who was standing in on the day of the accident felt that he had blown up his best mate. Twenty years later, I am still haunted by his image.

Over the next nine months, I was intimately involved in piecing together the detailed events that led to the accident. I was struck by the everyday nature of each event leading up to the accident, and by ordinary people doing their best oblivious to the ticking timebomb. I have tried below to capture the personal dimension of events in the few hours prior to the accident. I then present some of the many lessons to be learned and the impact over the following 20 years.

## The Royal Commission

In 1998, Esso's Longford Gas Plant was the dominant supplier of natural gas to Australia's second largest city, Melbourne. Although the three gas plants at Longford had been located to minimise the risk of common mode failure, the fire was in an unfortunate location. The heat exchanger that failed was adjacent to a major intersection of pipe bridges known as Kings Cross. The fire damaged many of these pipes, including those taking heavier hydrocarbons to the single Crude Stabilisation Plant for processing. As a result, all three gas plants had to shut down. Consequently, Melbourne lost gas supply for two weeks. Without anyone realising it, in the thirty years since gas had been discovered the city had become dependent on it. It was the public outcry due to cold showers and no fish and chips, rather than the needless loss of two lives, that resulted in the Victorian State Government calling a Royal Commission to investigate the cause.

The Royal Commission was a legal entity charged with determining the cause of the accident and making recommendations to prevent a recurrence. The Commission's primary powers were to subpoena people and documents. To ensure transparency and fairness, all evidence was tested in open hearings through cross examination by lawyers representing any of the 13 parties to the Commission. Behind the scenes, the technical team of which I was part was piecing together the technical evidence, running simulations and applying our engineering knowledge to determine the technical cause of the accident. With access to Esso personnel and documents only available by subpoena, this was a slow task. However, such an enquiry provides unprecedented insight into the detailed events of an accident and the underlying causes, details that would not normally be publicly available. Esso was also held in high esteem for their process safety management practices, which were well ahead of those of most other major hazard facilities in Australia at the time. As a result, this accident provided a powerful case study.

## The Longford Gas Plant

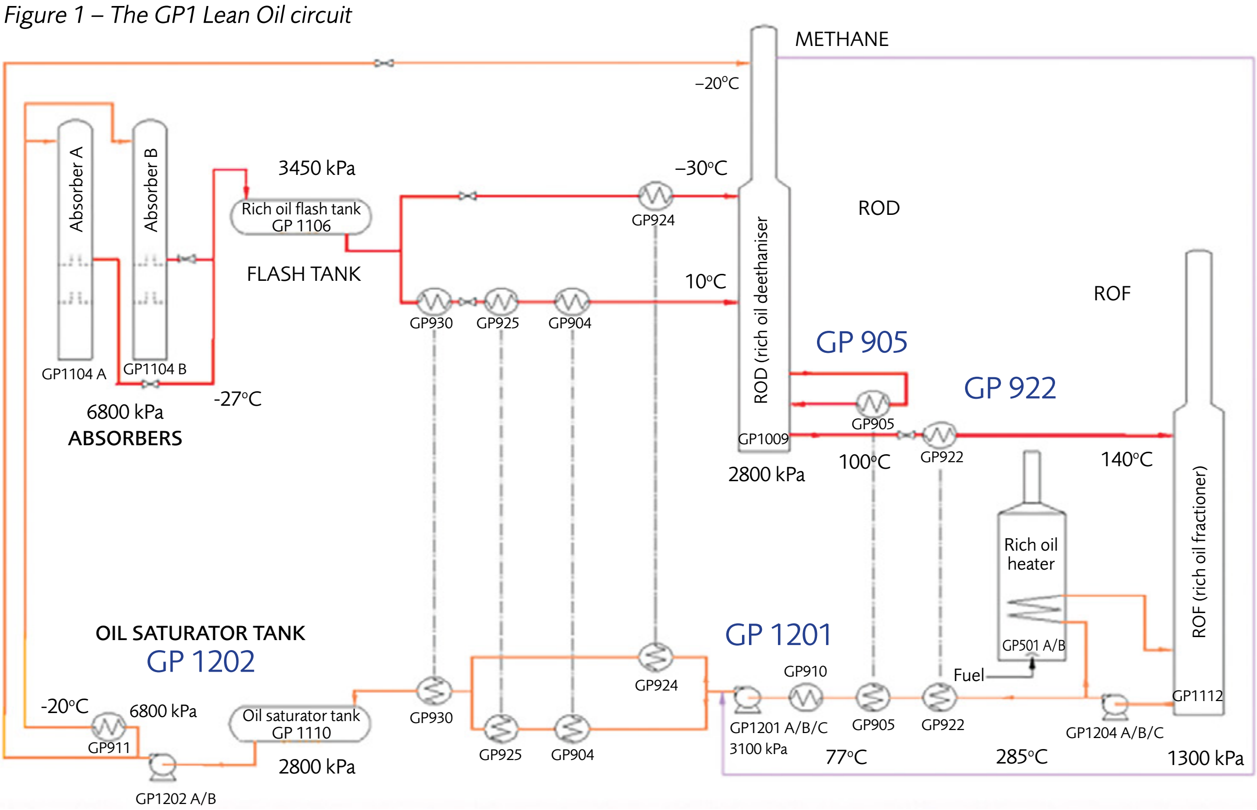
Esso and BHP's Longford Gas Processing Plant came online in 1969 to process natural gas from offshore fields in Bass Strait. Gas Plant 1 (GP1) and the Crude Stabilisation Plant (CSP) were later supplemented by GP2 and GP3 in 1975 and 1983 respectively.

GP1 was a lean oil absorption plant (see Figure 1). Inlet gas from the slugcatchers, having had $CO_2$ and other impurities removed, was cooled to -25 °C and fed to the bottom of the two absorbers. A light oil, similar to aviation kerosene, absorbed most of the ethane and heavier hydrocarbons with the residue gas from the top of the absorbers being fed to the sales gas pipeline.

What was now "rich oil" was collected from trap trays part way up the absorbers. The pressure of the rich oil was reduced across level control valves, flashing off lighter material in the flash tank. The remaining liquid was then heated by the returning lean oil in several heat exchangers before being fed to the Rich Oil Deethaniser (ROD). This was a distillation column that removed ethane (and some methane) from the rich oil. The bottom of the column normally operated at about 100°C, with heat supplied from the returning lean oil by the reboiler GP905.

After being heated further by GP922, the rich oil was fed to the Rich Oil Fractionator (ROF). This distillation column recovered propane and heavier hydrocarbons, in the process regenerating the lean oil for recycle. The ROF reboiler, a gas-fired heater, heated the lean oil to about 285 °C. The hot lean oil was then pumped back to the absorbers through a series of heat exchangers by three sets of pumps (known as GP1204, GP1201, GP1202). At the discharge of GP1201, methane was injected to saturate the lean oil so as to minimise absorption of

*Figure 1 – The GP1 Lean Oil circuit*




methane from the sales gas. The heat exchangers progressively cooled the lean oil to 20°C by interchange with the colder rich oil. The cycle then repeated.

## What happened

The following account is for 25 September 1998 and is presented from the viewpoint of those involved. My comments follow in italics.

**Nightshift** It was a cold night, just above 0°C outside. High gas demand and high condensate flows from offshore led to unusually heavy condensate formation in the absorbers, particularly B. The temperature control valve on Absorber B had been faulty for more than a week. Manual control with the bypass was only partially effective, and the temperature was as low as -20 °C, exacerbating the high condensate production.

**05:51** The display showing condensate level in Absorber B went off-scale high, remaining there until 11:20. This was a fairly common occurrence.

*The actual level exceeded the measurement range of the instrument, so was not known. It is highly likely that condensate was carried over into the Rich Oil circuit early in this period. This would drop its temperature and increase flashing.*

**07:00** Jim Ward, the GP1 Control Panel Operator, Ron Rawson, ROD/ROF Area Operator, and Bill Visser, the Plant Supervisor, started their shift. Bill was standing in for the Acting Area Supervisor, who was away, as it was school holidays.

*The handover from the operators on the previous shift appears to have been perfunctory, and Jim Ward was unaware of the abnormally high condensate levels and low temperature issue.*

**07:03** The oil saturator tank level started to increase above setpoint.

*This appears to be due to carryover of light material from the ROD, which was probably flooded, at least for part of the time.*

**08:19** The GP1201 lean oil booster pumps stopped unexpectedly.

*The level controller had shut the control valve on the saturator tank inlet as the level increased. Eventually the pump low flow trip operated to protect the pumps.*

**08:29** At Jim Ward's request, Ron Rawson tried to restart the GP1201 pumps. This was the first of several unsuccessful attempts throughout the morning.

*The reason for the inability to restart GP1201 was never conclusively determined. One possibility was that the start button was not held down until flow was established, which could take some time if the pumps contained vapour rather than liquid. The operators were unaware of this requirement, necessary to bypass the low flow trip. Ron Rawson had not started the pumps previously when all were stopped, which was a rare requirement. Normally, when one pump was already running, a quick press was all that was required. A notice by the button would have helped.*

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**08:30** The GP1202 pumps stopped due to low level in the Oil Saturator Tank. Lean Oil circulation was now stopped.

*They stopped automatically to protect the pumps from damage.*

**08:30** Gas inflow to the absorbers continued as did production of condensate, which, unknown to the operators, continued to overflow into the ROD.

*The piping and vessels around the bottom of the ROD, normally above 100 °C, were chilled. Simulation showed that GP905 would have reached -48 °C by 09:30. This was a highly hazardous condition, as the carbon steel was now brittle and liable to fracture. The operators were unaware that loss of lean oil was hazardous and regarded it purely as a production issue. The time bomb was now ticking!*

**08:38** An alarm in the ROF signalled the start of a period of significant instability over the next 90 minutes, requiring ongoing attention from the operators.

**Before 08:45** Ron Rawson and a contractor separately observed condensate leaking from the lean oil side of GP922. Ice was forming on some heat exchangers and around the ROD.

*The piping had cooled below 0 °C. Flanges were starting to distort and leak. Although liquid flow had stopped, the plant was still pressurised.*

**From 09:30** Bill Visser, the acting plant supervisor, returned to the control room from a meeting and started working with Ron Rawson to attempt to restore normal operation.

09:35 Jim Ward, in the control room, cut off half the inlet flow. GP1 was still pressurised.

**09:37** The Longford Liquids Recovery plant (LLRP) shut down. This resulted in many alarms from the DCS over the next hour or so. Attempts to restart it occupied Ron Rawson, Jim Ward and another operator for an hour and a half.

*70% of GP1 was controlled from the original pneumatic instruments on the 1969 control panel. They generated relatively few alarms that morning. However, the modern computer based distributed control system (DCS) that controlled the LLRP continued to raise an alarm every few minutes. This proved a major distraction to the operators, who should, with hindsight, have ignored liquids recovery, which was simply an efficiency measure.*

**10:19** Ron Rawson found pump GP1202B running so hot that it was smoking. The stop button failed to stop the motor, so Bill Visser isolated it four minutes later in the switch room.

*The pump had been running dry for up to an hour. The trip circuit had failed to operate. This large pump had a high voltage motor and so the stop circuit was "energise to trip", requiring power to open the isolating contactor. Some loosewires were later found that explained this failure, which was a further distraction.*

**~10:40** The leakage rate from GP922 had increased and Bill Visser decided to shut down the plant. Isolation and diversion of gas took until 11:14, from which time no gas or condensate was flowing to GP1. The oil circuit remained pressurised, however.

**From 11:00** Bill Visser arranged with other supervisors to help clean up the spill and fix the leak. For the next hour, operators and supervisors concentrated on GP922, cleaning up the leak and deciding how best to fix it. At one point, a valve on the rich oil side of GP922 was closed and the leak on the lean oil side increased, contrary to expectations and causing much confusion.

*Unknown to everyone, GP922 contained a broken tube that allowed liquid to pass internally from one side to the other. In normal operation, this resulted in a minor undetected efficiency loss. At this time, however, it added significantly to the confusion about the cause of the leak from GP922.*

**11:38** Production controller Mike Shepard returned from a chiropractor's appointment. As the person on site with the most experience in GP1 (he had been there since it started up), his views carried significant weight.

**~12:00** The group of supervisors decided to restart lean oil flow slowly through GP922, without lighting the fired heater. More attempts were made to restart the GP1201 pumps and were thought to be successful around 12:17. Attempts at tightening the bolts on GP922 were unsuccessful.

**12:20** Mike Shepard, standing near GP905 and puzzled by the low temperature at the bottom of the ROD, asked Jim Ward over the radio to manipulate "TRC4", the ROF bottoms temperature controller. Jim misheard and manipulated the unrelated controller "PRC4" instead.

**12:25** Mike Shepard, puzzled by the lack of response of the control valves, changed a switch next to GP905 intending to move the control valves so as to bypass the lean oil around GP905. The ROD and GP905 were still at a pressure of about 2800 kPa.

**12:25** Just after the switch was operated, GP905 failed catastrophically (see Figure 2), releasing 20 to 25 tonnes of vaporising liquid. The ten people near GP922 and GP905 were blown off their feet. A large white vapour cloud was formed but did not catch fire immediately.

*Peter Wilson and John Lowery were killed instantly by the force of the explosion, which sprayed gravel in all directions leaving a hole 1.5m in diameter and 1m deep.*




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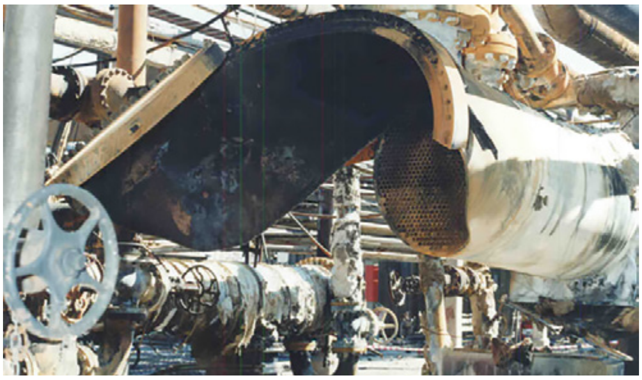

*Figure 2 – ROD Reboiler GP905 after the accident*

~12:26 The gas cloud drifted south until it reached some fired heaters, prudently located away from the main plant area. The cloud then ignited, and the flame front flashed back to GP905.

*Seven of the remaining eight men managed to crawl out of the area in the 30-60 seconds before the gas cloud ignited. One could not, and was badly burned by the ensuing fire, but survived. The individual stories by survivors in the Commission's report[1] make harrowing reading. Up to eight lives were saved by the delay before the gas cloud ignited. The electrical switchroom adjacent to GP905 was a potential source of ignition, but the door was closed and the pressurisation, intended to keep out flammable vapours, worked as designed. Other "explosion protection" of electrical equipment also functioned correctly. (Remember this if you want to prop open a switchroom door!)*

~12:45 The other gas plants were shut down and non-essential personnel evacuated from the site.

To 13:35 A large fire up to 100m high at times now emanated from GP905, which was located adjacent to the intersection of two large pipebridges known as "Kings Cross". The fire impinged on these pipes and, as they failed and released their contents, small BLEVEs occurred, increasing the size of the fire (see Figure 3).


*Figure 3 – The fire, two hours after the initial failure (from security camera)*

*GP905 was also adjacent to four large LPG "bullets" that were now exposed to the full radiant heat from the raging fire. They were fitted with thermally activated (by melted plastic tubing) deluge systems to keep the metal cool. Inspection from a helicopter confirmed that they were working as intended. Had this cooling not functioned correctly, it is likely that several very large explosions (BLEVEs) would have resulted with catastrophic results.*

17:30 The fire had reduced considerably after major sources of fuel were isolated. However, fires continued to burn until a flare connection was eventually crimped closed on Sunday afternoon, more than two days after the original release.

*Identifying the sources of fuel was a major challenge due to the interconnections between plants that had been added over the years and the absence of adequate current documentation.*

## The cause

The Commission found that the immediate technical cause of the accident was the introduction of hot lean oil into GP905 while it was still at about -48°C and pressurised. This resulted in brittle fracture of the east tube channel releasing the hydrocarbon contents, which inevitably eventually found an ignition source. The low temperature occurred because of carryover of low temperature condensate into the lean oil and the inability to restart GP1201 pumps once they had stopped.

The underlying cause was that those operating and supervising GP1 on 25 September 1998 did not have knowledge of the dangers of the loss of lean oil due to deficiencies in their initial and subsequent training and the absence of current operating procedures that could guide them in the problems they faced.

## Lessons

Following the Royal Commission, I presented more than 40 seminars around Australia and New Zealand in which I went through the detailed chronology of "ordinary" events that led to the accident, as presented above. The reaction of many (particularly outside the oil and gas sector) was "it could have happened here". The generic lessons learnt were powerful. A comprehensive treatment of the lessons to be learned may be found in Kenney et al (reproduced here on page 12). Here I reflect on some of the lessons that resonated most with me.

Accidents are about people. The impersonal tone of many accident reports can lead us technologists to forget this. Ordinary people trying to do their best need to be equipped with the knowledge and skills to handle combinations of abnormal situations such as these. The Commission exonerated the operators and supervisors on the day, who collectively had more than 200 years' experience on GP1. Experience is not a substitute for understanding.

Most of those involved were unaware of the hazardous situation that evolved, as was clear from their actions on the day. The Commission found that, despite the existence of Esso's extensive safety management system, hazard identification training and procedures were inadequate. The


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simple act of isolating the rich oil from the absorbers would have prevented the accident. This requirement was in an earlier version of the operating instructions, although they did not give the reason for this action. This clause was removed when the procedures were standardised. To aid understanding of their importance, operating procedures should include the reasons for each action.

The supervisors and operators lost "situational awareness". It was apparent that the operators did not make effective use of the strip chart recorders to assess the situation. Also, the old-style control panel did not provide the level of information available with a modern control system. The level measurement in the absorbers only covered the normal operating range. Despite warnings in the industry dating back to the 1950s, this practice continues today and has played a part in several major accidents[2, 3]. On the other hand, the number of alarms from the modern control system in the liquids recovery plant proved a major distraction. Designing an effective operator interface that provides good situational awareness during major upsets is challenging. Scant attention is often given to this critical requirement.

Lives were saved by the good design and maintenance of the electrical explosion protection coupled with the location of the fired heaters. The delay in ignition allowed all but one of the injured to escape. Also, effective water cooling of the LPG bullets by the deluge system averted a catastrophic explosion. On the other hand, mitigation of the impact on Melbourne's gas supply was ineffective due to inappropriate routing of common piping and inadequate documentation. Layout, detailed design and modifications must recognise the importance of mitigating the consequences of major events.

## The 20 years since

The Longford Royal Commission provided a powerful case study that is now widely referenced when teaching process safety to chemical engineering undergraduates in Australia. Although the Commission's terms of reference precluded examination of Esso's safety culture, Andrew Hopkins' book "Lessons from Longford"[4] on the organisational and cultural implications has been widely read. It is pleasing that the lessons learned are being passed on to future engineers and managers.

The safety case regulatory regime recommended by the Commission was introduced to onshore Major Hazard Facilities initially in Victoria and eventually throughout Australia (see Margaret Donnan's article in this issue). This has had widespread impact, not only for the Major Hazard Facilities who are regulated. Smaller organisations handling hazardous chemicals have also adopted the safety case principles, albeit managed internally. However, small operators responsible in part for smaller scale hazardous facilities have not all seen fit to learn these lessons.

A safety report is, by its nature, a complex and comprehensive set of documents. Consequently, it is not readily comprehensible by all employees. One organisation addressed this by producing a simple "Basis of Safety" document. On several A3 sheets, this tabulated the hazards and their controls, together with who was responsible for each. This proved an effective way of communicating the essentials of hazard management to all employees.

As abnormal events develop, operators must be able to quickly assimilate what is happening. Modern computer-based control systems provide much more information than was available in GP1. However, a major challenge is to present this information without overloading the operator. Since Longford, I have worked as a consultant to more than 50 process companies to help them implement control and automatic protective systems that give their operators a fighting chance when the chips are down. Despite increased awareness, many organisations still struggle to develop effective operator displays and to manage alarms effectively to avoid overwhelming the operator during major events such as this.

We should never forget that accidents involve people. If all of us in major hazard industries learn the lessons from Longford, Peter Wilson and John Lowerey will not have lost their lives in vain.

## References


1. *Dawson 1999; The Esso Longford Gas Plant Incident, Report of the Longford Royal Commission, (Govt Printer, State of Victoria) (available online)*
2. *CSB 2007; US Chemical Safety and Hazard Investigation Board Refinery Explosion and Fire, BP Texas City, Texas March 23, 2005 Report 2005-04-I-TX (available online)*
3. *HSE 1997; Health and Safety Executive, The explosion and fires at the Texaco Milord Haven Refinery, 24 July 1994 HSE, 1997 (available online)*
4. *Hopkins 2000; Andrew Hopkins, Lessons from Longford: The ESSO Gas Plant Explosion, CCH 2000*


## The Author

Robert (Bob) Weiss BE, MEngSci, FIChemE, TÜV Rheinland FSExp was a Technical Investigator for the Longford Royal Commission and presented all the non-metallurgical technical evidence to the Commission. Prior to the Commission, Bob had extensive experience as a process engineer with Monsanto and a control systems design engineer with ICI Australia and Orica. Subsequently he was Principal Consultant with Honeywell Process Solutions where he consulted to most of Australia and New Zealand's major process operating companies on functional safety and operator effectiveness with a particular focus on alarm management. Now semi-retired, Bob shares his experience through training courses and occasional university lecturing.




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