HSE

COMAH
Control of Major Accident Hazards

Chevron Pembroke
Amine regeneration unit explosion
2 June 2011

An overview of the incident
and underlying causes

Foreword

On 2 June 2011 four people were tragically killed and a fifth seriously injured when a tank exploded at Chevron's Pembrokeshire refinery. The incident investigation was initially led by Dyfed Powys Police under the Work-Related Deaths Protocol, working jointly with the Health and Safety Executive (HSE). Primacy for the investigation transferred to HSE in May 2017 with Dyfed Powys Police continuing to provide practical and helpful support.

Shortly after the explosion, HSE issued a safety alert to inform industry of the preventative measures required to avert a similar occurrence. The investigation was complex and we can now share further information about the underlying causes, so that everyone in major hazard industries (not just those involved in tank storage or tank cleaning) can learn from this incident, understand what went wrong, and apply lessons to their own organisations. Although a number of years have elapsed since the incident, the information contained within this report remains highly relevant today.

On completion of our investigation, HSE took enforcement action to ensure that those responsible for the incident were held to account in a criminal court. Two defendants pleaded guilty to charges under Sections 2 and 3 of the Health and Safety at Work Act 1974. When passing sentence on the defendants at Swansea Crown Court on 6 June 2019, the Judge, the Honourable Mr Justice Lewis, stated:

'The fact is that the serious nature of the failings, the number and range of failings, and the length of time over which certain of the failings occurred demonstrate serious errors and serious failures within the organisation to address the risks to health and safety.'

All major hazard industries should look carefully, both at their own operations and the control of contractors, in the light of the systematic failings that lay behind this tragic incident.

I hope that this prosecution will serve as a reminder to those with a responsibility for employees and contractors, to actively monitor their safety management system arrangements to ensure they are effective in keeping workers safe.

Jane Lassey
HSE Director of Chemicals, Explosives and Microbiological Hazards Division

Executive summary

Shortly after 6pm, on 2 June 2011, an atmospheric storage tank within the amine regeneration unit at the Chevron Pembroke Refinery exploded. A fireball split the tank open and killed four workers – Robert Broome, Julie Jones, Dennis Riley and Andrew Jenkins. The sole survivor, Andrew Phillips, sustained severe burns and suffered life-changing injuries.

The force of the explosion ejected the five-tonne steel tank roof over 55 metres through the air. After narrowly missing a multi-fuel pipe track, the roof crashed onto a pressurised storage sphere containing extremely flammable butane. Good fortune prevented the airborne roof from puncturing the butane storage vessel, which would have led to an uncontrolled release of liquified petroleum gas (LPG).

The explosion was caused by the unintended ignition of a flammable atmosphere within the tank (17T302), during what should have been a routine cleaning operation conducted in preparation for maintenance.

The investigation revealed a longstanding and widespread failure to understand and control risks posed by the flammable atmosphere inside the tank. The explosion and the resulting fatalities were therefore avoidable. The incident was not merely the consequence of errors by individual employees, but because of the failure of safety management systems to ensure a safe place and safe systems of work.

Contents

Part 1 Chevron

1 Background

1.1 Pembroke Oil Refinery

The refinery was constructed in 1963 and began operating the following year, initially refining 100,000 barrels of crude oil per day (bpd). Production increased over time, to the point that output had reached 220,000 bpd at the time of the incident.

The crude oil is processed to generate predominantly petrol and diesel products, which is sold worldwide. The refinery's corporate ownership has changed over the years. Historically it was owned and operated by Texaco and subsequently Chevron Limited until the explosion incident in 2011. By this time the site was up for sale – it was purchased by Valero in August 2011 and is now operated by Valero Energy UK Limited. Despite the various changes of ownership, the registered company number of the Pembroke Refinery has remained the same throughout.

In 2011 Chevron employed 543 workers on site, with additional support provided by approximately 700 contractors. A local company, B&A Contractors limited, was one such contractor, then employing 55 of their own staff.

1.2 The amine regeneration unit (ARU)

Crude oil consists predominantly of hydrocarbon compounds but also contains hydrogen sulphide (H_2S) which is toxic and must be removed. H_2S is separated from crude oil and other petroleum products by a process involving diethanolamine. This chemical is subsequently treated to remove the entrained H_2S and then recycled for re-use. The processing and recycling of diethanolamine takes place within the amine regeneration unit (ARU).

The ARU was at the centre of the incident and the process is briefly summarised in this section and schematically (see Figure 1). The ARU supplies diethanolamine to nine scrubbing units located across the refinery. The scrubbing of petroleum products involves combining diethanolamine (amine) and petroleum products under slight pressure, in order to remove hydrogen sulphide from the petroleum fraction.

Successful scrubbing relies upon the strong affinity between amine solution and hydrogen sulphide. Hydrogen sulphide chemically combines with the amine in the scrubbers to form 'rich' amine that

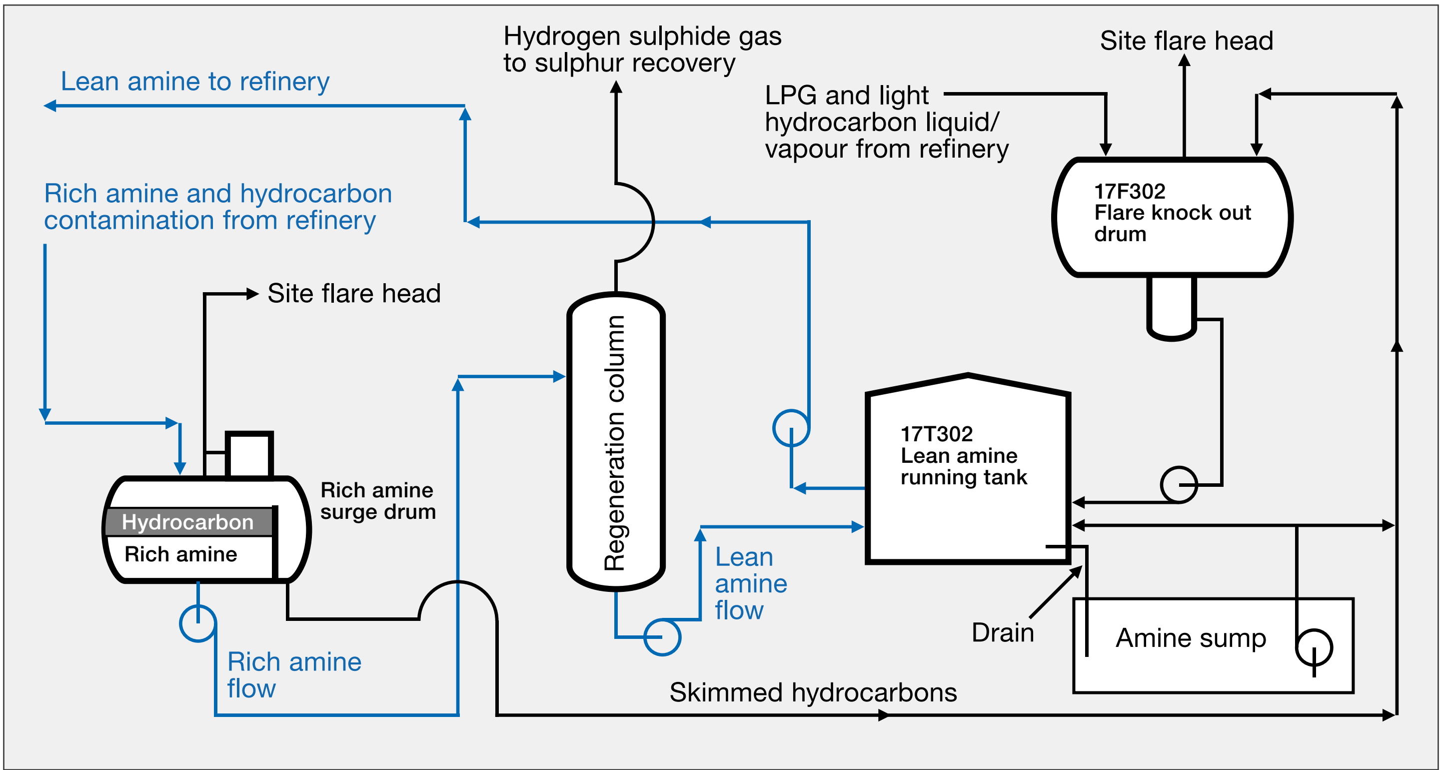


Figure 1 Simplified diagram of the amine recovery unit process

is pumped back to the ARU. There, rich amine is heated with steam in a regeneration column to remove and separate out hydrogen sulphide. The resulting sulphide-free amine solution is pumped from the bottom of the regenerator column back to the amine running tank, where it is stored temporarily, before being pumped out for use once again in the refinery scrubbers.

During scrubbing, the amine not only binds hydrogen sulphide but also collects up some of the hydrocarbon to which it has been exposed. The entrained hydrocarbon then returns with the rich amine to the ARU 'surge drum'. In this vessel, hydrocarbon would separate, floating above the aqueous amine. An internal weir system was used to skim off the upper hydrocarbon layer, which was subsequently routed to the ARU flare knock-out drum.

The ARU flare drum received light hydrocarbon material from various sources, not just the ARU. Much of this hydrocarbon would, as intended, evaporate and pass to the refinery flare system. The residue, which included a variety of hydrocarbons and some contaminated amine, would accumulate in the lower section of the flare drum, called the 'boot'. Originally, this residue would be automatically pumped to a remote crude oil slops system elsewhere on the refinery, or a dedicated slops separation tank on the ARU plot. However, in 1998 the decision was made to operate the ARU as a 'closed system', which meant the redirection and automated pumping of flare drum residue ultimately into the amine running tank.

As an important consequence of this change, any liquid hydrocarbon transferred to the ARU flare drum as a result of normal ARU operation (or events elsewhere on the refinery) was retained on the unit and eventually accumulated within the ARU running tank 17T302.

1.3 ARU storage tanks

The ARU had two vertical process tanks, identified as 17T302 and 17T303 (see Figure 2). Both were 9.7m in diameter and height, described as 'breathable' in terms of their ventilation arrangements. The vapour space above the liquid in each tank was connected to the atmosphere through an automatic pressure-vacuum valve. As the tank liquid level rose it allowed the tank atmosphere inside to be forced out of the vessel (breathe-out). Equally, when the level fell, to prevent the formation of a vacuum, air from the surroundings would enter the tank vapour space (breathe-in).

Figure 2 Pre-incident photograph of ARU tanks

The tanks had been designed for two different purposes. Tank 17T303 was optimised for the separation of waste streams and tank 17T302 was designed to operate as the lean amine process reservoir. Contrary to the intention of the original design, the tanks were used interchangeably over the years. One tank was the designated 'running tank', kept at 40 °C and used for the storage and recirculation of amine to the refinery scrubbers, while the other was used for the separation of 'slop' material into its component parts. To prevent the oxidation of amine, both tanks were dosed with a 300mm blanket of 'diesel', which floated above the aqueous amine to inhibit oxygen ingress. Tank 17T302 was constructed in 1979 and, prior to the incident, had been operating as the running tank since 2007.

1.4 Accumulation of light hydrocarbons

The bulk of the hydrocarbons returning to the ARU in the rich amine were relatively volatile, within the range of propane to nonane. They are collectively called 'light hydrocarbons', the majority being hexane to octane. These substances generate considerable vapour under normal atmospheric conditions. Since 1998, a proportion of this light hydrocarbon separated from rich amine in the ARU surge drum would eventually accumulate within the amine running tank. As there was also a route to the amine running tank through the ARU flare drum, there was the potential for other sources of light hydrocarbons to migrate into the running tank, causing further contamination. The amine running tank operated at around 40 °C. At these temperatures, the amount of vapour formed by those volatile hydrocarbons was well above the minimum required to form a flammable atmosphere in the headspace.

Over time the contamination of the 'diesel' blanket with accumulating light hydrocarbons significantly increased the depth of the blanket, to the point that there was a need to remove the excess hydrocarbon material. These removal operations give an indication of the speed and extent to which light hydrocarbon accumulated within tank 17T302. In 2007, the tank was originally dosed with 300mm of 'diesel'. By January 2009, this blanket had grown three-fold to 900mm deep and could no longer be considered 'diesel' due to the change in its composition – it could be more accurately described as the 'hydrocarbon layer'. Siphoning equipment was used to reduce the excess. Similarly, in June 2010 the depth of hydrocarbon had grown to 850mm and a vacuum tanker was used to remove approximately 23m^3 of hydrocarbon liquid.

1.5 Significant events

Looking back, HSE believes there were a number of significant events that should have alerted the refinery management team to the presence of light hydrocarbon within the running tank. These events presented several opportunities to reduce risk and prevent the incident, through the critical review and refreshing of risk assessments, training and maintenance arrangements. Regrettably, the significance of these opportunities went unrecognised.

1.5.1 Liquid petroleum gas in the flare drum

On 14 February 2001 the ARU was shut down due to concerns regarding a high liquid level in the ARU flare drum. Prior to shutdown, the relevant pumps had been aligned to transfer material from the flare drum to the ARU running tanks. The pumps were switched to discharge flare drum material into the refinery slop system, to avoid filling the running tank (17T303 at that time) with liquid petroleum gas (LPG). According to ‘lessons learned’ from this event, new instructions were required to avoid confusion when using the flare drum pumps to transfer LPG. The new instructions (see paragraph 1.5.2) did not materialise until 2005, four years later. By 2011 the investigation revealed that key operators were unaware of their existence and others considered the instructions impractical, so they were routinely ignored.

1.5.2 Tank explosion and new procedure

On 7 May 2004 an explosion and fire occurred in the Mercaptan Oxidation Processing Unit (Merox). This is a proprietary catalytic chemical process used in oil refineries and natural gas processing plants to remove mercaptans from LPG, propane, butanes, light naphtha, kerosene and jet fuel by converting them to liquid hydrocarbon disulphides. In this incident, light hydrocarbon vapour passed through a vent in an atmospheric tank and was ignited by a nearby diesel generator. The resulting fire was extinguished within 10 minutes and the hydrocarbon fuel source for the explosion quickly identified and isolated. Despite damage to the generator enclosure, no one was injured. This event triggered ‘A site wide review … to identify all process systems where there is potential for a loss of containment of hydrocarbon via an atmospheric vent’. In response, over a year later, a new operating procedure was developed for the ARU entitled: *Action to take on LPG getting in to the ARU/SRU Flare Drum*.

This procedure described the risk of LPG accumulating in the flare drum and then being pumped directly into the amine running tank. The document instructed operators to manually operate valves when necessary to prevent normal discharge from the flare drum to the running tank. This action was described locally as ‘blocking in’ the flare drum vessel. Of the operators aware of this new procedure, many were reluctant to follow it given that ‘blocking in’ any flare drum contradicted existing safety instructions.

In relation to this incident, it is understood by HSE that no liquid butane or propane was transferred from the flare drum to the running tank. Attention should be drawn to paragraph 33 within the sentencing remarks of The Honourable Mr Justice Lewis (see Appendix 3). He has noted that, while the prosecution rely upon previous incidents at the refinery, they are different in nature from the events leading to this explosion and have not been taken into account in determining sentence.

1.5.3 2008 hazardous area classification downgrade

1.5.3.1 What is a hazardous area classification (HAC)?

Flammable atmospheres can exist continuously or intermittently in the workplace, particularly where flammable liquids are stored and processed. Employers must classify such areas into zones, depending on the size, location, likelihood of an explosive atmosphere occurring and its persistence. Areas classified into zones must be protected from sources of ignition, for example from fixed or mobile equipment, electrostatic charges, matches, lighters etc.

International standard BS EN 60079-10-1: 2015 *Classification of areas – Explosive Gas Atmospheres* explains the basic principles of area classification for gases and vapours. The standard forms a suitable basis for conducting a HAC assessment and can be used as a guide to achieve compliance with the requirements of the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR).

Zones for vapours and gases are defined within Schedule 2 of these Regulations. In summary:

Zone 0 is a place in which an explosive atmosphere is present 'constantly' for long periods or frequently;

Zone 1 is a place in which an explosive atmosphere is 'likely' to occur in normal operation occasionally;

Zone 2 is a place in which an explosive atmosphere is 'not likely' to occur in normal operation but, if it does occur, will persist for a short period only.

Non-hazardous is a place where an explosive atmosphere is not expected to occur in any foreseeable circumstances, and no special protective measures are required for equipment used in this place.

Equipment and protective systems intended to be used in zoned areas should be selected to meet the requirements of the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996.

HAC studies usually take the form of three-dimensional drawings identifying the hazardous zones. Additional text gives information about the dangerous substances, work activities and wider assumptions. Prior to the incident, generic HACs applicable to the ARU running tank were well established and available within standards:

- BS EN 60079-10-1: *Classification of areas – Explosive Gas Atmospheres*, 2009

- Energy Institute – Model Code of Safe Practice Part 15: *Area Classification Code for Installations Handling Flammable Fluids* (Third edition, 2005)

Each standard contained a cross-sectional tank diagram, with hazardous area classifications clearly defined:

- Zone 1 and 2 areas around the tank shell;
- Zone 1 area around the tank vent;
- Zone 1 area within the tank drainage sump;
- Zone 0 area inside the tank vapour space, above the liquid.

1.5.3.2 *Suitability of ARU electrical equipment*

Chevron specified the minimum standard for certificated electrical apparatus to be used on the ARU plant. No fixed electrical apparatus was installed inside the 17T302 tank and there was little in the way of fixed electrical equipment in the immediate vicinity. During the investigation, the area surrounding the vessel was searched by HSE and several items of fixed electrical apparatus were identified and visually examined. The items were of a suitable design standard for use in a flammable atmosphere.

1.5.3.3 *Downgrading of the 2008 ARU HAC*

As a consequence of contamination with light hydrocarbon, both the amine running tank 17T302 headspace and the atmosphere surrounding the tank vent contained potentially flammable vapour.

Over the years, Chevron progressively downgraded the hazardous area classification for these ARU tanks. They were initially rated as Zone 1 and subsequently downgraded to Zone 2. In 2008 the tanks were finally downgraded from Zone 2 status to 'non-hazardous' (Figure 3 illustrates the ARU tanks outside the zoned area). The running tank headspace should have been classified as Zone 0 (highest risk), with additional zones around the exterior and tank vent depicted within a three-dimensional diagram, as described within Section 1.5.3.1.

Chevron staff involved in the 2008 ARU hazardous area classification work were simply unaware of the light hydrocarbon contamination hazard caused by the process change in 1998 (when the ARU became a closed system) and so disregarded the risk of a flammable atmosphere. The classification exercise performed by these Chevron staff did not include side elevation drawings but only a plan view as shown in Figure 3. As a result, the vertical extent of the hazardous zone (eg around the tank body and vents) was not considered.

The hazardous area classification for the ARU was therefore incorrect and misleading. Had it been accurate, such a resource could have been utilised to inform Chevron employees and contractors of the location, nature and size of any relevant flammable atmospheres when starting to prepare the tank cleaning

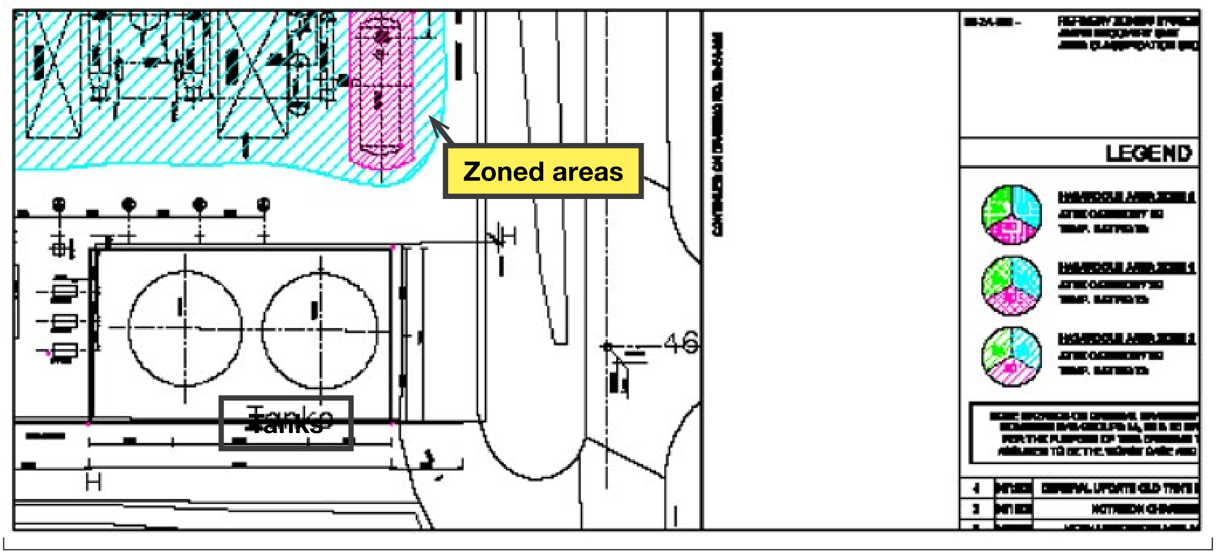


Figure 3 Hazardous area classification of ARU tanks

risk assessment. In this case, no one involved sought to consult the HAC during development of the ‘permit to work’ or risk assessments that were prepared for emptying the tank. This issue was raised during the court case and the judgement of The Honourable Mr Justice Lewis on this subject can be found within his sentencing remarks in Appendix 3, paragraph 34.

The development of the HAC is an example of a risk control system operating within a silo of isolation. The potential for LPG/flammable material to reach the ARU tanks was observed in 2001 and again documented in 2005, equally excess hydrocarbon was removed from the running tank in 2009 and 2010. However, not one of these events triggered a critical review of either the risk assessment or related hazardous area classification.

2 Events preceding explosion

2.1 Tank duty

Between 23 April 2011 and 14 May 2011 tank 17T303 was taken out of service for routine maintenance. During this period, tank 17T302 operated as both the running tank and the slops tank for the amine regeneration unit. Following maintenance, tank 17T303 was brought back into service as the running tank. To facilitate this the tank was charged with a new diesel blanket (300mm depth) and, between 14–17 May 2011, the bulk of the amine liquid within 17T302 was transferred over to 17T303 via low-lying connecting pipework. The hydrocarbon layer within 17T302 remained within the tank and was not transferred. On 17 May 2011, a Plant Operator carried out a manual dip test on tank 17T302 and recorded the depth of the hydrocarbon layer as 0.55m.

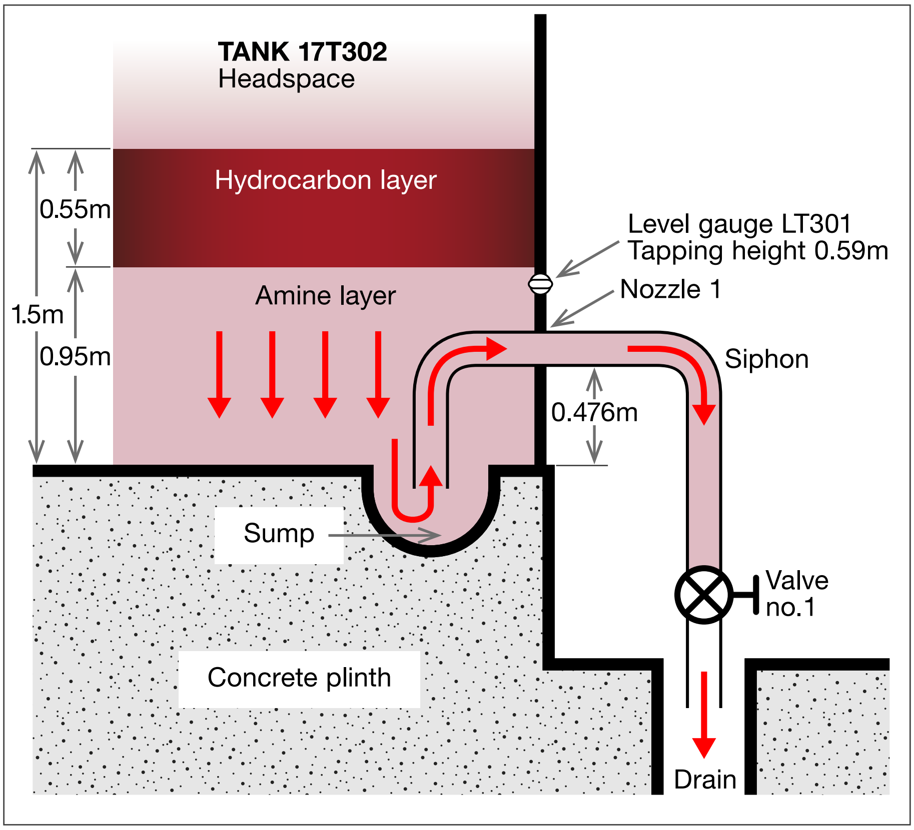


Figure 4 Schematic of tank 17T302 draining equipment

Figure 5 Post-incident section of tank 17T302 showing drain equipment

2.2 Draining of tank 17T302

The final stages of draining tank 17T302 was carried out by a Plant Operator. On 18 May 2011, in the early hours of the morning, he attempted to empty the tank by opening the main drain valve manifold (valve 1), with which he was unfamiliar. He was not aware of the presence or the purpose of the internal sump and siphon drain equipment, which was designed to empty the tank completely. A cross-section of the internal tank siphon is shown in Figures 4 and 5.

Tank 17T302 was also fitted with a float and tape level gauge, displaying tank liquid level on a dial and counter at ground level, capable of detecting and communicating liquid level right down to the tank floor. When emptying the tank, the Plant Operator relied solely upon the liquid level, which was displayed on the digital control panel within the unit control centre. This data was derived from level gauge LT301 installed in the tank wall, but 0.59m above the base, below which measurements were not captured. The last tank level for 17T302 observed on the control panel by the Plant Operator was 0.07m.

The Plant Operator opened the drain valve (valve 1 as shown in Figure 4) and observed a flow of material into the ARU sump. When flow from the drain valve ceased, he closed the valve, incorrectly believing that all the liquid had been drained and that the tank was empty. The float and tape level gauge was not used to confirm that the tank was empty. The Plant Operator was not aware that the cessation of flow had resulted from loss of the siphon, or that further draining of liquid may have been possible if the siphon had been re-established. In the shift log for the following day, the status of tank 17T302 was recorded as '*empty*' and this was repeated in subsequent shift reports, even though a substantial volume of liquid remained.

2.3 Tank isolation work

Before the initiation of cleaning and maintenance activities, between 26–28 May 2011, work was carried out on tank 17T302 to physically isolate it from the rest of the ARU process. To achieve this, flow from each pipe connected to the tank was blocked by the insertion of a thick steel disc in front of the valves closest to the vessel. The discs are referred to as either spades or spectacle blinds, illustrated in Figures 6, 7 and 9. This permit controlled work was undertaken by a team of engineering contractors, who were informed by Chevron that material inside the vessel was 'corrosive'.

Background permit information for this task was assembled by a Chevron employee who had never previously prepared tank permit documents. He was able to identify amine and hydrogen sulphide as anticipated hazards within the vessel, but was unaware of the presence of diesel, light hydrocarbon or potentially pyrophoric material.

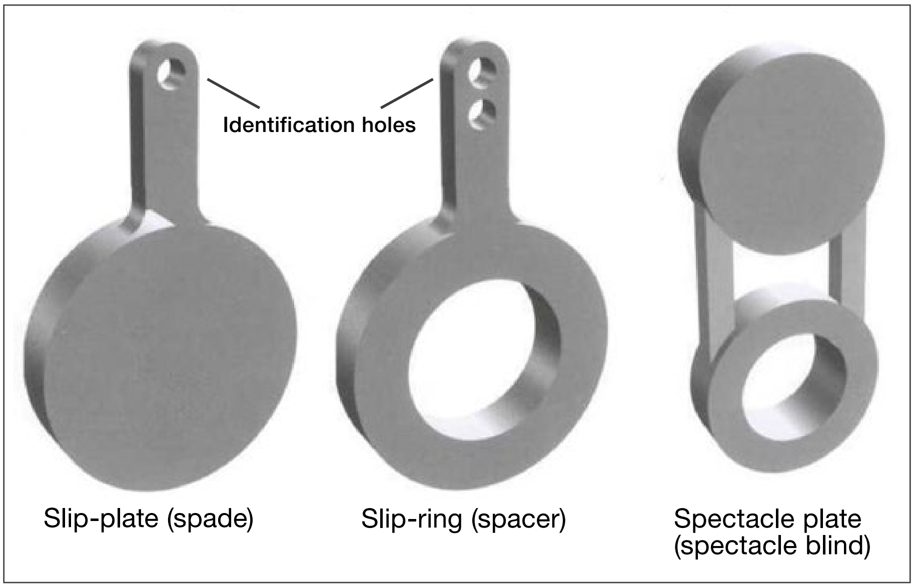


Figure 6 Tank isolation equipment

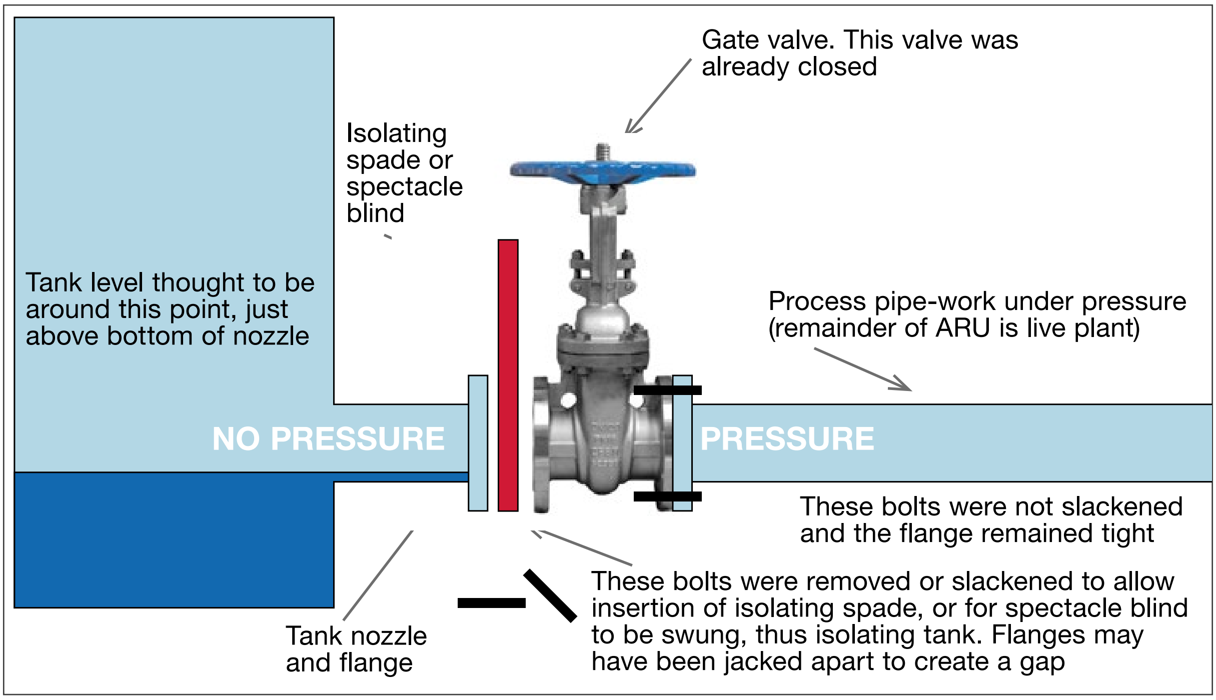


Figure 7 Valve isolation

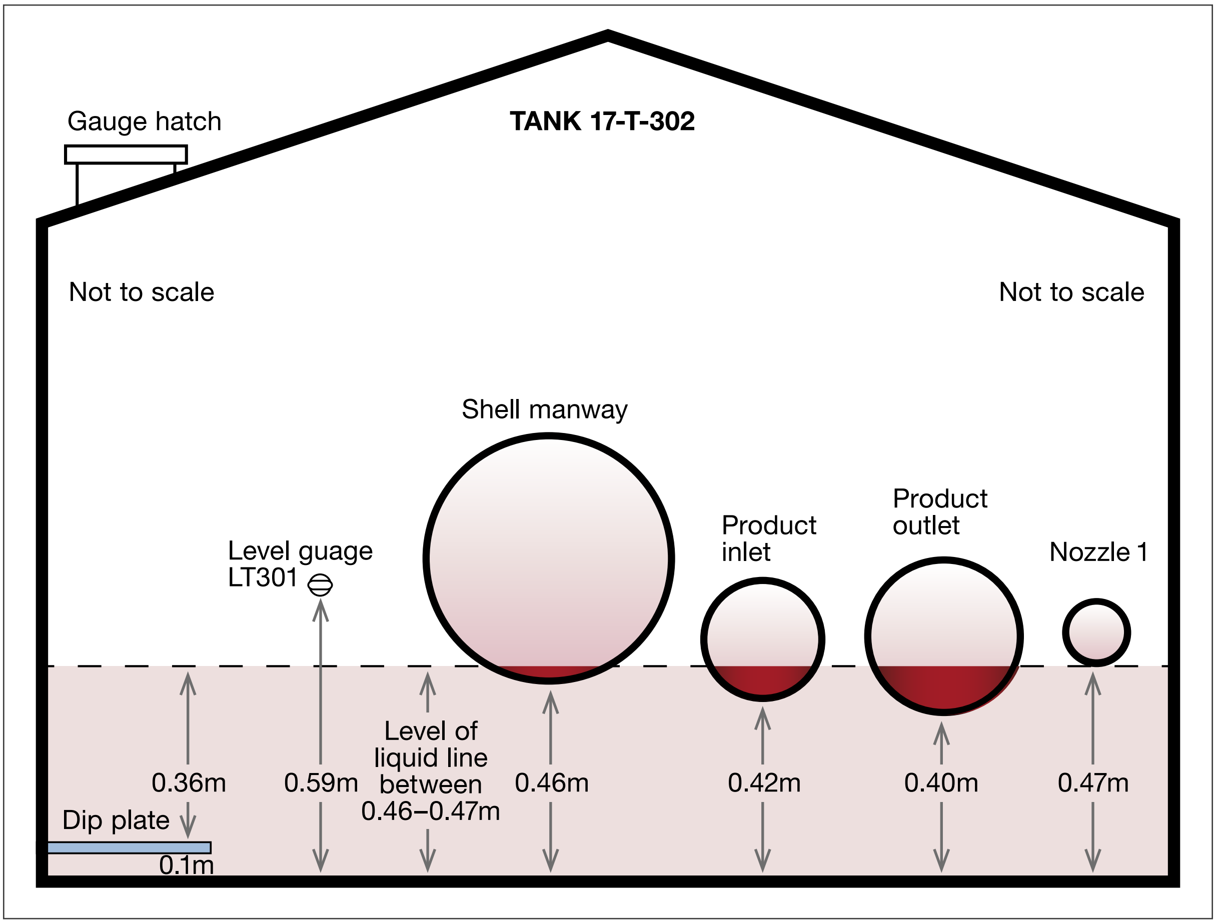


Figure 8 Schematic of liquid level in tank 17T302

The isolation task continued, despite the tank not being fully empty. Tank connections positioned higher than the liquid level (for example nozzle 1, connected to valve 1 and the sump) were successfully isolated by the contractors (see Figure 8). The main product inlet and outlet lines for the tank are relatively large (25.4 and 30.5 cm in diameter respectively) and situated at a low point, less than half a metre above the tank base. During isolation of these inlet and outlet lines, the contractors were met with a significant flow of liquid, gushing out of the valves. The contractors recall observing a shimmering haze, indicative of volatile hydrocarbon, and also registering a 'petrol-like' smell.

The engineering contractors returned to the vessel the following day and began to remove a shell manway, in order to ventilate the tank. The liquid inside was approximately 2.5cm above the bottom lip of the manway and continuously spilled from the tank for 45 minutes, until the manway gasket was replaced and the vessel resealed. As a result of this release, operatives were convinced that tank 17T302 had been totally emptied but that, prior to isolation, diethanolamine liquid had leaked back into the vessel through process lines. This mistaken belief was captured within the shift report for 28 May 2011 and repeated in all the subsequent shift reports until the explosion occurred.

Figure 9 Photograph of isolation spades and blinds from tank 17T302

Close inspection of the inlet and outlet valves, coupled with examination of the spades and blinds (see Figure 9), confirmed that the possibility of liquid leaking through isolated valves was not a credible scenario. The liquid seen to leak from the tank during isolation was the remaining hydrocarbon layer, which had previously not been effectively drained or removed.

Operators appeared unaware of the sump and siphon drainage equipment that could be used to empty the remaining liquid tank contents. During discussions, an informal decision evolved requiring tank cleaning contractors (B&A) to remove the remaining liquid by sucking through the roof manway, using a vacuum tanker. This was to be conducted without any preceding tank ventilation. This modified system of work was shared with B&A Contractors verbally that same day and insufficient consideration was given to the application of safer, alternative systems of work, for example:

- de-isolation of drainage equipment by removing the blind fitted to valve 1;
- introduction of water into the drain manifold in order to re-establish the siphon within the drain equipment;
- subsequent use of this equipment to remove the remaining tank contents;

- there was a facility to connect a vacuum tanker or diaphragm pump directly to the nozzle 1 drain manifold, in order to suck the residual material from the tank 17T302.

2.4 Manual testing

On 31 May 2011, the acting Operations Advisor asked the Plant Operator to carry out a gas test and manual dip test on tank 17T302 to ascertain the hazardous nature of the headspace atmosphere and to confirm the volume of material retained within the vessel. The Plant Operator carried out the testing through a small sample hatch in the tank roof using handheld portable equipment. A liquid depth of 36cm was observed and noted within his shift report. The float and tape level gauge was not used to corroborate the reading. The 36cm measurement was incorrect and underestimated the true depth of liquid.

There was a dip plate installed near the base of the tank, to protect the tank floor from anticipated impact damage, resulting from repeated dip testing. Positioned at 9.6cm above the base, the presence of the plate introduced measurement error for which adjustment was required. The Plant Operator was not aware of the plate and did not adjust the level recorded to obtain a true reading of liquid depth of approximately 46 cm.

The Plant Operator measured internal atmosphere of the tank using a four-way gas tester, capable of detecting of oxygen, carbon dioxide, hydrogen sulphide and hydrocarbon (as a percentage of the lower explosion limit – LEL). He had no previous experience of carrying out a gas test inside a vessel and only took one measurement using a 1-1.5m sample hose. To obtain results that represent the atmosphere within all sections of the tank, it is important to take several readings at different heights, as the concentration levels within the space may vary significantly.

The Plant Operator observed a hydrocarbon reading of 67% LEL and a hydrogen sulphide concentration of 10ppm. He did not formally record the results within his shift report or elsewhere. However, he radioed the unit control room and discussed the ‘high’ %LEL with his Lead Operator. During this discussion, the Plant Operator did suggest removing the drain isolation, to empty the tank further, but no meaningful consideration was given to his suggestion.

There were established legal standards available governing work in potentially explosive atmospheres.

HSE publication *Control and mitigation measures, Dangerous Substances and Explosive Atmospheres Regulations 2002. Approved Code of Practice and guidance* L136 (relevant at the time of the incident) stated:

‘During these activities the average concentration of dangerous substances should normally be maintained at or below 10% of the LEL, but occasional temporary increases up to 25% of the LEL may be permissible, eg during paint spraying or tank cleaning operations.’

Paragraph 219 within the current HSE DSEAR Approved Code of Practice and guidance L138 states:

‘Adequate ventilation is typically taken to be that which limits the average concentration to no more than 25% of the LEL within the building, room or enclosure containing the dangerous substance.’

Recording a hydrocarbon level of 67% LEL within the headspace should have led to an immediate cancellation of all further work on tank 17T302, until the cause had been identified and prevailing risks either eliminated or controlled.

As part of the investigation, the gas testing equipment used by the Plant Operator on tank 17T302 was retrieved and the relevant test data extracted from it.

Table 1 Gas test data from tank 17T302 headspace – taken on 31 May 2011

Hydrogen sulphide (PPM)	*Carbon monoxide (PPM)*	*Hydrocarbon (% lower explosive limit)*	*Oxygen (%)*
10	213	67%	20.9

2.5 Planning the task

B&A had a four-year term contract with the Pembroke Refinery, signed in 2010, for the cleaning of storage vessels, specifically diesel, kerosene, gasoline, slop fuel oil and water tanks. Distinctly, 17T302 was a diethanolamine process tank and not a storage vessel, which fell outside the existing arrangements in the formal contract. Irrespective of this, both Chevron staff and B&A contractors proceeded on the basis that this job was equivalent to normal work under the term contract.

The planning and organising of tank cleaning on 17T302 were conducted by the team described below. They came together during planning meetings on 1 and 2 June 2011, during which no official notes or minutes were taken.

The planning team consisted of:

- Chevron – ARU Control Operator, deputising as Operations Advisor;
- Chevron – Pembroke Refinery Tank Maintenance Coordinator;
- Chevron – ARU/SRU Area Process Engineer;
- B&A – Supervisor.

The team understood that the task required removal of liquid from the tank, using a vacuum tanker and flexible pipework, entering the vessel through the roof manway. The planning process did not question the selected system of work, so another opportunity to consider alternative and safer means of working was lost.

The planning team discussed the potential presence of pyrophoric material within the tank and reviewed historical ARU tank cleaning documentation. Based on their assumptions, the risk associated with spontaneous pyrophoric heating was dismissed and no controls were put in place. Following the removal of liquid by B&A, Chevron staff planned to obtain and test a sample of sludge given that they were aware that the presence of pyrophoric material could influence arrangements for sludge disposal.

Overall, the team had an incomplete understanding of what was in the tank, including the potentially flammable atmosphere resulting from light hydrocarbon contamination of the running tank. It was unclear whether the 67% LEL gas test reading recorded by the Plant Operator had been shared with the planning team, although this reading was not included within any risk assessment, method statement or permit documentation associated with the task. Similarly, the court was also unable to decide whether the results were not properly communicated or, if they were, their significance was not understood (see the sentencing remarks of The Honourable Mr Justice Lewis, paragraph 14). Generally, there was insufficient evaluation of the risk posed by static ignition sources, particularly B&A's work equipment.

The planning process outlined above resulted in the production of key documents:

- Chevron document - *Management of change/Activity risk assessment*
The document was described by the ARU/SRU Area Process Engineer as a 'risk assessment of a risk assessment'. It did not identify significant hazards, including the presence of flammable liquid, or consider the hierarchy of control.* Actions recommended by Chevron staff were largely minor. The only hazards analysed originate from the B&A contractor's documents. There was no reference to the 67% LEL gas test reading conducted on 31 May 2011.

- B&A documents - *Activity risk assessment and Method Statement*
The presence of toxic hydrogen sulphide and amine was recorded, but the flammable nature of the liquid contents and residual sludge were not fully described.

* The hierarchy of control is a systematic approach to the management of safety, where risks are reduced to the lowest reasonably practicable level by implementing preventative measures, in the order of efficacy. Specifically, these are elimination, substitution, engineering controls, administrative controls and, last of all, personal protective equipment.

The documents may have been modified from a previous task as there were some generic requirements for venting that were outside the agreed system of work.

Both documents specify that to reduce the risk of fire or ignition, all plant and equipment should be bonded at the workplace, non-metallic work equipment was to be used and mobile plant was to be fitted with a Chalwyn valve and spark arrestor. Overall, the risk posed by the presence of flammable liquid/pyrophoric material was not addressed in great detail and there was no reference to the 67% LEL gas test reading.

2.6 Permit to work

Chevron operated an electronic permit-to-work system, where permits were drafted by selecting a series of icons deemed relevant to the task. As a contractor, the B&A Supervisor received training and had access privileges to create permits for B&A activities at the refinery, including the work on tank 17T302. This task was covered by permit 10128789-1-1, created on the morning of 2 June 2011 through a process that took approximately seven minutes.

The icons selected relate to:

- use of the vacuum tanker;
- operation within a bunded tank area;
- the use of hoses;
- use of a vehicle within an operational unit;
- cleaning activity;
- general plant hazards.

On completion, the permit was saved within the electronic permit system. Ordinarily, the draft permit created by the contractor would be checked, reviewed and progressed by the Operations Maintenance Coordinator (OMC), to ensure that all the appropriate information was included. Following this, depending on the permit complexity, the Unit Lead Operator or Shift Team Leader should carry out a secondary review to ensure specific control measures were in place prior to permit issue.

However, in this case the permit was briefly examined by a Chevron staff member who accessed the document for one minute and made no alterations to it. Further along the line, the acting OMC opened the permit for one minute to conduct his review, during which, the phrase '*Electrical isolation not required*' was added. The permit was saved and transferred onto the permit board for issue by operational staff. In the late afternoon, between 15:37 and 15:40, the permit was reviewed by the Lead Operator who gave his approval and 'issued' the permit to the B&A Supervisor.

In order to progress the permit through the electronic system, the Lead Operator confirmed that the Plant Operator had inspected, and gas tested, the external ARU work area, which was recorded as satisfactory. In truth, at the time of permit approval, no such test had taken place on site.

2.7 Authorisation

The Chevron and B&A documents described above in Section 2.5 were formally authorised by the Day Shift Team leader, who was deputising for the more senior Business Unit Leader (BUL). Around 16:00 hrs on 2 June 2011, the acting BUL was approached by the acting Operations Advisor (OA), to obtain his signature of authorisation for the job on tank 17T302. At this time B&A contractors had already begun to unload newly purchased hose and set up their equipment on the ARU.

The substitute BUL reviewed the documentation and received a brief verbal overview from the acting OA, who explained that the tank was to be emptied through the roof, due to the presence of amine liquid that had leaked back into the tank through a passing isolation valve. The BUL queried why the excess liquid could not be removed through the drainage system and was informed that the drain valve had already been physically isolated and so could not be used. This issue was not explored further by the BUL, who proceeded to sign the documentation and authorise the job without visiting the unit to inspect the ongoing work.

2.8 Tank cleaning operation

To start the operation, contractor Redhall Engineering extracted nearly all the bolts from the circular roof manway of tank 17T302, leaving only four in place. These remaining bolts were removed by B&A contractors, who broke the containment envelope and opened the vessel. The tank had not been previously ventilated and no internal gas test was taken on 2 June 2011, in advance of the manway opening.

At approximately 17:47 hrs, B&A contractors discussed the disposal of liquid to be removed from the vessel with a trainee Plant Operator. This Operator began his training on the amine regeneration unit in January 2011 and was scheduled to complete his final written assessment on 3 June 2011. He was working under 'loose cover' supervision provided by the Plant Operator who had previously emptied the tank and taken the gas test reading on 31 May 2011. It was agreed by all that the liquid could be discharged into the amine sump, a decision confirmed with the Lead Operator over the site radio. Following this exchange, the trainee Operator left the ARU and returned to the control room, whilst B&A contractors began their attempt to remove liquid from the tank using their own 2000-gallon vacuum tanker.

Employees of contractor Hertel, acting as 'Fireguards', joined the team of B&A contractors working on tank 17T302. The remit of Hertel was to provide safety support, specifically regarding the operation of air-fed breathing apparatus, the location of which is shown in Appendix 1 (a schematic of the incident scene).

Andrew Jenkins (B&A) was positioned at the top of the tank, manoeuvring the green PVC vacuum hose through the open manway. Behind him stood Julie Jones (Hertel), whose role involved monitoring Andrew's airlines and overall well-being. Both people were wearing air-fed breathing apparatus due to the anticipated presence of toxic hydrogen sulphide. Andrew Phillips (Hertel) was positioned on the ground, from where he operated the breathing air equipment system. Robert Broome (B&A) stood at the rear of the vacuum tanker, operating the pump. Dennis Riley (B&A) was not directly involved in the activity but was positioned adjacent to the tank, observing the task at close quarters.

The team worked to remove liquid for approximately 20 to 30 minutes, using a non-conducting green flexible hose, two inches in diameter. A steel scaffold pole (shown in Figure 14) was later

Figure 10 Two-inch inlet adapter on rear of vacuum tanker

retrieved from inside the tank, trapped beneath an internal heating coil. This pole may have been attached to the open end of the green hose to act as a weight, which the investigation discovered was common practice amongst B&A staff when using vacuum tankers.

The inlet connection at the rear of the vacuum tanker was a four-inch diameter fitting, designed for a hose of the same size. A non-standard adapter (see Figure 10) was used by B&A to attach the smaller green hose, which subsequently halved the inlet diameter. A reduction in hose diameter would have significantly increased the linear velocity of liquid being drawn into the vacuum tanker and increased the extent of static charging within the non-conductive hose.

The contractors experienced some difficulty achieving suction and liquid removal. During radio transmissions they reported: 'It must be stuck or something, it's not sucking anything'.

3 Tank fire and explosion

3.1 Explosion incident

An explosion occurred within tank 17T302 at 18:19 hrs. After the initial point of ignition, the overpressure created by the expanding combustion gases within the vessel ripped the tank shell away from the floor and subsequently ejected the roof. A fireball jetted from the base of the vessel, which fire-engulfed the immediate area to the south, including the vacuum tanker vehicle.

The explosive force projected the 5-tonne tank roof approximately 55m (see Figure 12) in a north-easterly direction to its first point of impact with the ground, narrowly missing a multi-fuel pipe track by 1m, before somersaulting and colliding with a butane storage sphere, causing structural damage to the vessel legs and supports (see Figure 13).

B&A contractors Dennis Riley, Robert Broome and Andrew Jenkins were killed. Hertel fireguard Julie Jones was also killed, while her colleague Andrew Phillips was severely burned, sustaining life-changing injuries.

The fire was brought under control using on-site firefighting staff and equipment. It was extinguished within approximately 23 minutes. Mid and West Wales Fire and Rescue service attended, deploying 10 pumps. A police helicopter used thermal imaging cameras to search for additional casualties. The COMAH on-site emergency plan proved largely effective in this case, as the fire was contained and did not spread to neighbouring vessels.

Figure 11 Post-incident – tank 17T302 minus vessel roof

Figure 12 CCTV image showing ejection of tank 17T302 roof

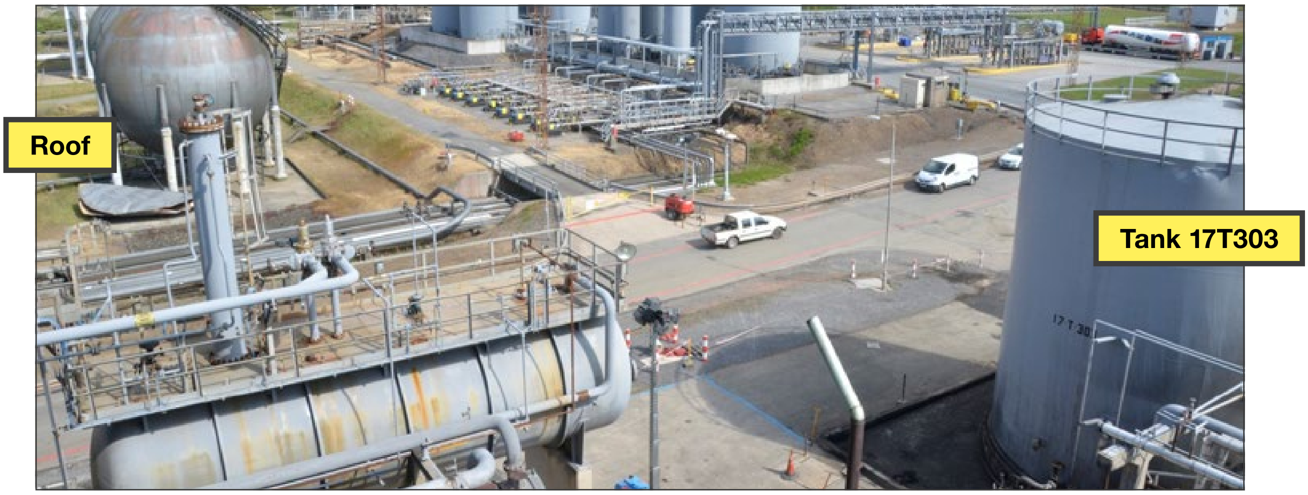


Figure 13 Post-incident photograph of tank roof location

3.2 Explosion constituents – ARU tank contents

As part of the incident investigation, samples were collected from the accident scene, specifically from the following locations with the ARU plant:

- liquid from the hydrocarbon layer within tank 17T303;
- liquid from the tank 17T303 drain line;
- liquid from the tank 17T302 drain line manifold;
- liquid from the amine sump tank 17T301.

At the HSE Laboratory in Buxton, these liquid samples were subjected to flashpoint analysis to establish their flammability. Tests were carried out in line with British Standard techniques BS EN ISO 3679:2004 and BS EN ISO 1523:2002. The results are summarised in the following table.

Table 2 Flashpoint analysis of liquor samples – amine regeneration unit

Sample location	*Test result* *BS EN ISO 3679:2004*	*Hazard category*	*Test result* *BS EN ISO 1523:2002*	*Hazard category*
Tank 17T303 – top layer	54 °C			
Tank 17T303 – main drain line	15 °C	Flammable		
Amine sump – top liquor layer	4 °C	Flammable		
Tank 17T302 – drain line manifold	-1 °C	Flammable	-3 °C	Flammable

The flashpoint of the hydrocarbon layer within tank 17T303 was 54 °C, which is similar to what would be expected for diesel-like material, though subsequent more detailed analysis showed it contained components not normally found in diesel fuels. The material within the drain line of the same tank had a much lower flashpoint of 15 °C, which would easily produce potentially flammable amounts of vapour under the normal process conditions of 40 °C. This material represents the properties of material found within tank 17T303 when it was drained previously.

The drain line manifold to tank 17T302 was used to empty the tank contents into the amine sump as described in Section 2.2. Flashpoint analysis of this material found within the drain line was representative of the last known material that was drained from tank 17T302 in May 2011 and material present within the tank prior to the explosion incident. This material was found to have a very low flashpoint of -1 to -3 °C, with an extremely high-flammability hazard and the potential to produce flammable vapour concentrations even at ambient temperatures.

3.3 Potential source of ignition

3.3.1 Static

The ignition energy required to ignite a vapour cloud is extremely small, measured in milli-Joules (mJ). The minimum ignition energy (MIE) for hydrocarbon fuels is in the range 0.2–0.3 mJ at 25 °C and atmospheric pressure. Electrical charge is created in materials by movement across their surfaces. If the charges created cannot dissipate to earth, then large amounts of potential energy can build up on the material. Where materials of different charged states come into proximity to each other, the result can be the creation of sparks. The energy of such discharges can be far in excess of the MIE required to ignite an explosive atmosphere.

To aide manoeuvrability, it was common practice for B&A contractors to weigh down the end of the non-conductive PVC suction hose with a length of steel scaffold pole. Although it is a good conducting medium, any such pole would be isolated from earth by the material of the hose itself. Therefore, any potential energy accumulated on the PVC hose (by the conveyance of the non-conducting hydrocarbon fluid within) could be discharged rapidly from the surface of the steel pole as high energy sparks. The use of such equipment within the flammable headspace of tank 17T302 would be a potential source of ignition.

3.3.2 Pyrophoric material

Pyrophoric substances ignite spontaneously on exposure to air. This risk was identified and discussed by the planning team (see Section 2.5). However, no positive action to either confirm the presence or prevent the ignition of potential pyrophoric substances was undertaken.

In fact, investigation sampling and analysis did detect large amounts of iron sulphide compounds (a potentially pyrophoric material) within residues taken from tank 17T302. Whilst no pyrophoric activity was seen in iron sulphide samples tested, the risk that some of the iron sulphides may have had the potential to be pyrophoric prior to the incident cannot be discounted.

For pyrophoric ignition to occur it would have been necessary for this material to become exceedingly dry and exposed to atmospheric levels of oxygen. Prior to the incident, the liquid level in the tank had dropped exposing the surface of the heater coils. However, there was no airflow to promote the drying of residue and so it is uncertain whether any pyrophoric material within the tank was sufficiently dry for ignition to occur.

The explosion occurred whilst work was being carried out by B&A contractors. However, there was no conclusive evidence regarding whether the ignition was an electrostatic spark or pyrophoric self-ignition. Therefore, neither ignition source can be completely discounted.

4 Safety management system failings

Consideration of the underlying causes which led to the explosion are considered and include inadequacies relating to:

- operating procedures;
- the permitting system;
- monitoring and management of contractors;
- Chevron's risk assessment;
- competence.

Separate consideration is given to the failings of B&A in Section 7.

4.1 Operating procedures

In October 2002, a Chevron Operations Procedure (MPP-0007) was published, describing the cleaning out of amine tanks in preparation for inspection, repair or dismantling. Similarly, in February 2003 a Chevron Operating Procedure (MPP-0008) was released, concerning the recommissioning of tank 17T303 as the running tank whilst taking tank 17302 out of service. It emerged that few, if any, of those involved in preparing tank 17T302 for maintenance in 2011 used either procedure. The procedures appear to have formed no part of the risk assessment and planning processes described previously.

In any event, the procedures were inadequate, as they contained no instructions or warnings in relation to the presence of flammable hydrocarbons or pyrophoric material within the amine tanks. Risk information focused solely on the presence of toxic hydrogen sulphide, which may have misled the reader by reinforcing the belief that this was the only area of concern. It is HSE's view that although there were a number of references to gas tests within the documents, it may have been understood from the context that these tests were to detect the presence of hydrogen sulphide.

The MPP-0007 and 0008 procedures were created several years before the incident and had not been revised, in light of newer procedures, for example '*Action to take on LPG getting in to the ARU/SRU Flare Drum*', developed in 2005. See Section 1.5.2 for more information.

In brief, there were clear shortcomings regarding the provision of procedures, including the absence of an overt description of the flammable atmosphere in the ARU tanks. Reading the procedures provided would not have alerted anyone to the risk. Inadequate management, control and use of procedures led to a degradation of technical knowledge over time.

4.2 Permit system

Chevron used an electronic, icon-based, risk-assessed permit system. Where contractors were authorised to create permits, they were also required to identify the relevant risks associated with each job.

Permits to work on tank 17T302 were obtained by Redhall Engineering contractors for tank isolation work and subsequently B&A contractors for liquid removal. The permit system was not linked, as it should have been, to hazardous area classification studies. Consideration of the location and proximity of hazardous zones should have informed those developing, reviewing and issuing permits. Although in this case, previous downgrading of the tank to non-hazardous status may not have made any difference to permit preparation.

The B&A Supervisor created a permit for work on tank 17T302 on the morning of the job which took just seven minutes to complete. All B&A tank cleaning activity on the tank was registered within this one permit, even though the work consisted of three specific tasks – entrance of the vacuum tanker into a restricted process area, removal of the roof manway which can be described as breaking containment, and lastly extraction of liquid from the tank. Each involved different risks and required distinct control measures.

The permit was created and issued before the risk assessment and COSHH assessment had been finalised or approved. The permit document did not quantify or specify what solid, liquid or gaseous material was contained within tank 17T302 or clearly specify the type of hose to be used. There was a cross-reference within the permit, identifying the separate B&A risk assessment, in which the use of earth bonded hose was stipulated.

In addition, the relevant icons listed below were not selected:

- '*Hose Specification for Hydrocarbon Duty*';
- '*Breaking Containment – Flammable*';

- ‘*Breaking Containment – Toxic*’;
- ‘*Hazardous Substances*’.

As a consequence, an internal tank gas test and other automatically self-selecting control measures were not enunciated as necessary by the automated permit system, before work began. Effective risk assessment during the permit process could not be achieved, given the initial failure to identify the relevant hazards and select the corresponding icons.

The permit created by B&A was very briefly reviewed and progressed by three Chevron employees, none of whom were involved in the risk assessment or planning activities. The permit system utilised by contractors and facilitated by Chevron staff had insufficient information regarding the presence of flammable material within the tank and the risks associated with the work for which permission was being sought. In this case, the permit system did not fulfil the primary objective, as it was not sufficiently robust to prevent hazardous work from being undertaken in a manner that was unsafe.

4.3 Control of contractors

A significant proportion of the labour at Pembroke Refinery was contractor based. Managing, coordinating and monitoring the performance of contractors and their employees was manifestly critical not only to business, but also to the safety of all concerned.

Pembroke Refinery considered B&A to be a good contractor which, during 2010–2011, was assessed and awarded the ‘A’ rating, the highest grade attainable, within the Chevron Contract, Health Environment and Safety Management system (CHESM).

B&A competed successfully against other contractors and in December 2010 won a four-year contract to provide Chevron with storage tank cleaning services.

The contract between Chevron and B&A refers to a range of standards and guidance, the most pertinent of which was BS5958 *Control of Undesirable Static Electricity*, but no specific tank cleaning standards relevant to safety were included.

Examples of relevant task-specific tank cleaning guidance that could have been included within the contract were as follows:

- Energy Institute, Model Code of Safe Practice, Part 16, *Tank Cleaning Safety Code* (Third edition, July 2008)
- HSE Guidance, CS15 (1985) – *The Cleaning and Gas Freeing of Tanks Containing Flammable Residues*
- API 2015 (2001) – *Safe Entry and Cleaning of Petroleum Storage Tanks*

- API 2016 (2001) – *Guidelines and Procedures for Entering and Cleaning Petroleum Storage Tanks*
- API 2219 (2005) – *Safe Operation of Vacuum Trucks in Petroleum Service*

An obligation regarding earthing under paragraph 2.2.1 of the contract between Chevron and B&A states:

'EARTHING

a) The Contractor shall be responsible for earthing of all hoses, generators, air movers, etc.

b) Chevron will check the earth of any generators, hoses, air movers etc.'

It emerged that Chevron routinely did not check the earthing arrangements of B&A during tank cleaning tasks carried out at the refinery, as recommended within the guidelines in the Energy Institute's Model Code of Safe Practice, Part 16: *Tank Cleaning Safety Code*, which specifically states that 'All bonding and earthing connections should be inspected and tested for electrical continuity before tank cleaning operations commence.'

The cleaning of storage vessels was an established process and guidance was widely available. During the contract stage, Chevron did not behave as an 'intelligent customer' and failed to establish which regulations, codes of practice or technical standards were relevant for tank cleaning, despite awareness that this task involved major accident risks.

Chevron assumed B&A were competent in this field but did not act to verify the level of B&A's competence in line with industry good practice. In addition to Chevron, B&A did not seek to develop any 'standards based' competence in the field of tank cleaning, even though this was their primary role. Prior to the incident, tank cleaning at Pembroke Refinery was performed by B&A without adherence to relevant good practice.

4.4 Risk assessment – amine regeneration unit

In 2008, an internal audit revealed to the Chevron Pembroke Refinery that their risk assessments were too generic and did not take account of site-specific conditions.

The amine regeneration plant PHA/SOA (process hazard analysis and safety objective analysis) was completed in February 2010. This study was a risk assessment, with the purpose of identifying hazards and implementing control measures to reduce the likelihood of the hazard occurring. This group analysis was carried out by a team of eight, including two facilitators.

This study was flawed as the possibility of light hydrocarbon contamination of the amine tanks was not sufficiently considered, either in relation to carry over from the regeneration columns or in terms of light hydrocarbons being periodically pumped from the flare drum. The study was not based on all the relevant information available and the process awareness of some team members was limited. The cumulative effect was a failure to identify the risk posed by contamination of tank 17T302 by light hydrocarbons.

4.5 Risk assessment – tank cleaning task

Chevron did not carry out a meaningful or effective risk assessment of the task. The *Management of change/Activity risk assessment* documentation (as described in Section 2.5) was little more than a review of the B&A Method Statement and risk assessment documents. These, in turn, were based on incomplete information and fundamentally flawed, largely because the contractor B&A was not familiar with the ARU processes or the function of the running tank. The contractor had not been informed of the presence of flammable material within the tank and it is unclear whether they had been given the 67% LEL internal gas test result recorded on 31 May 2011.

The work represented a clear departure from normal practice (emptying the tank through the roof), but this fact was not treated as significant by the planning team. The risk of trying to empty a tank from a roof manway by inserting a hose into the tank, when the nature of its contents had not been definitively established, ought to have caused alarm bells to ring amongst all those charged with formally assessing the risks. Furthermore, no samples of the tank contents were taken before the work began.

Legislative requirements under the Dangerous Substances and Explosive Atmospheres Regulations and relevant industry guidance should have been prioritised when considering both the risk assessment and the practical approach to emptying tank 17T302. If this had been the case, the chosen method of emptying the tank through the roof would almost certainly have been promptly abandoned in favour of a safer method, for example draining the tank from its base, using purpose-built siphon equipment. The hierarchy of risk control was not well understood by those involved and so measures to reduce risk at source (such as draining the tank) were not given sufficient priority or importance.

The planning, organisation, risk assessment and execution of the tank cleaning task took place over a very short of period of just two days. The authorisation of the Chevron documentation was unplanned and did not allow sufficient time for genuine scrutiny by the acting BUL, since the equipment had already been set up before any authorisation had been received. There was a presumption that the task would proceed as planned without any additional requirements or control measures emerging from the formal sign-off process.

The Hertel personnel were not provided with information regarding the flammable tank contents on which to base their own risk assessments. Risks from exposure to toxic hydrogen sulphide were anticipated by the support staff, as Julie Jones wore breathing apparatus. However, the Hertel fire watchers did not monitor the %LEL levels during the operation, using the four-way gas detectors at their disposal. If Hertel contractors had been made aware of the flammable atmosphere within the tank, it is likely that they would have taken additional steps to measure and monitor %LEL levels throughout the work. It is possible that such monitoring may have provided a last-minute warning to all involved regarding the fire and explosion risk present.

4.6 Competence

Significant mistakes made by Chevron staff were related to a lack of knowledge. In this case, the investigation concluded that key refinery employees interviewed did not have sufficient training or competence to carry out important activities for which they were responsible. For example, action taken in response to the safety-critical gas test results. As a consequence, the risk control elements associated with their positions were not sufficiently effective. The Plant Operator's lack of understanding regarding the sump and siphon tank drainage equipment that he was instructed to operate, was a notable example.

The investigation considered the communication of safety-critical information, namely the 67% LEL gas test result, which was found to be wholly inadequate. There was no formal requirement by Chevron that the results should be logged or written down, nor that any process of repeating or confirming the results should be undertaken.

The high %LEL level measured within the tank should have stopped all involved in their tracks as it was a red flag moment. The fact that this key information became lost, and thereafter ignored, points to flaws in the management system for the recording and communication of safety-critical information.

During the course of the investigation, many instances of deputising or 'acting up' have been noted, where junior individuals undertake key roles of more senior colleagues. When giving employees the responsibility for acting in the place of others, it is important to ensure their competence to act in those positions, and as a minimum to ensure that they are competent for any safety-critical operations that they may be engaged in for the period of cover. Experience and length of time in post is not an adequate measure of competence to act in an alternative post. If those 'acting up' are not deemed fully competent for that role, then it may be appropriate to allow cover for limited purposes by providing control over what specific work is performed during periods of cover.

5 Chevron incident – specific root causes

Whilst the flaws within the Chevron health and safety management system have been described above, the significance of each becomes more apparent when considered against the specific incident root causes, summarised below.

5.1 Lack of knowledge regarding light hydrocarbons in tank 17T302

Chevron Pembroke Refinery possessed information relating to the contamination of the ARU running tank with light hydrocarbon. However, key Chevron personnel, some of them senior, were not aware of this fact or the magnitude of contamination. For example, the procedure entitled '*Action to take on LPG getting in to the ARU/SRU Flare Drum*', designed to prevent LPG entering the running tank, was not fit for purpose and routinely ignored.

5.2 Inadequate risk review

Following the decision in 1998 to operate the ARU as a closed system, there were a number of events that should have triggered a review of the unit risk assessment, in particular the need for repeated removal of excess light hydrocarbon material that had accumulated within the running tank. At no time did this repeated accumulation of material trigger an investigation into the cause, including sampling and analysis of the excess hydrocarbon material removed.

The application of site-wide procedures, for example for hazardous area classification (HAC), should have, but did not, identify the risk of a flammable atmosphere within the running tank.

5.3 No safe system of work

The work carried out was not based upon a formal procedure or work instruction, which itself should have been developed based upon a suitable and sufficient risk assessment, industry guidance (for example the Energy Institute's Model Code of Safe Practice, Part 16: *Tank Cleaning Safety Code*) and DSEAR regulatory requirements.

Significantly, the risks posed by two potential ignition sources (electrostatic spark and self-ignition of pyrophoric material) were not fully appreciated or controlled.

Part 2 B&A Contracts Limited

6 Background

B&A Contracts Limited and BDS Contracts (Milford Haven) Limited were two sister companies which operated from Milford Haven under the stewardship of one Managing Director. Historically BDS had carried out tank cleaning work, but B&A later took over those contracts whilst BDS transformed into an industrial painting contractor.

At the time of the incident B&A had 55 employees and undertook contract work across two local oil refineries. Chevron in Pembroke and Murco based at Milford Haven, with the larger share of its work being undertaken at Murco.

The Health and Safety Officer for both companies was employed by BDS. At Murco refinery, they demonstrated a hands-on management approach, checking work systems, permit compliance, method statements and risk assessments. The vacuum tanker hoses used at Murco differed from that used by contractors at the Chevron refinery. The hoses used at Chevron were a non-conductive PVC Kanaflex-type hose, whereas conductive hoses were used at the Murco site. Furthermore, the Health and Safety Officer would also inspect the earthing and bonding of such vacuum tanker hoses at the Murco site but not at Chevron.

The Health and Safety Officer’s intervention at the Chevron Pembroke Refinery was very limited by comparison and did not include any involvement in risk assessments, method statements or the inspection of hoses. In contrast to Murco, B&A safety management at the Chevron refinery was delegated to the B&A Site Supervisor, who was not specifically trained for this role.

6.1 The B&A and Chevron contract

Chevron awarded a tank cleaning term contract to B&A Contracts Ltd in December 2010. The scope of work specified within the contract required B&A Contracts Ltd to complete the following activities on storage tanks:

- removal of remaining liquid using a vacuum tanker;
- removal of solid debris from the bottom of the tank by manual handling;
- bag and remove debris from tank roof, foam dam and centre roof drain sump;
- high-pressure jet internal surfaces of the tank.

The Master Products & Services Agreement which formed part of the contract, specified that:

'a) The contractor shall be responsible for the earthing of all hoses, generators, air movers etc.

b) Chevron will check the earth of any generators, hoses, air movers etc.'

Throughout their operations on site as part of the term contract, B&A's hoses and equipment had not been checked by Chevron staff.

6.2 Work equipment

The vacuum tanker owned by B&A was originally built by Whale Tankers Ltd in February 2001. The unit was supplied as a 'non-hazardous tipping vacuum and pressure tanker' and not specifically designed for use with flammable material. It was fitted with a notably powerful pump capable of operating at 600–700 cubic feet per minute (cfm). B&A purchased the vehicle from its previous owner in 2010 and modified it to comply with refinery requirements, specifically the installation of a Chalwyn valve and spark arrestor.

A galvanised steel scaffold pole was located within tank 17T302 after the incident (see Figure 14) and it is believed (but not conclusively confirmed) that this was attached to the hose to weigh

Figure 14 Photograph of scaffold pole found within tank 17T302

it down during the cleaning operation. Witness evidence indicated that this was common practice by B&A across both the Chevron and Murco refineries.

6.3 Training and supervision

There were accessible industry standards and guidance documents available in relation to the safe cleaning of tanks, as described in Appendix 2. None of the B&A or BDS senior management, the Health and Safety Officer or Workshop Manager were familiar with these standards or any equivalent despite being fundamental to their work activities. Training in relation to these industrial standards was not provided to employees carrying out the tank cleaning activities.

7 B&A – summary of failings

The B&A Supervisor was hard-working, well-regarded and given considerable accountability for day-to-day health and safety management by B&A. However, he was neither a trained health and safety professional nor the ‘employer’ in a formal sense. B&A as the ‘employer’ had a non-delegable duty towards its employees and others affected by its work. This duty was not discharged by the contracting company given:

- There was a lack of knowledge and understanding at all levels of the company regarding regulations, industry standards and guidance relevant for tank cleaning activities.
- There was no effective system to ensure work equipment was fit for purpose.
- Due to a lack of management and supervision, poor standards and work practices developed, in contrast to safer methods deployed at the nearby Murco Refinery.
- Key staff providing services to both B&A and BDS, such as the Health and Safety Officer and a Workshop Manager, were not aware of relevant industry standards or of the risks posed by using the company’s equipment at the Chevron site. For example, the vacuum tanker and associated hoses were not designed or equipped to handle flammable material. In violation of the measures stipulated in their own documentation, the hose used was not bonded to earth, and may have had a metal scaffold pole attached to the end.
- B&A permitted its employees to use a vacuum tanker to remove material through a tank roof, without a safe system of work, or establishing the nature of the tank contents.
- B&A did not consider the potential presence of pyrophoric material and the risk posed by this ignition source.

8 Findings and conclusions

Procedures documenting modification of ARU processes, combined with incident reports and accounts of hydrocarbon removal practices, constitute a body of information. This confirms unequivocally that Chevron was aware of the potential presence of extremely flammable material within ARU tank 17T302, prior to the incident. Furthermore, the company could have foreseen the risk of fire and explosion.

Due to a lack of cohesion, awareness of hazardous material within 17T302 was not reflected within training arrangements, competence assurance or amongst other relevant risk control systems (PHA/SOA, management of change, risk assessment, hazardous area classification, maintenance procedures, permit to work etc). In addition, final safety-critical gas test results were not appropriately shared. As a consequence, key Chevron personnel were not aware of the hazard posed by extremely flammable material within tank 17T302 and so, in turn, did not warn contractors of the dangers that were present, or ensure appropriate methods were used.

Chevron did not embrace their role as an intelligent customer and relied wholly upon the knowledge and experience professed by B&A. Chevron's failure to establish the tank cleaning standards to which B&A were expected to conform was a lost opportunity to expose this critical knowledge gap. Furthermore, verification of the contractor's performance on site was not linked to industry guidance, enabling B&A's use of inappropriate equipment and practices to continue unchallenged.

The risk assessment and permit for the task were developed by B&A, who did not possess the relevant safety-critical information or process safety knowledge to complete the risk assessment or permit successfully. In turn, the contractor relied upon Chevron to highlight key hazards, but did not verify the nature of the tank contents or request additional gas testing or sampling.

Chevron staff continued doggedly to progress the maintenance task. Opportunities to re-evaluate and repeat the tank draining process were ignored. The hierarchy of control did not form part of the decision-making process. There appeared to have been self-imposed pressure to complete this task and move on to the next.

A review of the investigation findings reveals an alignment of vulnerabilities within the layers of protection, culminating in the failure of a range of key risk control systems, where insufficient competence was a reoccurring feature.

8.1 Broader lessons

The law requires that companies should possess clear and accurate information regarding hazardous material stored within tanks. Furthermore, all employees and contractors involved in planning and maintenance activities on tanks should know and understand the dangers presented by the materials inside. This should include rigorous analysis (including sampling when appropriate) of the hazards of all constituents remaining within the tank prior to starting removal work. Section 2.5 of the Energy Institute's Model Code of Safe Practice Part 16: *Guidance on Tank Cleaning* contains detailed information regarding pre-cleaning checks and inspections.

A risk assessment and the establishment of clear work instructions for any tank cleaning operation should be conducted by trained and competent staff.

To organise the work as safely as possible, the planning and preparation work should be based on knowledge of the hazardous tank contents, combined with a good understanding of and adherence to the published HSE guidance and specific tank cleaning standards, for example the Energy Institute's Model Code of Safe Practice Part 16: *Tank Cleaning Safety Code*.

HSE believe there are some clear lessons to be learned for all businesses in relation to safety management systems. Our recommendations are set out below.

8.1.1 Process safety performance indicators

Effective management of major hazards requires a proactive approach to risk management. Information to confirm that critical systems are operating as intended is essential. Carefully chosen process safety performance indicators can monitor the status of key systems, providing assurance that major hazard risks are under control or an early warning, should controls deteriorate. HSE publication HSG254 *Developing process safety indicators: A step-by-step guide for chemical and major hazard industries* contains practical information.

8.1.2 Process modification and the management of change

Process modifications, in this case converting the ARU from an open to a closed system, should not be undertaken without having carried out a safety, engineering and technical review. Risk assessment should then identify what hazards have been created by the change that may affect plant or personnel safety, and what action can be implemented to reduce or eliminate the risk.

Changes may affect other parts of the plant which may be remote from the source of the change. Therefore, all parts of the plant should be considered in undertaking hazard identification and risk assessments. Additional hazards that may be introduced which need to be considered include fire, explosion and loss of containment. Further guidance can be found within HSE publication L111 *The Control of Major Accident Hazards Regulations 2015: Guidance on Regulations*.

8.1.3 Safety-critical communications

A communications protocol should be developed and embedded within the workplace for the transmission of safety-critical information. In this case the %LEL reading that was taken from the top of the tank on 31 May 2011. For effective communication, information to be shared should be conveyed through more than one medium, for example oral and written, combined with clarification and confirmation offered by the recipient. Clearly this relies upon employers ensuring that those involved in a task understand what constitutes safety-critical information. HSE publication HSG48 *Reducing error and influencing behaviour* contains relevant guidance.

8.1.4 Competence management systems

Hazard identification, risk assessments and risk controls are all essential elements in ensuring that effective workplace precautions are implemented. Systems need to be in place to ensure that those carrying out these tasks are trained and competent, and that their work is monitored by competent managers.

Employers should ensure that an effective competence management system is in place, so that staff are adequately trained and competent to undertake the tasks for which they are responsible. This should include arrangements for limiting staff engagement in complex safety-critical activities, when deputising for senior colleagues. The Office of Rail and Road publication *Developing and maintaining staff competence* provides useful guidance (see References).

8.1.5 Management of contractors

Companies engaged in the use of contractors should assume the role of an ‘intelligent customer’, rather than relying solely upon the contractor’s knowledge and experience. An intelligent customer will establish the regulatory and industry standards to which the contractor is expected to conform. The company will use this information to supervise the contractor’s performance and verify the adequacy of work carried out on its behalf. The Office of Nuclear Regulation guide *Licensee Core Safety and Intelligent Customer Capabilities* provides useful information (see References).

8.1.6 Contractor competence

Contracting companies should understand HSE legislation, guidance and industrial standards relevant to their work activities. Technical requirements associated with topic-specific guidance, such as tank cleaning, should form a critical part of safety management systems. This is particularly important in relation to risk assessment, established systems of work, the procurement of work equipment, training and competence assessment.

8.2 Learning points

HSE believes that the deaths were preventable. The fact that the tank contained flammable material emerged several times, but Chevron did not take the opportunity to train staff and update their systems. Any change of plant operation should be critically risk assessed, adequately controlled and relevant systems updated accordingly, to ensure the significance of a newly generated hazard is not lost over time. This is particularly important where hazardous waste streams are recycled back into the process.

Other opportunities to prevent the explosion were also missed. Two days before the incident, a gas test indicated a potentially explosive atmosphere within the tank, but this information was either not shared or acted upon by those planning or carrying out the job. Companies should reflect upon this failure and review their own systems to ensure that they provide training and arrangements for the recording and communication of important safety-critical information.

This incident clearly demonstrates that safety management systems are only effective when robustly audited, monitored and enforced. Safety arrangements that have been allowed to degrade over time become weak and ineffective. Whilst providing an illusion of safety and risk control, as seen in this case, ineffective systems do not remain strong enough to prevent real harm occurring.

This prosecution serves as a reminder to those with a responsibility for employees and contractors to actively monitor their safety management system arrangements and ensure they are effective in keeping workers safe.

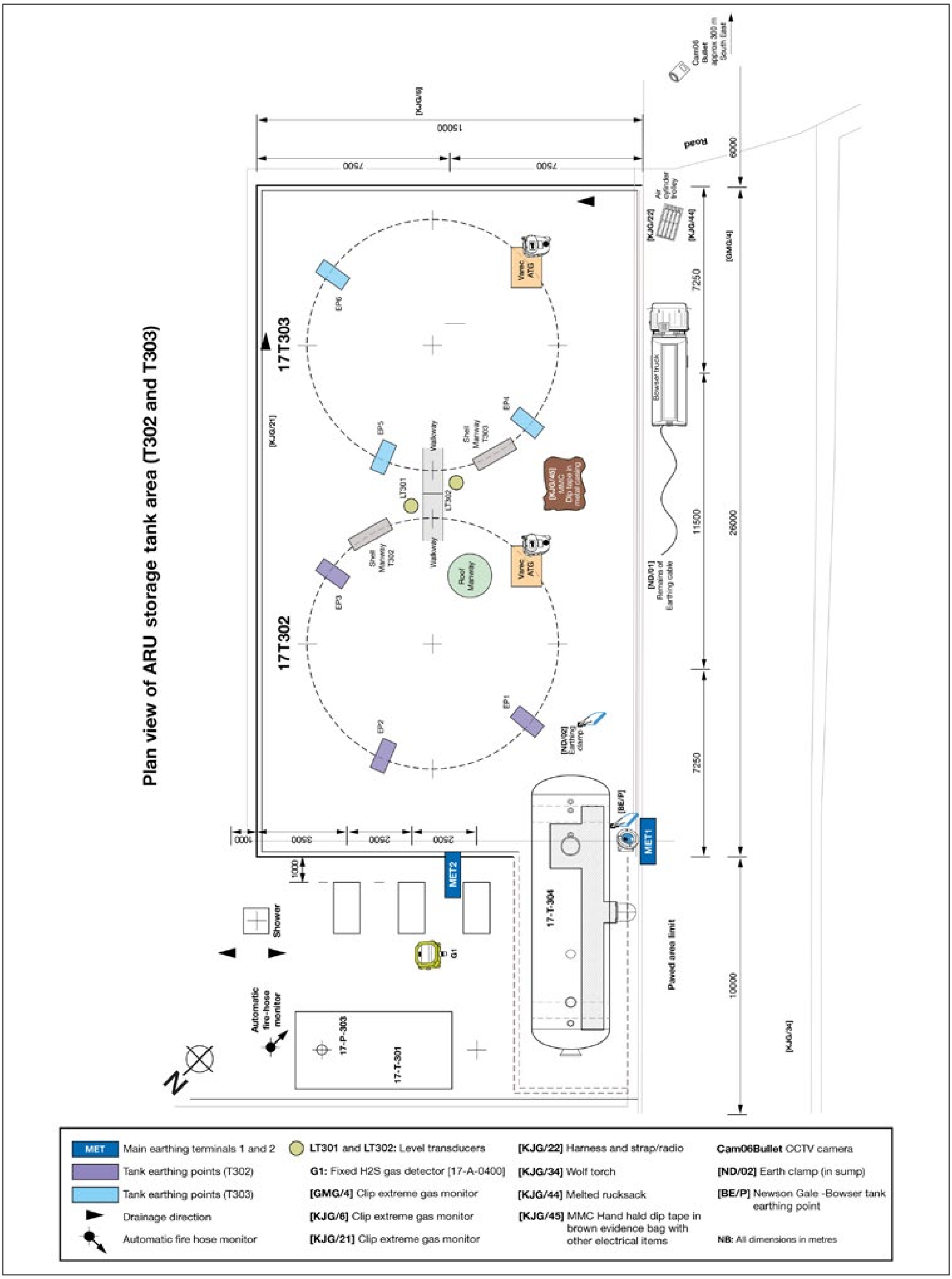
9 Sentencing

Charges were laid against Valero Energy UK Limited under Sections 2 and 3 of the Health and Safety at Work etc Act 1974 (HSWA), to which they pleaded guilty. The company was fined £5 million and ordered to pay costs of £1 million.

Charges were laid against B&A Contracts Limited under Sections 2 and 3 of HSWA, to which they pleaded guilty. The company was fined £120,000 and ordered to pay costs of £40,000.

The judge at the sentencing hearing was the Honourable Mr Justice Lewis, whose full sentencing remarks, issued on 6 June 2019, can be found in Appendix 3.

Appendix 1
Schematic diagram of the incident scene



Appendix 2 Applicable regulations and guidance prior to the incident (2011)

Widely recognised guidance documents applicable to the tank cleaning work were readily available at the time of the incident (key extracts are summarised in Sections A and B below). Chevron staff and B&A contractors were ignorant of their existence and did not use specific tank cleaning technical guidance documents to ensure legal compliance or to inform their working practices.

Section A – HSE publication *Safe maintenance, repair and cleaning procedures. Dangerous Substances and Explosive Atmospheres Regulations 2002. Approved Code of Practice and guidance* (L137)

This Code of Practice provided practical advice for employers carrying out maintenance and cleaning activities. This included actions necessary to meet the requirements of regulations 5 and 6 of DSEAR, regarding risk assessment and corresponding risk control.

Paragraphs 16-17 of the guidance state the following:

'Cleaning tanks, plant and other equipment

16 The employer should ensure that risks are assessed and appropriate control measures are identified before cleaning tanks, plant and equipment.

17 Isolating and cleaning plant and equipment is a hazardous activity and as well as considering the factors listed in paragraph 9 the employer will also, where necessary, need to implement measures to:

(a) isolate plant and equipment from sources of dangerous substances;
(b) control ignition sources in any additional hazardous zones created by the work;
(c) establish acceptable concentrations of dangerous substances for particular work activities;
(d) monitor the concentration of dangerous substances within the plant and in the surrounding area;
(e) maintain concentrations of dangerous substances below predetermined safe limits by ventilation or inerting techniques;

(f) establish action limits and procedures should the predetermined limits be exceeded during cleaning work; and

(g) ensure that the plant or equipment is inspected by a competent person and is declared clean and safe for the intended work.'

Where an item of plant has contained a dangerous substance, the operator has a legal duty to conduct a suitable and sufficient risk assessment of any proposed work on that plant and implement effective safeguards to control or mitigate the risk of igniting a flammable atmosphere that it may contain. On 31 May, when the presence of a dangerous substance within the tank became known to the company, the guidance and requirements in this ACOP should have been applied.

Section B – the Energy Institute's Model Code of Safe Practice Part 16 *Tank Cleaning Safety Code*, Third edition 2008 (EI16)

This is a detailed and extensive publication that provides practical guidance regarding all aspects of tank cleaning, including preparation, selection and use of equipment, gas freeing, cleaning procedures and recommissioning. An earlier edition was referenced within the HSE Approved Code of Practice L137 (see Section A). EI16 supports the requirements of the Dangerous Substances and Explosive Atmospheres Regulations 2002.

If followed, the guidance set out in this document, particularly in Section 2 (preparatory stages for tank cleaning), would have been sufficient to prevent the ARU tank explosion:

- '(Section 2.2.1) A competent supervisor, fully conversant with the relevant regulations, procedures and the nature of the products being handled should be appointed.
- (Section 2.2.2) The work force should be competent for the type of tank cleaning operations to be undertaken. They should be adequately trained, should have relevant experience and should be medically fit. They should understand the hazards of tank cleaning and how to control them to reduce risks.
- (Section 2.6.1 - 2.6.2) Before a storage tank is taken out of service for cleaning, a number of preparatory activities should be undertaken. The operational history of the storage tank as regards the products that have been stored in it should be determined … Particular attention should be paid to the physical properties such as flashpoint, electrical conductivity, pyrophoric material and for the presence of hazardous substances, eg lead, benzene, biocides, other additives, micro-organisms and H_2S.

- (Section 2.6.3) Tank engineering drawings and inspection records should be checked for relevant construction details that may influence the work programme … This information should be confirmed by external physical examination of the storage tank. The system of tank connections, valves and piping should be carefully assessed for the means of isolation and possible use for drainage and recirculation during the tank cleaning operation.
- (Section 4.2.1) After the storage tank and its connections have been drained and flushed to the maximum extent, preparations should be made for gas-freeing and/or opening of the storage tank.
- (Section 4.2.1) Where storage tanks cannot be emptied completely using the operational piping system, special measures should be considered such as temporary connections to low drains, or introduction of a water bottom to raise the level to the normal product suction level.
- (Appendix C2.2.3) The generation of static electricity in itself does not represent a hazard unless the charges reach a sufficient strength to result in a discharge with sparks of sufficient energy to ignite a flammable atmosphere that is simultaneously present. Therefore, static electricity generating operations should not be carried out unless the flammable gas concentration is below 10%LFL.'

Appendix 3
Sentencing remarks of
The Honourable Mr Justice Lewis

JUDICIARY OF
ENGLAND AND WALES

R

-v-

(1) Valero Energy UK Limited

(formerly known as Chevron Limited)

(2) B & A Contracts limited

In the Crown Court at Swansea

Summary of the sentencing remarks of THE HONOURABLE MR JUSTICE LEWIS on

6 JUNE 2019

Note: this is a summary of the sentencing remarks in this case. A copy of the full sentencing remarks is available.

1. On 2 June 2011, an explosion occurred at a storage tank at Pembroke Oil Refinery. The force of the blast blew off the steel roof, which weighed 5 tonnes and carried it a distance of 55 metres. A fireball engulfed the nearby workers. Four workers died, They were Robert Broome, Andrew Jenkins, Julie Jones and Dennis Riley. A fifth worker, Andrew Phillips survived but suffered terrible injuries. The explosion occurred as a result of the ignition of highly flammable vapour in the storage tank during what should have been routine maintenance.

2. The oil refinery was operated at the time by Chevron Limited and was subsequently sold to Valero UK Energy Limited. The contractors carrying out maintenance work on the storage tank in June 2011 was B & A Contracts Ltd.

3. Both companies have each pleaded guilty to two offences of failing to ensure the safety of their employees and others. Chevron's failures were highly culpable. They

created a system whereby a flammable atmosphere could develop in the storage tank. They failed to take steps to guard against that risk and their employees had a poor understanding of the nature and significance of the risk. Chevron arranged to carry out a gas test ten but failed to heed and act upon the results which showed the presence of a highly flammable atmosphere in the tank. An explosion occurred. The appropriate fine, taking account of the fact that Valero pleaded guilty to these criminal offences, is £5 million. Valero will also pay £1 million towards the prosecution's costs.

4. B & A Contracts failures were highly culpable. They used an unearthed hose to carry out the maintenance work, contrary to its own risk assessment. It will pay a fine of £120,000 and will pay £40,000 towards the prosecution costs.

JUDICIARY OF
ENGLAND AND WALES

R

-v-

(1) Valero Energy UK Limited

(formerly known as Chevron Limited)

(2) B & A Contracts limited

In the Crown Court at Swansea

6th June 2019

Sentencing remarks of THE HONOURABLE MR JUSTICE LEWIS

Introduction

1. On 2 June 2011, an explosion occurred at a storage tank at Pembroke Oil Refinery. The force of the blast blew the steel roof, which weighed 5 tonnes, into the air and carried it a distance of 55 metres. A fireball engulfed the nearby workers. Four workers died. They were Robert Broome, Andrew Jenkins, Julie Jones and Dennis Riley. A fifth worker, Andrew Phillips survived but suffered terrible injuries. The explosion occurred as a result of the ignition of highly flammable vapour in the storage tank during what should have been routine maintenance.

2. At the time, the oil refinery was owned and operated by Chevron Limited. It was subsequently sold to the first defendant, Valero Energy UK Limited. The second defendant, B & A Contracts Limited, was one of the contractors carrying out work at the site. Both of these defendants have pleaded guilty to criminal offences of failing to ensure, so far as reasonably practicable, the safety of employees and failing to avoid risks to the safety of others.

3. The tragedy has had a devasting impact on the families of those who died and on Mr Phillips and his family. Nothing this court says or does can bring back the four people who lost their lives or minimise the suffering of Andrew Phillips. This court only has power to impose a fine on each of the two defendants. No fine can ever reflect the value of a person's life. No punishment could ever compensate for the loss of life or the suffering or fill the void left in the lives of the families affected by this tragedy.

4. It is right, however, that the two companies be punished and sentenced according to law for the criminal offences that each committed. It is right that others carrying on hazardous activities realise the need to ensure the safety of employees and others and are aware of the legal consequences if they fail to do so.

The Amine Recovery Unit

6 I turn to the events themselves. The explosion occurred in Tank 302. That tank was part of the amine recovery unit. Amine is a solution (20% diethanolamine and 80% water) used to remove hydrogen sulphide from oil products. The process, known as scrubbing, involved mixing amine with the oil products under pressure. The amine picked up hydrogen sulphide from the oil products. In addition, the amine picked up light hydrocarbons from the oil products. Some of these light hydrocarbons, in particular, heptane, hexane, and octane, were highly flammable in certain circumstances.

7 The amine was then conveyed to the amine recovery unit where the hydrogen sulphide was removed from the amine. Most of the light hydrocarbons would also be removed by skimming off the top of the amine and sending that to a flare drum. The light hydrocarbons would evaporate and pass up a flare stack and be burnt off. A proportion of light hydrocarbons would, however, remain in the amine. Originally, the residue of

the amine would be disposed of by being sent to a slops system. In 1998, however, the decision was taken to send the cleaned amine into the system. The residue of the amine was therefore sent to the tank and was reused. No assessment of the risks of directing the residue of amine, containing some light hydrocarbons, into the tank was carried out.

8 There were in fact two tanks involved in the amine recovery process. One was tank 302 and one was tank 303. They were used interchangeably. One would be the running tank, that is the tank which fed amine to the oil refinery and which also, after 1998, received back the residue of the amine which would still contain some light hydrocarbons. Tank 302 had been in use as the running tank since 2007, that is for about 4 years. at the time of the explosion. Tank 302 was 9.7 metres high and had a similar diameter.

9 Tank 302 was an atmospheric tank, that is one that allowed atmosphere to enter into what is called the headspace, that is the space above the amine in the tank. In order to prevent the amine oxidising, a blanked of diesel of about 300mm was laid on top of the amine. Over time, the light hydrocarbons contaminated the diesel blanket above the amine. That contamination led to an increase in the depth of the diesel blanket. In 2006, an unspecified amount of diesel was removed to reduce it to 300 mm. In 2009, the diesel blanket had tripled in size to about 900 mm and was again reduced. In June 2010 it was about 850 mm and was reduced again to 300mm. In June 2011, the depth of the diesel blanket had increased to about 560 mm because of the presence of light hydrocarbons.

The Explosion

10 In mid-May 2011, the intention was that Tank 302 cease being the running tank and that role would be taken by Tank 303. Tank 302 was emptied of amine as Tank 303 was filled so that Tank 302 could be prepared for cleaning and maintenance.

11 On 25 May 2011, the operations adviser, Mr Wotton, decided to postpone the work as he would be away. Mr Wotton telephoned the relevant person, the integrity co-ordinator, and asked that the work be postponed. The integrity co-ordinator, however, thought he was speaking to someone else (not Mr Wotton) about a different tank, not tank 302. The circumstances in which this misunderstanding arose are not clear. The consequence was that the work in the tank continued but with another team of employees. The members of that team did not know of, or appreciate, the risk of flammable vapour being present in the tank from light hydrocarbons. They did not know of the relevant operating procedures, that is Operating Procedure 0008 to put one of the two tanks into service as the running tank and to take the other tank out of service in preparation for repair and Operating Procedure 0007 for the entry into and cleaning of the tank taken out of service (here tank 302).

12 The residue of liquid in tank 302 was to be siphoned out of the tank. However, a loss of siphon occurred and the tank was not emptied. The worker involved, however, did not realise that and believed that the tank had been emptied. The operation proceeded on the basis that the tank was empty. It was not.

13 On 26 and 27 May 2011, contractors called Redhall Engineering began the process of isolating tank 302 by sealing the many pipes and inlets at the tank. On 27 May 2011, liquid began to spill out of the tank because it was not, in fact, empty. At some point,

it seems between 27 and 31 May 2011, a decision was taken that all the remaining liquid would be removed by bowsering it from the manway in the roof of Tank 302. B & A were instructed to carry out that operation.

14 On 31 May 2011, an operator, Mr Bowen, took a gas reading inside the tank. That test revealed that the level of flammable gases were high. Energy Industry Standard 16 says that static generating operations should not be carried out unless the flammable gas concentration was below 10%. The test showed a level of 66%. Mr Bowen told persons in the control room by radio that the gas level was quite high (and that radio call is recorded) . Mr Cole in the control room told Mr Bowen that he would tell Mr Street, the acting operations manager (who was acting in place of Mr Wotton). Mr Cole says that Mr Bowen later went to the control room and told him that the level was 66%. Mr Bowen and Mr Cole both say, in witness statements, that each of them told Mr Street of the results of the gas tests. Mr Bowen says that he told Mr Street via the radio and Mr Cole says he told Mr Street in a meeting. Mr Street says in a witness statement that the information that he was given from the tests was that hydrogen sulphide was present but with no lower level explosives or hydrocarbons. It is not possible for this court to decide whether the results of the gas test were not properly communicated or, if they were, their significance was not understood. In either case, the first defendant accepts, in its basis for its guilty plea, that;

> "having rightly required a gas test before any work took place Chevron then failed to heed and react properly to the results obtained that confirmed the presence of a potentially explosive atmosphere".

15 The results of the gas tests showed a highly flammable atmosphere in the tank. All maintenance work on the tank should have been stopped immediately until the cause was identified and the risks eliminated or controlled. If the work had been stopped,

the explosion would not have happened and the four deaths, and the injuries to Mr Phillips, would not have occurred. Chevron, however, did not stop the work.

16 On 1 June 2011, Denis Riley prepared a risk assessment. He had already been provided with a hazard identification check sheet on 25 May 2011 by an employee of Chevron as part of the process of obtaining the necessary work permit. That identified certain hazards (by ticking a box on a list of hazards). There was no tick against hazardous substance comprising hydrocarbons. Mr Riley was never warned about the possible risk of flammable atmosphere arising from light hydrocarbons. The risk assessment he prepared provided, amongst other things, that “To reduce the risk of fire, and possible ignition source, all equipment will be bonded at the work place, chalwyn valves and spark arresters to be fitted to all mobile plant” and that non-metallic equipment would be used within the tank. Mr Riley also prepared a method statement. That provided, amongst other things, that:

> “To reduce the risk of fire all plant and equipment will be bonded at the work place, spark arrestors and chalwyn valves will be fitted to all diesel driven plan. ... To remove the danger of ignition source with the tank all plant will be earthed and all equipment, i.e. shovels, etc. will be made of non-metallic products”.

17 Two meetings took place on 1 June 2011 involving employees of Chevron (the integrity co-ordinator, Mr Forrest, the area process engineer, Ms Jones, and Mr Street). Mr Riley may have been present for part of one meeting. The Chevron employees, either in the meeting or outside the meeting, discussed the possibility of pyrophoric materials being present and concluded that there was no risk of this. None of the Chevron employees appreciated the risk of a flammable atmosphere in the tank as a result of light hydrocarbon Mr Street did not mention the results of the gas test

carried out the previous day. At one of the meetings Ms Jones approved the risk assessment prepared by Mr Riley.

18 On 2 June 2011, Mr Riley created a work permit enabling B & A "to remove liquid via the roof manway". That work permit was approved by relevant Chevron employees.

19 B & A did not comply with its own risk assessment or its method statement both of which required that an earthed hose be used (in order to avoid the risk of a static charge creating a spark). Indeed, the contract between B & A and Chevron provided that the hoses would be earthed. Instead, B & A delivered a new, recently purchased, unearthed hose. B & A's health and safety operator did not review the risk assessment or the method statement. She did not attend the site to supervise and check that the work was being carried out in accordance with those documents. B & A's workshop manager did not conduct an independent assessment of the appropriate equipment for the job. The relevant employees of Chevron did not carry out any checks to ensure that B & A complied with the risk assessment and method statement.

20 At about 5p.m. on 2 June 2011, arrangements for carrying out the work were nearly complete. Denis Riley collected the final paperwork. Staff from B & A were unloading the unearthed hose for use and the bowser vehicle was in position. At about 5.51 p.m. attempts began to suck out the remaining liquid from the tank.

21 Andrew Jenkins was on top of the tank working the hose leading from the bowser vehicle. Julie Jones was standing on a platform between tank 302 and 303 monitoring the operation. Andrew Phillips and Robert Broome were on the ground. Andrew Phillips was operating the mechanism that provided air to the breathing apparatus worn to guard against hydrogen sulphide. Robert Broome was operating the bowser

pump. Dennis Riley was sitting at the kerb side making notes. At about 18.04 problems were encountered in the attempt to suck out the residue of the liquid in the tank. Mr Riley went to get a torch.

22 At about 18.19, the tank exploded engulfing those nearby in flames. Four people died - Andrew Jenkins, Julie Jones, Robert Broome and Dennis Riley. Andrew Phillips was also surrounded by flames but managed to run and survived although he suffered terrible burns and other injuries.

23 The flammable atmosphere in the tank had ignited. The expert evidence is that there are two possible causes of ignition neither of which can be ruled out. One was the presence of pyrophoric materials (iron sulphide) in the tank which, if that material had dried out, could have burst into flames on contact with air. The second was an electrostatic charge which could have given rise to a spark. That could, for example, have arisen when using an unearthed hose. As neither can be ruled out, I cannot be sure which of the two events was the cause of the explosion.

The Charges

5. Following a long investigation, charges were laid against each of the two defendants.

under section 2 and 3 of the Health and Safety at Work Act 1974. In the case of the first defendant, the particulars are, in essence, that, between 17 February 1998 and 3 June 2011

(1) it failed to discharge its duty under section 2 to ensure so far as reasonably practicable the safety of its employees working at the site including from risks arising from work carried out in the vicinity of atmosphere made flammable by hydrocarbon contamination of tanks with the amine recovery unit; and

(2) it failed to discharge its duty under section 3 to conduct the operation of Pembroke Refinery, including the work carried out in the vicinity of atmosphere made flammable by hydrocarbon contamination of tanks within the amine recovery unit in such a way, as to ensure that persons not in its employment including Andrew Jenkins, Robert Broome, Denis Riley, Andrew Phillips and Julie Jones were not exposed to risks to health or safety.

6 In relation to B & A Contracts the particulars are that, Between 6 December 2010 and 3 June 2011:

(1) it failed to discharge its duty under section 2 to ensure the safety of its employees, including Andrew Jenkins and Robert Broome, including from risks arising from the provision of industrial tank cleaning services including the preparation of tank 302 in the amine recovery unit for scheduled inspection and maintenance; and

(2) it failed to discharge its duty under section 3 to conduct its undertaking of providing industrial tank cleaning services, including the preparation of tank 302 for scheduled inspection and maintenance, to ensure so far as reasonably practicable that persons not in their employment, including Dennis Riley, Andrew Phillips and Julie Jones, were not exposed to risk to their health and safety.

The Defendants' Guilty Pleas

24 Each pleaded guilty to two offences. Each provided a detailed, updated basis of plea the essential parts of which are set out below. In addition, there were some additional issues which the prosecution and the defendants considered could be determined by

written and oral submissions at the hearing based on the documentary material and witness statements before the court. There were, in fact, over 1,700 pages of witness statements and many hundreds of pages of documents. There were reports of experts instructed by the prosecution and each of the defendants and joint statements from the experts setting out the extent of agreement, or disagreement, between them. Submissions took three days and judgment was reserved. I thank all counsel for their helpful written and oral submissions. I should also record that the families of those who died in the explosion, and Mr Phillips and his family, attended the hearing. I thank them for the dignity and quiet curtesy that they all displayed in court as they listened to accounts of the harrowing events of that June night in 2011.

The Basis upon which the First Defendant Pleaded Guilty.

25 The First Defendant pleaded guilt to the two offences on the following basis:

"3. Chevron accepts the following matters combined to expose those carrying out the scheduled inspection and maintenance of tank 17-T-302 (T302) to an unacceptable risk to their safety:

3.1 By reason of the decision to operate the Amine Recovery Unit (ARU) as a closed system from 1998, it followed logically that light hydrocarbons were liable to contaminate the ARU running tank, whether T302 or T303 (depending which was in service).

3.2 The company was aware of this potential but failed to put in place adequate measures to guard against either:

3.2.1 such contamination occurring in the first place; or

3.2.2 the consequent risk, during the emptying of the running tank, of a flammable atmosphere developing within its headspace.

3.3 The diesel blanket on top of the liquid within T302 was, of itself, an inadequate safeguard against repeated light hydrocarbon contamination over a protracted period of time.

3.4 Over time, by reason of the matters outlined above, the diesel blanket within T302 instead served to harbour an increasing quantity of light hydrocarbons. Whilst the diesel blanket was reduced on occasions, there was a failure to address the underlying cause of why it was increasing and whether it contained light hydrocarbons.

3.5 The planning for the draining of T302 in May 2011 failed to include sufficient consideration as to the risk of a flammable atmosphere developing in its headspace during this operation.

3.6 The activity of removing the liquid contents of T302 in May 2011, in preparation for cleaning and maintenance, drew air into the tank which, when mixed with the light hydrocarbon vapours emanating from the by now saturated diesel blanket, generated a flammable atmosphere.

3.7 The foreseeable and foreseen risk of the creation of a flammable atmosphere within the headspace of the running tank should have been the subject of a clearer and structured focus within the First Defendant's maintenance procedures and the training provided thereon, albeit that there were measures within those procedures (such as gas testing) that did address it.

3.8 By June 2011, the evidence from personnel in charge of the cleaning and maintenance of T302 demonstrates a poor understanding of the nature and importance of this risk.

3.9 Those in charge of that work being undertaken on T302, having rightly required a gas test before any work took place, then failed to heed and react properly to the results obtained that confirmed the presence of a potentially explosive atmosphere.

3.10 Those in charge of the work failed properly to control or mitigate the risk of a flammable atmosphere developing or igniting."

26 The basis of plea reflects an acceptance of the prosecution's essential case against the first defendant. The prosecution also put forward five further systemic deficiencies on the part of Chevron. Both the prosecution and the first defendant accepted that I could resolve those issues, if necessary, on the basis of the material provided and their written and oral submissions. In fact, on analysis, these additional issues were either already reflected in the basis of plea or did not add, materially, to the prosecution's case and would not alter the sentence that I consider appropriate. For completeness, I set out, briefly, my conclusions on those issues.

27 First, it is said that the operating procedures 0007 and 0008 suffered shortcomings in relation to the absence of overt consideration of the risks of a flammable atmosphere in the tanks. The basis of plea accepts that the risk of a flammable atmosphere in the headspace of the tank should have been the subject of a clearer and structured focus within the maintenance procedures. I agree. The procedures should have identified the need to consider the risk of a flammable atmosphere. It did expressly recognise the risks from hydrogen sulphide and set out the steps to take. Specific provisions should have been included to identify the possible risk from a flammable atmosphere in the tank, and the appropriate steps to take, in the relevant operating procedure, 0007.

28 Secondly, it is said that the system for obtaining work permits was insufficiently robust in preventing hazardous work being undertaken in a manner that was unsafe. In reality, this, too, is already reflected in the basis of plea which accepts that there was a poor understanding of the nature and importance of the risk of a flammable atmosphere within the tank. That is why such a hazard was not identified and why Mr Riley was never told of the risk of a flammable atmosphere arising from hydrocarbons before he created the work permit.

29 Thirdly, it is said that there was inadequate monitoring and management and supervision by Chevron of B & A. In its basis of plea, the first defendant accepts that, in relation to the central issue, Chevron was deficient in not supervising B & A to ensure that B & A complied with its own risk assessment and method statement.

30 The prosecution also makes criticism of the person who was the contract owner, that is, the person appointed by Chevron to liaise with the contractor to ensure that certain reviews were carried out. The first defendants contend that the contract owner did acquire the relevant knowledge of the reviews to be carried out and the reviews were in fact carried out either by him or another Chevron employee. I do not consider it necessary to resolve this dispute as it would not affect the sentence. I do not therefore take this particular aspect of the prosecution case into account.

31 The fourth additional matter that the prosecution refers to is the inadequacy of Chevron's own risk assessment. In fact, the first defendant accepts at paragraph 8. 4 of its basis of plea that Chevron's own risk assessment did not identify the potential for a flammable atmosphere to be present in the tank.

32 The fifth additional matter relates to alleged inadequate training and a system for gathering, recording and communicating safety critical information. I do not have sufficient information to form a view on training and I do not take any allegations in relation to this aspect of the prosecution's case into account. In relation to the recording and communicating of information, that relates principally to the arrangements relating to the results of the gas test carried out on 31 May 2011 which showed a highly flammable atmosphere in the tank. The basis of plea already accepts that, whilst a gas test was carried out, Chevron employees failed to heed and react properly to the results. That is the most significant substantive failure in relation to the results of the gas test. It is right, however, to note that the relevant industry standards

(paragraph 3.5.2 of Part 16 of the Energy Institute Tank Cleaning Safety Code) does state that the "results of all measurements of flammable gas concentrations should be recorded and retained in the health and safety file" and that was not done.

33 For completeness, there are a number of matters where the prosecution and the defendants now agree on certain matters. Most significantly, I record that the prosecution do not now suggest that liquid petroleum gases such as butane and propane, which are extremely flammable, were transferred to the tank. That no longer forms part of the case and I do not take that into account in determining the sentence. I note that the prosecution still relies on other incidents at the refinery from 2001 to 2005 but those are different in nature from the events leading to this explosion and I do not take those into account in determining the appropriate sentence.

34 There is one other issue that arose concerning the hazardous area classification. In 2008, Chevron wrongly downgraded the hazard area classification status for the two tanks, and the proximate area. The headspace within the tanks should have been classified as Zone O, or the highest grade of risk, and the area around the tanks as either Zone 1 or Zone 2. They were erroneously classified as non-hazardous areas. In fact, no one involved in the process considered the classification (and if they had, would have been misled but it). There is an issue as to whether the hazardous area classification should have been looked at prior to tank cleaning. Paragraph 2.7 of Part 15 of the Energy Institute Code states that before tank cleaning operations start, the hazardous area classification should be established. Paragraph 8.4 of Part 16 says that the classification is "primarily" a means of determining what equipment should be used in a particular location during normal operations and that is "not intended to apply during repair and maintenance" and that many installations have rules restricting maintenance operations in a wider classification area. If it were necessary to decide

this question, I consider that paragraph 8.4, read in context, is saying that the classification is not the only document intended to apply during maintenance work as other additional restrictions may apply. It is not saying that the hazard area classification does not apply and can be disregarded during maintenance. In any event, the fact that no one looked at the (erroneous) classification would not have any affect on the sentence in this case.

The Basis upon which the Second Defendant Pleaded Guilty

35 The second defendant pleaded guilty to the two offences on the basis that:

(1) B & A failed to follow its own procedures contrary to B & A's own risk assessment and method statement and its contractual obligations in that on 2 June 2011, B & A employees used an unearthed hose to clean out the tank whereas an earthed hose was required to be used and that would have been a reasonably practicable step to take to avoid a potential ignition source;

(2) B & A failed to supervise the operation and relied on Chevron and Mr Riley and that resulted, in particular, in the following failings of supervision. B & A's own Health & Safety Officer (a) did not review the risk assessment and method statement produced for the tank cleaning operation (b) did not attend the Chevron site to supervise the work or ensure that it was carried out in accordance with the risk assessment and method statement. B & A's workshop manager could not properly conduct his own independent assessment in the appropriate equipment for work at the Chevron site. B & A management had less involvement in, or

supervision over work taking place on the Chevron site than over work at a different refinery operated by a different company.

(3) B & A's employees, including its health & safety manager, and its workshop manager, were unaware of the Energy Institute standards for tank cleaning or the relevant British Standard (BS 5958) both of which dealt with tank cleaning operations. B & A did not have a copy of BS3958 prior to the explosion.

36 B & A accept that its duties under the 1974 Act were not delegable to others such as Chevron. Their basis of plea, broadly, accepts the prosecution case. There are additional issues raised by the prosecution which it is unnecessary to make any rulings on as they would not affect the appropriate sentence. In particular, it is not necessary to determine whether B & A's bowsers were designed and equipped appropriately or whether a scaffold pole was, or was not, attached to the hose during the work. I do not take those matters into account. Mr Riley was properly trained and I do not take any allegations about lack of training into account. There is one issue, relating to one of the factors relating to the assessment of harm, which I deal with later.

THE DETERMINATION OF THE APPROPRIATE SENTENCE.

37 The only sentence available for the two health and safety offences to which the defendants have pleaded guilty is a fine. The appropriate fine is to be determined in accordance with the Sentencing Council's Definitive Guideline on Health and Safety Offences. That sets out a structured approach which requires a fine to be fixed following certain steps. I start with the first defendant although, as the refinery was operated at the time by Chevron, I refer for convenience to Chevron.

Step 1 Chevron's culpability and harm.

38 Step one requires consideration of culpability and also harm. Chevron's culpability is high as measured by the Guidelines. There were serious, and in some cases systemic, failures on the part of Chevron. It decided to operate the amine recovery unit as a closed system in 1998 and sent amine containing light hydrocarbons into the tank, creating the risk of a flammable atmosphere developing in the tank. It did not carry out a risk assessment of this procedure. It failed to prevent the contamination from light hydrocarbons occurring. The diesel blanket increased on a number of occasions because of an increasing quantity of light hydrocarbons but Chevron failed to investigate the underlying cause of the increase. The planning for the maintenance of the tank in 2011 failed to include sufficient consideration of the risk of a flammable atmosphere in the tank. A gas test was conducted but the results, which showed a highly flammable atmosphere in the tank and should have led to the work being stopped, were not heeded or acted upon. There was no proper system of recording and communicating the results of the test. All these are serious failings, some systemic. Some of the failings could, alternatively, be described as Chevron falling far short of the appropriate standards either by failing to put in place procedures to record the results of gas tests (as required by the Energy Institute Code) or by allowing breaches to subsist over a long period of time.

39 The fact is that the serious nature of the failings, the number and range of failings, and the length of time over which certain of the failings occurred demonstrate serious errors and serious failures within the organisation to address the risks to health and safety resulting from the creation of a closed system where light hydrocarbons were directed into the storage tank leading to the development of a flammable atmosphere in the tank. In the words of the basis of plea, there was "a poor understanding of the

nature and importance of this risk" and "this was an underlying systemic and organisational breach".

40 The first defendant submits that this was a case where there were procedures in place but they were not followed with people using their own judgment instead. That argument focussed principally on the fact that operating procedure 0007 was in place and, in addition, made provision for a gas test which would detect a flammable atmosphere. It was submitted that the explosion occurred because this procedure was not followed. This description does not reflect the serious nature of the failings which occurred before 2011. By way of example, these include the fact that Chevron set up the closed system without assessing the risk of a flammable atmosphere developing and failed to consider the reasons why the diesel blanket, containing the light hydrocarbon carbons, was expanding. Even in relation to operating procedure 0007, that does not specifically refer to the risk from light hydrocarbons. The first defendant relied upon the fact that 0007 required a gas test which would have picked up the presence of flammable atmosphere developing from light hydrocarbons and it would, it was said, be common knowledge that the presence of such an atmosphere should lead to the work being stopped. Even here, there is no procedure in place, as required by the relevant code of practice, to record the results of the gas test. The first defendant submitted this is a case where not all the errors were the product of defective processes and systems. it submitted that this is not a case that fits squarely into the high culpability bracket within the Guidelines but one which sits on the threshold between high and medium. For the reasons already given above, I disagree. This is a case where Chevron were highly culpable.

41 Dealing next with harm, that depends on both the seriousness of the harm risked and the likelihood of that harm arising. This is a case involving the most serious level of

harm, that is Level A, as the failures constituting the offences gave rise to a risk of death.

42 The next, and in some ways the most difficult, question is the likelihood of that harm arising. That involves consideration of two principal factors, first the period of time when a flammable atmosphere was present in the tank and secondly, the likelihood of a cause of ignition occurring during that period.

43 In the light of the evidence of the experts, and the joint statement of Dr Kyotamaa and Mr Summerfield dated 21 March 2019, a risk of a flammable atmosphere developing which was capable of being ignited would not occur during normal operations. It would occur if one of two major operations were being carried out, namely when a fresh layer of diesel were introduced into the tank and when major maintenance operations were carried out. Those operations would lead to the introduction of sufficient air which could result in the atmosphere falling within the explosive range. The first of those operations, namely laying a fresh layer of diesel would lead to a situation where, over a period of 12 days, the concentration of air and light hydrocarbons would reach the flammable level and would then remain flammable for a period of 53 days. In relation to the second of those operations, namely maintenance work, there were three occasions (prior to June 2011) where major works were being carried out on either tank 302 or 303 where a flammable atmosphere could develop, namely October 2002, April/May 2007 and January 2008.

44 In terms of the cause of ignition, the expert evidence is that there are two possible causes of ignition neither of which can be ruled out. One is the presence of pyrophoric materials (iron sulphide) in the tank which, if they dry out, can ignite on contact with air. The second is an electrostatic charge which could give rise to a spark. That could, for example, have arisen because of suction when using an unearthed hose. As neither

can be ruled out, I cannot be sure which of the two events was the cause of the explosion.

45 In terms of assessing the likelihood of pyrophoric material causing the harm, I accept that the risk would be low. During the replacement of the diesel layer, any pyrophoric material in the tank would be covered with liquid and would be unlikely to dry out and be capable of ignition. In terms of routine maintenance work, pyrophoric material, if present, would be unlikely to have dried out and ignite. In terms of the Guidelines, therefore, the likelihood of death arising because of ignition from pyrophoric materials is low. One possible cause of ignition here is that the residue of material in the tank was below the level of the heater coils in the tank and, if it contained pyrophoric materials, could have ignited. I cannot determine on the evidence if that is what happened. But the likelihood of it happening would have been low.

46 I turn then to the other possible cause of ignition, that is, an electrostatic charge from the use of an unearthed hose. The offences involved failures to recognise or protect against the risk of a flammable atmosphere in the tank, a failure to heed the results of a gas test indicating the presence of a flammable atmosphere, and then the contractors failing to comply with their contractual obligations and their own risk assessment and method statement (approved by Chevron) which required the use of earthed hosepipes. B & A supplied its workers with an unearthed hose. B & A staff did not attend and supervise the work. It is correct, therefore, that this sequence of events would involve not simply the failures amounting to an offences by Chevron: failures by the contractors would also need to be present if the ignition were, in fact, caused by an electrostatic charge from an unearthed hose. But the first defendant admits at paragraph 8.3 of its basis of plea that Chevron's own monitoring of B & A was deficient in failing to uncover the contractors' failure on 2 June 2011 to follow its own

risk assessment and method statement. Given all the circumstances, there was at least a medium likelihood of death arising from an explosion created by Chevron's offence, that is by its failings - allowing the development of a flammable atmosphere, failing to heed the gas tests and then failing to monitor the contractors adequately.

47 I look, therefore, at the circumstances overall in assessing the likelihood of harm arising created by offences for which the first defendant is liable. I bear in mind that I cannot be sure which of the two causes of ignition caused the explosion. The risk of an explosion from caused by the presence of pyrophoric materials was low but the risk of an explosion from unearthed hoses was at least medium. Overall, it is appropriate to categorise the likelihood of harm arising from Chevron's offences as medium. My provisional assessment is, therefore, that the situation involved harm category 2 within the Guidelines.

48 Before reaching a final classification, the Guidelines require two further factors to be considered. The first is whether the offence exposed a number of workers to the risk of harm. Here, the offences did do so. There was the risk to those carrying out the maintenance operation (the four workers who died and Mr Phillips). There was also the risk to others in the vicinity and who might have also have been killed (for example, by the roof of the tank which blew off and landed metres away, having damaged, but not penetrated, a butane tank).

49 The second factor is whether the offence was a significant cause of actual harm. Here, the offences did cause significant harm and, whether the cause was the presence of pyrophoric material or an electrostatic charge, the harm arose from Chevron's offences. The first defendant accepts that both factors are satisfied here.

50 In those circumstances, that justifies moving the offences up a harm category into harm category 1.

Step Two – Starting Point and Category Range

51 This is, therefore, a high culpability case involving category 1 harm. In addition, given the fact that the offence resulted in 4 deaths, and serious injury to a fifth person, it is appropriate to place the offending at the very top of the range for that level of offence: see the decision of the Court of Appeal in *Whirlpool UK Appliances Ltd. v The Queen* [2017] EWCA Crim. 2186, at paragraph 31.

52 In the case of a company with a £50 million turnover, the Guidelines provide that the starting point for assessing the fine would be £2,400,000 and the range would be £1,500,000 to £6,000,000. If the first defendant had fallen into this category, the appropriate fine, subject to any aggravating and mitigating features, and a reduction to reflect its guilty plea, would have been £6 million.

53 The first defendant and the prosecution both agree, however, that the first defendant should be sentenced on the basis that the offences were committed by a company which was a very large organisation. That means that it may be necessary to move outside the suggested range to achieve a proportionate sentence. In the circumstances, it is appropriate to increase the fine to at least £7.5 million. A figure in that region would, in my judgment be justified and would amount to a proportionate increase over the figure for the top of high culpability in category 1 harm cases.

54 I note that an increase of £1.5 million is just under half of the amount of the difference between the top of harm category 2 (£2.9 million) and harm category 1 (£6 million) in high culpability cases. It is a little more than the amount of the difference between the starting points for harm category 2 (£1.1 million) and harm category 1

(£2.4 million) in high culpability cases. That confirms my view that increasing the fine by an amount in the region of £1.5 million, as the offender was a very large organisation, is a proportionate, measured and not excessive step to take. That approach is also broadly analogous to the structured, stepped approach taken by the Court of Appeal in the *Whirlpool* case at paragraphs 35 to 36 where the Court had regard to the next range in the Guidelines in the case of a very large organisation. That was a case of low culpability in harm category 2, and the Court looked to the next level, harm category 1, to assist in determining the fine for a very large organisation and took a mid-point between the two. As this case is at the top of category 1 harm, an approach which increases the fine by an amount which is roughly ½ of the difference between the top of category 1 and category 2 does involve a similar type of balanced, measured and structured approach resulting in an appropriate increase in the fine.

55 In terms of aggravating factors, Chevron has one relevant previous conviction. That is a conviction in 1994 (four years before the start of the period covered by the current offences). That involved failures in management, equipment and control systems following an electrical storm which led to the release of about 20 tonnes of flammable hydrocarbons that formed a cloud and was ignited. That conviction is an aggravating factor. The first defendant also has a conviction concerning a collapsed gangway. That particular offence was different in nature and does not materially affect the sentence.

56 In terms of mitigating factors, the first defendant submits that it has taken steps voluntarily to remedy the problem and has now put effective procedures in place. These steps and procedures are described in the statements of Mr Hanghi and Mr Tomp. I accept that the first defendant has taken steps to remedy the problem and to improve industry standards and that that is a mitigating factor. The first defendant also relies on the fact that it provided a high degree of co-operation with the investigation.

That is correct but I note that the Guidelines treat co-operation as a mitigating factor if it is beyond that which always expected. In this case, given the serious nature of this explosion, a relatively high degree of co-operation would have been expected and this factor is of relatively little weight. Overall, the aggravating factor and the mitigating factors broadly balance each other out and would, in any event, not justify a reduction in the fine below £7.5 million. Subject to the reduction for the guilty plea, that would be the appropriate fine for the first defendant in this case.

Step Three

57 The first defendant and the prosecution agreed that the fine for the first defendant should be determined on the basis that it was a very large organisation. The actual position is more complicated. At the time of the explosion, the refinery was operated by Chevron Ltd. Its turnover for the years immediately before the explosion was in excess of £5 billion. For the year end to 31 December 2009 turnover was £5,794,200, 000 to 31 December 2010 £8,129,100,000, and to 31 December 2011 £9,411,700.000 Its pre-tax profit for each of those years respectively was £154,000,000, £67,100,000 and £181,100,000. It paid dividends to Chevron Global Energy Inc, an American company (whose total revenues in 2018 amounted to £10.55 billion).

58 Chevron sold the oil refinery to the first defendant and that sale was completed about two months after the explosion. As part of the final terms, Chevron Global Energy Inc agreed to indemnify Valero for any financial penalty (and legal costs) imposed. The first defendant will, therefore, be able to call upon the terms of that indemnity to pay its fine and any legal costs it is ordered to pay.

59 The first defendant itself has a turnover to year end 31 December 2015 of £89,778,000 to 31 December 2016 of £78,575,000 and to 31 December 2017 of £27,626,000. It had

pre-tax profits for each of those years respectively of £3,100,000, £2,939,000 and £2,861,000.

60 The prosecution and defendant agree, and I concur, that it would be artificial and inappropriate to approach the sentencing on the basis that the first defendant should be treated as a medium organisation (with a turnover in 2017 of between £10 and £50 million) rather than a very large organisation. That would ignore the fact that the explosion happened when it was owned and operated by Chevron. More importantly, there would be a need to recognise the fact that the parent company had agreed to indemnify the first defendant for any fine. In those circumstances, it was right to approach sentencing on the basis that the failings occurred on the part of a very large organisation.

61 If I had not done that, I would have accepted the first defendant's alternative approach under step 3. That would have required me to consider the seriousness of the offence and the financial circumstances of the offender. That includes, in this case, the indemnity from the parent company of Chevron to pay the fine. Any fine would have to reflect the objectives of punishment and deterrence and should be sufficiently substantial to have a real economic impact bringing home both to management and shareholders the need to comply with health and safety legislation. If I had treated the first defendant as a medium organisation, I would have had regard to those principles, and to the reality that it was Chevron, a very large organisation with a turnover in the billions, which failed to provide for the health and safety of its employees and others and that the fine would be paid, ultimately out of an indemnity provided by its parent company. I would, therefore, have fixed the fine, subject to the reduction for the guilty plea, at £7.5 million.

62 Standing back, and reviewing the fine, I am satisfied that a fine of £7.5 million does reflect the principles set out in the legislation and step 3 of the Guidelines. I am satisfied that none of the additional factors referred to in step 3 apply and there are no reasons for adjusting the fine (other than the reduction for the guilty plea).

Steps 4 and 5

63 None of these factors apply.

Step 6

64 The court is required to take into account the fact that the first defendant pleaded guilty to the two offences at the earliest opportunity. In accordance with relevant guidance, the court should therefore reduce the fine by 1/3 from £7.5 million to £5 million.

Steps 7, 8 and 9

65 I understand that compensation has been, or will be paid, to the families and Mr Phillips and that this court does not need to make a compensation order.

66 In relation to step 8, for clarity, I make it clear that I have fixed one fine to reflect the overall conduct of Chevron Limited. In reality, there was one set of failings, from 17 February 1998 to 2 June 2011 and the fine reflects the entirety of the offending behaviour during that period. There are in fact two offences and, for administrative convenience only, I allocate ½ of the fine to each offence.

67 These sentencing remarks constitute my reasons and explanation for the fine as required by legislation and step 9 of the Guidelines.

Costs

68 The prosecution has incurred legal costs of in the region of £1.3 million. The prosecution and the first defendant agree that the amount of the costs that should be borne by it is £1 million. I order the first defendant to pay prosecution costs of £1 million, in addition to the fine of £5 million.

The Second Defendant B & A

Step 1 B & A culpability and harm.

69 B & A were responsible for failings over a shorter period of time (approximately six months) than Chevron. The range and nature of their failings were not as extensive as those of Chevron. Within the context of what B & A was instructed to do, however, its culpability was high. It was responsible for serious failings including the failure to comply with its own risk assessment and method statement. It provided an unearthed hose for use when, given the risk of fire and ignition, it should have provided an earthed hose. Some of its failings were systemic. It failed to supervise staff at the Chevron site. Its health and safety manager, and workshop manager, were not aware of the relevant safety standards.

70 This was level A harm, as it involved a risk of death. I have already explained above why the likelihood of harm is to be assessed by referenced to the periods when the tank was being refilled with diesel or undergoing maintenance works. I have already explained why the risk of ignition from pyrophoric material was low. In relation to the use of the unearthed hose, that could cause an electrostatic charge. I recognise that for an explosion to occur as a result of such a charge would have required failings on the part of Chevron. In particular, there would need to be a flammable atmosphere in the tank and a failure to heed the results of any gas test indicating that the atmosphere within the tanks was within explosive levels. However, the likelihood of harm,

including death resulting from B & A's own failure to use an earthed hose was at least medium. I note that, in its basis of plea and sentencing note dated 15 February 2109, B & A submits that the likelihood of harm arising from B & A's failings is properly categorised as medium and that the case is initially within harm category 2. I agree

71 The provisional assessment, therefore, is that B & A's offences fall within harm category 2. I consider the two factors set out in the Guidelines under harm. First these offences did expose a number of workers to the risk of harm. They included those carrying out the maintenance work and those in the immediate vicinity.

72 In terms of the second factor, there were two potential causes of ignition, the presence of pyrophoric material or electrostatic charge from the unearthed hose. However, I cannot be sure that the harm resulted from the electrostatic charge (for which B & A would be responsible, together with Chevron). It may have resulted from the presence of pyrophoric materials. The prosecution allege that, even if the cause of ignition was pyrophoric material, that amounted to a materialisation of a risk which B & A should have appreciated and considered before it commenced the work. I accept the submissions made by Mr Popat for B & A that, on a proper reading of the relevant guidance, Chevron were responsible for identifying dangers from the presence of materials in the tank. B & A were responsible for seeking information as to what was present to ensure that it assessed the risks appropriately. The initial hazard identification provided by Chevron did not include a risk from pyrophoric material. That matter was discussed at a meeting involving Mr Jones, Mr Forrest, Mr Street and Mr Riley. But those at Chevron decided that the risk was nor present. In all the circumstances, I do not consider that B & A could be held responsible for a failure to appreciate a risk from the presence of pyrophoric material in the tank. I do not consider that the second factor under harm in the guidelines is establishedi n the case

of B & A. The presence of one factor, however, justifies moving up from category 2 harm to category 1 harm.

Step Two – Starting Point and Category Range

73 B & A therefore fall to be assessed as a high culpability in a category 1 harm case. B & A is a micro company within the Guidelines, that is a company with a turnover of not more than £2 million. The starting point for determining the fine is £160,000 and the range is £100,000 to £250,000. Its turnover for 2 of the last 3 years was close to £2 million and for the last year £1.2 million. It would be appropriate to place B & A towards the top of the range, but not at the top, bearing in mind its turnover and the differences between Chevron and B & A in terms of the extent of their culpability and the reasons why this falls within category 2 harm so far as B & A is concerned. The appropriate fine, before mitigating factors and a reduction for the guilty plea are considered, would be £200,000.

74 None of the aggravating factors listed in the Guidelines are present. There are mitigating factors. B & A has no previous convictions. It has a good health and safety record. It has taken steps to remedy the problems and to ensure that no further accident occurs. It also relies on the fact that it provided a high degree of co-operation with the investigation but, as I have noted, the Guidelines treat co-operation as a mitigating factor if it goes beyond that always expected. In this case given the serious nature of this explosion, a relatively high degree of co-operation would have been expected and this factor is of relatively little weight. In all the circumstances, it would be appropriate, given the mitigating factors, to reduce the sentence to £180,000 before taking account of the guilty plea.

Step 3

75 B & A's turnover for the year to the end of January 2016 was £1,798,970 and its profits before tax of £292,134 and for the year to the end of January 2017 was £1,763,484 with profits before tax of £225,332. For the year to 31 January 2018, its turnover was £1,226,978 but it made a loss before tax of £722,643. That was largely, but not exclusive, the result of two particular items – pension contributions amounting to £544,327 and a loss on disposal of tangible assets of £154,313. Without those particular items, there would still have been a relatively small loss. Mr Popat explained in submission that B & A would be likely to be able to pay up to £50,000 a year, given its estimate of future business and ability to reduce costs.

76 In the circumstances, I am satisfied that a fine based on its turnover is proportionate and that, with appropriate time to pay, B & A has the means to pay the fine. The fine does reflect the extent of B & A's failings and will have a real economic impact bringing home to the management the need to comply with health and safety legislation. Having considered the profitability of the organisation, and the likely effect on the company of the fine, and the power to allow payment of the fine over a number of years or instalments, it is not necessary to make any adjustment to the fine.

Steps 4 and 5

77 None of these factors apply.

Step 6

78 The court is required to take into account the fact that the first defendant pleaded guilty to the two offences at the earliest opportunity. In accordance with relevant guidance, the court should therefore reduce the fine by 1/3 from £180,000 to £120,000.

Steps 7, 8 and 9

79 I understand that compensation has been, or will be paid, to the families and Mr Phillips and that this court does not need to make a compensation order.

80 In relation to step 8, for clarity, I make it clear that I have fixed one fine to reflect the overall conduct of B & A. In reality, there was one set of failings, from December 2010 to June 2011 and the fine reflects the entirety of the offending behaviour during that period. There are in fact two offences and, for administrative convenience only, I allocate ½ of the fine to each offence.

81 These sentencing remarks constitute my reasons and explanation for the fine as required by legislation and step 9 of the Guidelines.

Costs

82 It is right that B & A make some contribution to the costs of the prosecution in bringing these proceedings. An appropriate figure, given the likely income available to B & A, is £40,000. I will hear submissions on the length of time that B & A will need to pay the fine of £120,000 and the costs of £40,000.

CONCLUSION

The first defendant, Valero Energy UK Limited, has pleaded guilty to two offences. For the reasons given, the defendant is ordered to pay a total fine of £5 million and to pay £1 million towards the prosecution's legal cost. The second defendant, B & A Contracts Ltd., has also pleaded guilty to two offences. It is ordered to pay a total fine of £120,000 and to pay £40,000 towards the prosecu

Glossary

%LEL and %LFL	Lower explosive limit, or lower flammable limit. The minimum fuel in air concentration capable of sustaining combustion
16F302	Fuel gas knock-out drum
17T302	Lean amine running (incident) tank
17T303	Slop amine tank (sister tank to 17T302)
Aliphatic hydrocarbons	Compounds whose molecules are composed of chains of carbon atoms
Amine sump	A concrete pit into which waste amine can be transferred prior to disposal, or fresh amine concentrate made up prior to addition to the circulating flow
Aromatic hydrocarbons	Compounds whose molecules are composed of or include rings of carbon atoms – most commonly six carbon atoms joined in a ring form
Boiling point	The temperature at which a liquid vaporises at such a rate that bubbles of vapour form within the liquid mass
Boot	A small, round-bottomed cylindrical sump attached to a much larger vessel into which small quantities of liquid and contaminates can drain prior to removal from the vessel
Chalwyn valve	If this valve is attached to a diesel engine air intake system, it will shut down the engine if vapours or gasses are drawn into the engine through the air intake
Flammable atmosphere	A mixture of fuel vapour in air that is capable of burning when ignited
Flashpoint	The minimum temperature at which a liquid produces sufficient vapour that instantaneous ignition occurs at the surface. Burning is not sustained
Headspace or ullage	The volume of space inside a tank or vessel, situated above the liquid stored within
Hierarchy of control	A systematic approach to the management of safety, where risks are reduced to the lowest reasonably practicable level by implementing preventative measures, in the order of efficacy, specifically elimination, substitution, engineering controls, administrative controls and, last of all, personal protective equipment
Hydrocarbons	Compounds composed entirely of hydrogen and carbon atoms. These include many important naturally occurring fuels such as methane, propane, butane, petroleum and other oils
Intelligent customer	The capability of an organisation to understand where and when work is needed; specify what needs to be done; understand and set suitable standards; supervise and control the work; and review, evaluate and accept the work carried out on its behalf
Liquified petroleum gas (LPG)	A compressed gas that consists of flammable hydrocarbons, such as propane or butane

Pyrophoric	A substance that on exposure to air ignites spontaneously
Regeneration column	A distillation column in which rich amine is heated in the presence of steam to release H_2S and thus be regenerated to lean amine, which is circulated for re-use in the refinery H_2S adsorption systems
Rich amine	Diethanolamine rich in hydrogen sulphide (around 2%) returning to the amine regeneration unit to be recycled
Sentencing guidelines	New sentencing guidelines proposed for health and safety offences, published by the Sentencing Council
Spark arrestor	A device that stops flammable debris being emitted from an engine exhaust
Surge drum	Tank where rich amine returns to the ARU from the plant for regeneration. Hydrocarbons are separated from the amine in this drum
UEL and UFL	Upper explosive limit, or upper flammable limit. The maximum fuel in air concentration capable of sustaining combustion
Vacuum tanker	A road tanker fitted with a powerful pump, that can be used to load into the tanker barrel by creating a vacuum inside the tank and sucking up liquids and sludge. Alternatively, the pump can be used to create internal pressure in the tanker and any liquid of sludge inside can be discharged

References

The Control of Major Accident Hazards Regulations (COMAH) 2015: Guidance on Regulations L111 (Third edition) HSE Books 2015
www.hse.gov.uk/pubns/books/L111.htm

Dangerous Substances and Explosive Atmospheres Regulations 2002. Approved Code of Practice and Guidance L138 (Second edition) HSE Books 2013
www.hse.gov.uk/pubns/books/L138.htm

Guidance on permit-to-work systems: A guide for the petroleum, chemical and allied industries HSG250 HSE Books 1999
www.hse.gov.uk/pubns/books/hsg250.htm

Reducing error and influencing behaviour HSG48 (Second edition) HSE Books 1999
www.hse.gov.uk/pubns/books/hsg48.htm

Developing process safety indicators: A step-by-step guide for chemical and major hazard industries HSG254 HSE Books 2006
www.hse.gov.uk/pubns/books/hsg254.htm

Managing for health and safety HSG65 (Third edition) HSE Books 2013
www.hse.gov.uk/pubns/books/hsg65.htm

Leadership for the major hazard industries: Effective health and safety management INDG277(rev1) HSE Books 2004
www.hse.gov.uk/pubns/indg277.htm

Leading health and safety at work: Actions for directors, board members, business owners and organisations of all sizes INDG417(rev1) HSE Books 2013
www.hse.gov.uk/pubns/indg417.htm

PSLG Principles of Process Safety Leadership HSE 2009
https://www.hse.gov.uk/comah/buncefield/pslgprinciples.pdf

Model Code of Safe Practice Part 16: *Guidance on Tank Cleaning* (Fourth edition) Energy Institute 2017 ISBN 978 0 85293 831 6

Model Code of Safe Practice Part 15: *Area classification for installations handling flammable fluids* (Fourth edition) Energy Institute 2015 ISBN 978 0 85293 717 4

BS EN 60079-10-1:2015 *Explosive atmospheres. Classification of areas. Explosive gas atmospheres*, British Standards Institution

API STD 2015 *Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks* 2018 American Petroleum Institute

API RP 2219 *Safe Operation of Vacuum Trucks Handling Flammable and Combustible Liquids in Petroleum Service* 2016 American Petroleum Institute

Developing and maintaining staff competence Railway safety publication 1, Office of Rail and Road 2016 https://orr.gov.uk/__data/assets/pdf_file/0016/4264/developing-and-maintaining-staff-competence-rsp1.pdf

Licensee Core Safety and Intelligent Customer Capabilities Office for Nuclear Regulation 2019 http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-049.pdf

This publication is available at www.hse.gov.uk/comah/