Loss Prevention Bulletin

Improving process safety by sharing experience

Issue 306, December 2025

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Information for authors and readers

Loss Prevention Bulletin

Helping us to help others

- The *Loss Prevention Bulletin* (*LPB*) aims to improve safety through the sharing of information. In this respect, it shares many of the same objectives as the Responsible Care programme particularly in its openness to communication on safety issues
- To achieve our aims, we rely on contributions providing details of safety incidents. This information can be published without naming an affiliated author, and details of the plant and location can be anonymised if wished, since we believe it is important that lessons can be learned and shared without embarrassment or recrimination.
- Articles published in LPB are essentially practical relating to all aspects of safety and loss prevention. We particularly encourage case studies that describe incidents and the lessons that can be drawn from them.
- Articles are usually up to 2500 words in length. However we are also interested in accepting accident reports to be written up into articles by members of the Editorial Panel. Drawing and photographs are welcome. Drawings should be clear, but are usually re-drawn before printing. Any material provided can be returned if requested. For further information, see https://www.icheme.org/knowledge/loss-prevention-bulletin/submit-material/
- Correspondence on issues raised by LPB articles is particularly welcome, and should be addressed to the editor at:

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Coming up in future issues of *lpb*

We are especially interested in publishing case studies of incidents related to:

- Organisation structure & process safety
- Emergency planning & response
- Ageing plant
- Lessons from other industries
- Management of Change
- Hazardous waste
- Hidden hazards
- Transfer of hazardous materials
- Electrostatic hazards
- Energy

If you can help on these or any other topic, or you would like to discuss your ideas further, please contact the editor.

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Loss Prevention Bulletin

Articles and case studies from around the world

Issue 306, December 2025

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Editorial

The Buncefield legacy — are we safer today?

During the night of Saturday to Sunday, 10-11 December 2005 a storage tank overflowed releasing over 250 000 litres of petrol. A vapour cloud formed then ignited causing a massive explosion and a fire that burned for five days. Pollutants from fuel and firefighting liquids leaked from the tank bund, flowed off site and entered the groundwater. Over 40 people were injured.

Failures of design and maintenance in both overfill protection and liquid containment systems were the technical causes of the incident. Keeping the process operating was the primary focus and process safety did not get the attention, resources or priority that it required.

The final HSE report is clear and hard-hitting and should be required reading for all senior managers of high hazards installations: https://www.icheme.org/media/10706/buncefield-report.pdf

In this Buncefield 20th Anniversary Special Issue of LPB, we revisit some of the key issues relating to the incident:

- Roy Wilshire, His Majesty's Inspector of Fire & Rescue Services, talks about the emergency response.
- Ken Rivers discusses process safety leadership and regulatory collaboration
- Ramin Abhari's short graphic novel re-tells the story of the Buncefield explosion.
- Mark Hailwood describes Germany's reaction to Buncefield.
- Ken Patterson outlines the evolution of CDOIF and environmental risk assessment
- Wayne Vernon describes the HSE operation.

You don't have to work in fuel distribution to find value in this issue of *LPB*. Ask yourself these seven questions:

1. Do you have a clear understanding of your major accident risks and the safety critical elements designed to control them? What about your procurement department, suppliers and contractors? What about board-level senior management?
2. What is your safety critical equipment? How do you detect problems? How effectively do you respond to them? How do you prevent temporary fixes masking the danger signals?
3. How effective is your auditing in identifying the gaps between management intent and custom and practice?
4. If you supply equipment do you understand your responsibilities? TAV were prosecuted and fined by the HSE.
5. If you maintain equipment do you understand your responsibilities? Motherwell were prosecuted and fined by the HSE.
6. How robust is your management of change process?
7. Do your staff have capacity, time and resources for safe operation?

So, are we safer today, twenty years on? In his barnstorming Trevor Kletz memorial lecture at Hazards 35, Ken Rivers warned against being fooled by appearances (the sky is blue, the grass is green...) and urged leaders to maintain a sense of *chronic unease* – a mindset that goes beyond compliance. At the same conference, Gus Carroll reminded us how fast the landscape is changing, with traditional industries in decline and new sectors emerging (hydrogen, carbon capture, modular nuclear reactors, batteries, biofuels).
The fundamentals remain unchanged — process safety depends on a realistic assessment of hazard, a vigilant approach to controls and an honest assessment of risk.

Leadership is not about what you say; it's all about what you do. People care about what their leaders care about. Read the HSE report. Ask some open questions. Set an example today.

Fiona Macleod
Chair, LPB
Editorial Panel

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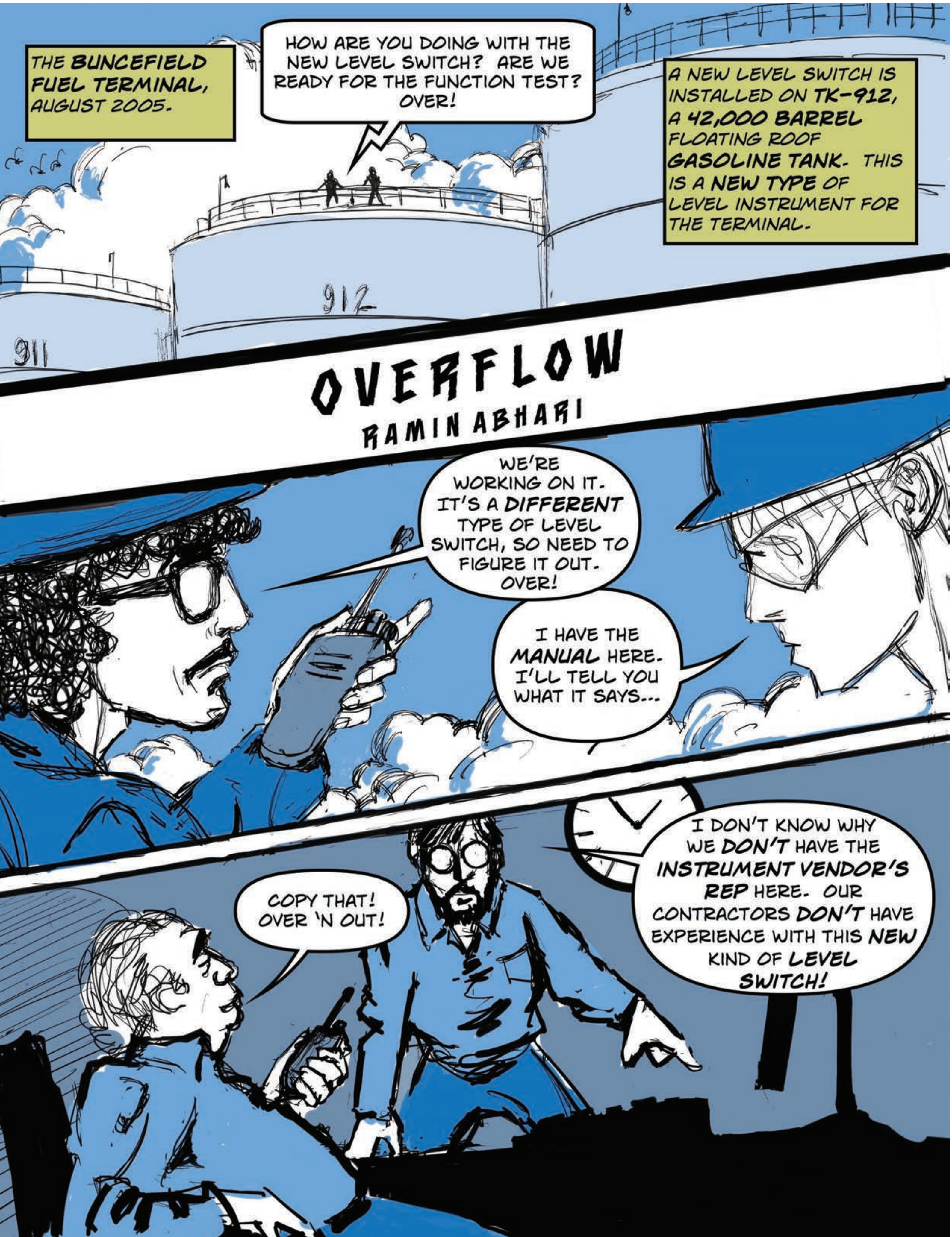
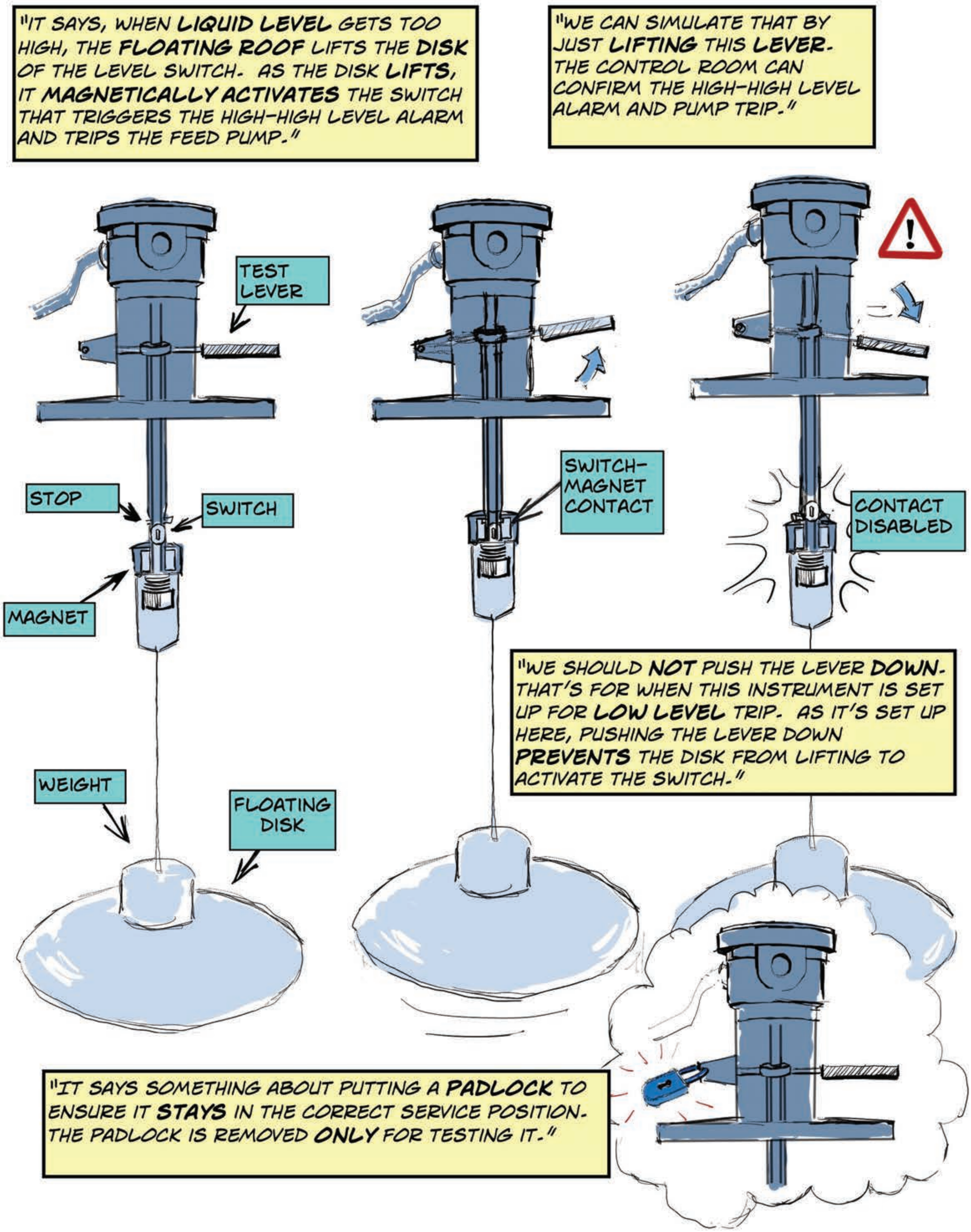

THE BUNCEFIELD FUEL TERMINAL, AUGUST 2005.
HOW ARE YOU DOING WITH THE NEW LEVEL SWITCH? ARE WE READY FOR THE FUNCTION TEST? OVER!
A NEW LEVEL SWITCH IS INSTALLED ON TK-912, A 42,000 BARREL FLOATING ROOF GASOLINE TANK. THIS IS A NEW TYPE OF LEVEL INSTRUMENT FOR THE TERMINAL.
912
911
OVERFLOW
RAMIN ABHARI
WE'RE WORKING ON IT. IT'S A DIFFERENT TYPE OF LEVEL SWITCH, SO NEED TO FIGURE IT OUT. OVER!
I HAVE THE MANUAL HERE. I'LL TELL YOU WHAT IT SAYS...
I DON'T KNOW WHY WE DON'T HAVE THE INSTRUMENT VENDOR'S REP HERE. OUR CONTRACTORS DON'T HAVE EXPERIENCE WITH THIS NEW KIND OF LEVEL SWITCH!
COPY THAT! OVER 'N OUT!



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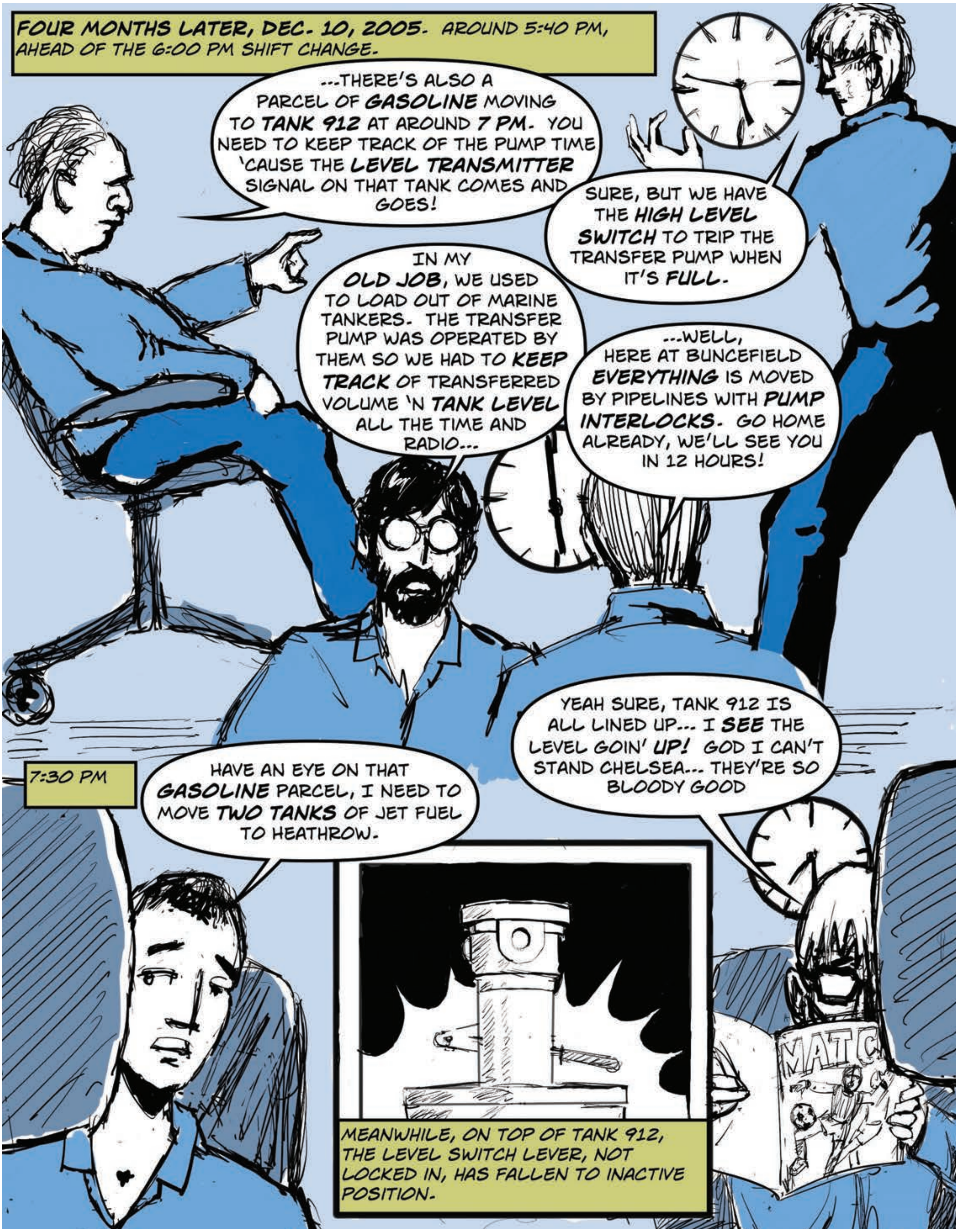
WE DIDN'T BRING A PADLOCK! ANYWAY, DOES THIS MEAN EACH TIME WE TEST THE LEVEL SWITCH WE HAVE TO UNLOCK A PADLOCK WITH ALL THE "LOCK OUT TAG OUT" PAPERWORK?
WE DON'T NEED IT FOR THE HIGH LEVEL TRIP FUNCTION TEST. WE'LL TELL THE TERMINAL MAINTENANCE MANGER ABOUT IT AND THEY CAN FOLLOW UP WITH THE VENDOR.
COME IN CONTROL ROOM. HIGH-HIGH LEVEL SWITCH ACTUATED FOR TK-912. COMMUNICATE RESPONSE! OVER.
EEEEE...
HIGH-HIGH LEVEL ALARM AUDIBLE AND PUMP TRIP CONFIRMED, OVER.



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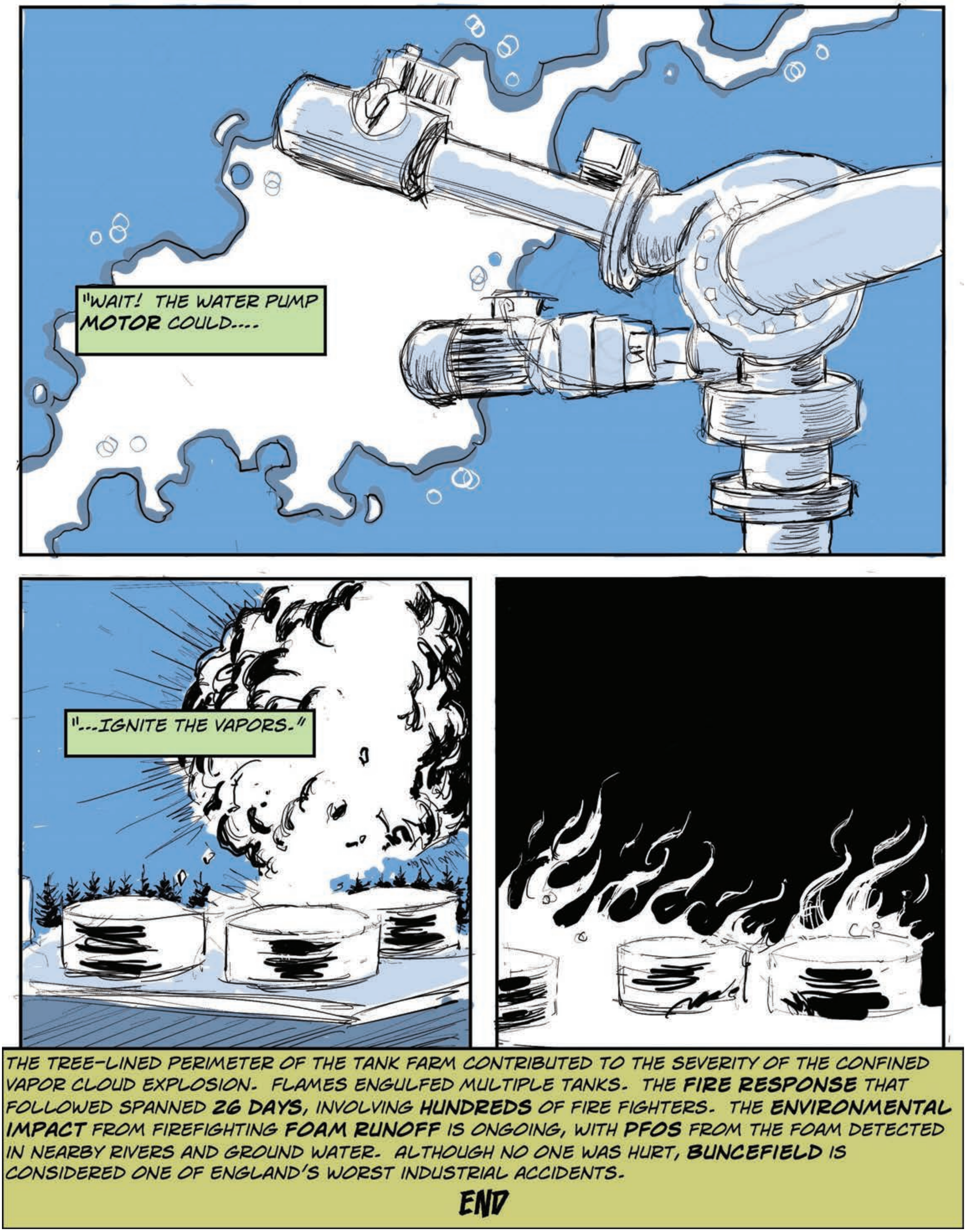

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Buncefield response

Reflections on Buncefield – twenty years on

HMI Roy Wilsher, His Majesty's Inspector of Fire & Rescue Services

Twenty years since one of the largest incidents of my career, one of the largest fires of its kind in peacetime Europe, I feel fortunate to still be heavily involved in fire and rescue services as one of His Majesty's Inspectors of Constabulary and Fire & Rescue Services (HMICFRS). I was asked to reflect on the Buncefield incident, particularly the operational aspects, but I have also taken the opportunity to reflect on the wider impact.

2005 was a defining year for me and for the fire service. It was the year we lost firefighters Jeff Wornham and Michael Miller, along with resident Natalie Close at the Harrow Court high rise fire. It was the year of the 7/7 London bombings and the year the capital, my home city, was awarded the Olympics. It was the year I was promoted to Chief Fire Officer at Hertfordshire Fire and Rescue Service and it was also the year of Buncefield. This article will concentrate on the Buncefield incident, the impact, and what has changed, or not, twenty years later.

The events at Buncefield attracted international attention for years. There was a time when a day wouldn't go by without someone in the fire service mentioning Buncefield, but time has passed and many firefighters who joined after the fire will now be halfway through their careers. Still, the lessons identified remain relevant and it is reassuring that some of the lessons were learnt, and positive changes made as a result.

For those not familiar with fire and rescue service operations, it is important to set the context of those operations in 2005.

- It was a time before the complete roll out of the New Dimensions project (hi-volume pumps (HVPs), mass decontamination, urban search and rescue etc).
- It was a time before the National Co-ordination and Advisory Framework (NCAF, now on its 6th edition).
- There was an interim National Co-ordination Centre in West Yorkshire Fire and Rescue Service and the Fire Emergency Information Centre (FEIC, an innovation for the 2002/3 national strikes and forerunner of the Emergency Room) although it didn't replicate the current National Resilience Fire Control located in Merseyside.
- Her Majesty's Fire Service Inspectorate was being wound down, although fire service inspections became part of what is now HMICFRS in 2018.
- The position of Chief Fire and Rescue Adviser did not exist, and after a few years and two postholders, the position no longer exists.
- The Joint Emergency Services Interoperability Programme (JESIP) was years away.
- Fire policy was with the Office of the Deputy Prime Minister. It is now back with the Ministry of Housing Communities and Local Government (MHCLG) having spent a few years back in the Home Office.

I won't dwell too long on the sequence of events on Sunday 11th December 2005, the cause is well documented, but it is worth a brief recap from a fire service perspective. The explosion that occurred at just after 0600 on the Sunday morning engulfed twenty tanks across seven bunds, later spreading to just two more tanks as fire service action was taken to reduce spread.

As Hertfordshire's Chief Fire Officer, I knew phone calls in the early hours were never good news. I was woken a few minutes after the explosion by a phone call and the words "guvnor, Buncefield's alight". I rang my Deputy Chief Fire Officer, Mark Yates[1], and agreed he would head to the depot and establish Fire Tactical (Silver) command on or near the site whilst I would make my way to Strategic Co-ordination Group (Gold) at Hertfordshire Police HQ, Welwyn Garden City, some 12 miles from the scene.

The fires created a massive smoke plume that rose several thousand feet and by mid-afternoon had blocked the sunlight to central London. The fire control rooms in Hertfordshire and adjoining services received hundreds of 999 calls as the explosion was heard across many counties and measured 2.4 on the Richter scale. It is interesting to note that when Buncefield was constructed in 1968 it was two miles from the nearest building, but by 2005 commercial buildings had been constructed right up to Buncefield's boundary.

The first fire crews in attendance were confronted by unprecedented destruction covering several square kilometres. The destruction meant that two of the three emergency water suppliers on site were inaccessible, firefighting water was eventually pumped from a balancing tank 1.8km from the site using multiple Hi-volume pumps for the first time. The incident had to be dealt with in phases; first the area was divided into four quadrants to commence search and rescue, meanwhile a three-storey office complex adjacent to the depot was well alight and required eight fire engines and one high-reach vehicle to bring it under control.

I must commend the response of all those involved, including 31 fire and rescue services, police, ambulance, oil industry firefighters and specialists, local and County Council, voluntary sector, and companies such as Angus and Tesco. Everyone played their part magnificently. The expertise provided by the specialist teams was invaluable, including advice from Niall Ramsden who appeared at Gold early on and told me about his experience in fighting these types of fire. I asked him to join my Deputy, Mark Yates, at Silver and add his expertise to the plans being developed to tackle the blaze.

The significance of the event cannot be underestimated. Gold remained in place for five days and teams continued to work on site until January 2006, having been left in charge of safety over Christmas. In successfully extinguishing one

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systems and procedures

human factors

culture

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of the largest fires of its kind in Europe and co-ordinating the multi-service response, Hertfordshire Fire and Rescue Service clocked up some significant statistics:

- 786,000 litres of foam concentrate was used to extinguish the fire and maintain foam blankets, following an estimation that 250,000 litres would be used. The original plan had to be revised after the Environment Agency raised concerns about groundwater contamination, as the whole area sits on chalk aquifers.
- Both 'clean' and recycled water was used to extinguish the fire and maintain cooling water jets, 53 million litres of clean water and 15 million litres of recycled water were used. In addition, 10 million litres of contaminated water was held on site and only removed in February 2006 under the direction of the Environment Agency.
- There were 642 fire appliance movements to Buncefield; 86% of these were by Hertfordshire Fire and Rescue Service.
- Hertfordshire Fire and Rescue Service also supplied over 90% of the personnel who attended.

The foam concentrate was to become a significant issue both during and after the incident as claims of contamination became a concern. One thing we knew at the time was, once we started attacking the fire by smothering, we had to maintain the foam flow to maintain the foam blankets and avoid re-ignition. This is why the foam attack on the depot fires didn't start until 0822 on Monday morning, 12th December. As the foam attack continued, the manufacturer was producing foam concentrate to order and for this to continue, we had to get a tanker of raw material diverted from Rotterdam to Tilbury to keep production going. We also discovered later that fire services had delivered old PFOS concentrate at Buncefield which later led to fears of ground contamination.

The foam attack and firefighting effort was hampered during the early hours of 13th December when a tank suffered a structural failure resulting in a running fuel fire, posing a significant threat to firefighters and other tanks that were being kept cool by covering water jets. But fortunately, this fire was soon brought under control and all but two tanks were extinguished by Tuesday evening, though bund fires and one tank (tank 912) were still alight. The last fire was extinguished by Wednesday afternoon, 14th December, a lot earlier than many had predicted or expected.

The response to the Buncefield incident was a multi-agency and national response that worked extremely well. Hertfordshire Resilience Forum was well established with a long history as the Hertfordshire Emergency Services Major Incident Committee with well-rehearsed and established procedures. With these procedures in place, it meant that my decision to go to Gold and Mark to Silver was an easy one. It is what we had always planned for, should such an event unfold. But Gold is not just about being at the Strategic Coordinating Group table making decisions, it is about the work within your own agency and with other agencies outside the formal SCG meetings.

Gold command worked well, I worked in tandem with the police chair, Assistant Chief Constable Simon Parr at the formal Gold meetings and outside. This means planning and reporting to ensure the strategic decisions are taken forward

Chiltern Air Support

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and implemented. And even more so now than 20 years ago, it is about reporting to government so there is a common recognised information picture. Simon Parr and I also visited the site during the first 24 hours; as any fire commander will tell you, you need a picture of the incident in your mind. It is very difficult to command a fire attack from a room or back of a control unit if you don't have that understanding of what the firefighters are facing on the ground.

A good example of working at Gold outside the formal SCG were the meetings between myself, the police force and Environment Agency that worked through the detail of the fire attack plan, and the EA's request to change the plan. Another aspect of the command structure was that Hertfordshire Police established their Silver at Watford Police station, with multi-agency partners and a fire liaison also located there, probably referred to as a Tactical Co-ordinating Group today. This way of working with Silver command at the scene and Police Tactical being remote is still with us and is why JESIP developed the term 'On-scene Commander' and introduced Police command tabards supporting the concepts of co-location, communication and co-ordination through shared situational awareness with the use of the Joint Decision Making Model and METHANE (Major Incident, Exact location, Type of incident, Hazards, Access, Number of casualties, Emergency services) model of communication.

The response was national for the fire and rescue service, but the New Dimension project (now known as FRS National Resilience) had not been completed. There was an interim National Co-ordinating Centre (NCC) in West Yorkshire, urban search and rescue and incident response units (mass decontamination) had been rolled out, but HVPs had just been delivered to services and local training was not complete. Those HVPS are still in use today, although the New Dimensions 2 programme means their replacement is planned. There was no National Coordination and Advisory Framework (NCAF), National Strategic Advisers (NSATs) National Resilience Advisers (NRATs), Tactical Advisers, Enhanced Logistics Support (ELS) and many of the other supporting functions we now take for granted. Fortunately, there was a Hertfordshire Officer working in the New Dimensions project team, Gordon MacMillan, who was able to advise me on what was possible – an NRAT in today's parlance. He advised me about the capabilities of NCC, and we were able to mobilise HVPs, along with the national HVP trainers, subject matter experts, who would now be called TacAds – this set up supplied the water for the fire attack plan and water recycling. I knew that significant resources had to be gathered and marshalled, so the old M10 (now the A414) was used as a rendezvous point with a logistics officer and marshalling officer; a forerunner of a strategic holding area and ELS officer still detailed in NCAF and supporting guidance today.

The impact of the explosion was significant financially, politically and economically:

- Ninety businesses were directly impacted (sixteen of which moved out of the area, some out of the UK completely, impacted by severe under insurance).
- By the end of 2007, there were over 1000 Buncefield related redundancies.
- There were 244 Buncefield related visits to accident and emergency.
- 76% of residents in the local area reported damage to property.
- Remarkably, even though there were seven staff and drivers on site at the time of the explosion, thankfully no one was killed.
- 2000 people were evacuated and 60 children aged between five and 14 had Buncefield-related counselling for up to two years.
- The local population also reported high levels of anxiety and demonstrated severe stress for years afterwards.

Some of the greatest impacts were on aviation as Buncefield supplied approximately 35-40% of the aviation fuel for Heathrow:

- The smoke plume delayed flights for four days, with long haul flights having to stop in Europe to re-fuel, putting 90 minutes on a flight to Sydney. For example, South African Airlines would top up fuel in Milan.

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- 83 airlines were affected with a cumulative 480 days of disruption costing an estimated £245 million.
- Various other costs mounted up to over £1 billion for compensation, demolition and rebuilding fines, road re-surfacing and environmental protection brought the total known cost of the incident to well over £1 billion.
- There was also the uncosted impact of 200+ schools closed for two days.
- The closures of the M1 and M10.
- The unseen impact on the data infrastructure housed at Buncefield. The data and digital services impacted included outsourced payroll, London congestion charge admin, medical records, the Police National Computer and benefit payments.

No one can be in any doubt that this was a major incident with a significant impact.

The response to this incident was national for all fire and rescue services. One consequence of these actions including the debriefs and reviews, the lessons identified, and recommendations made to the Lord Newton Inquiry, along with similar learning after the 2007 floods, was the development of the National Coordination and Advisory Framework (NCAF) and the way the fire and rescue service now co-ordinates national resilience and its response to major incidents.

This time of reflection also enabled me to look back on the thirty recommendations made by Hertfordshire Fire and Rescue Service, all of which were adopted by Lord Newton within the 'Emergency preparedness for, response to and recovery from incidents' section. Those recommendations included a national system for mobilising assets, such as the Fire and Rescue Service National Co-ordination Centre, FRSNCC, now the National Resilience Fire Control, Strategic Holding Areas with suitable facilities, incident command support teams (ELS), tactical advisers for all national defence assets, a national system for hot debriefs, large hose ramps and national welfare arrangements. National and Joint Operational Learning, JESIP and National Operational Guidance all have links back to 2005 and 2007 and laid the foundations of what we have today.

There were also one or two wider recommendations that have been implemented to a greater or lesser degree or not at all — for example, nationally funded and provided foam concentrate resources and delivery mechanisms and complete guidance for the establishment of a health advisory cell at a Strategic Coordinating Group. It is also interesting to note that one of Hertfordshire's recommendations was that all fire and rescue services should work to the Incident Command manual at the time. This was an issue ten years after Buncefield but has been resolved today by National Operational Guidance, a project I was proud to have launched as the Chief Fire Officers' Association Operations Director. The recommendations also covered the issue of self-deployment. One particular fire and rescue service self-deployed a significant resource to Buncefield and set up outside command, communication and health and safety structures until brought into line. Something that is just as relevant now — proper ordering and mobilisation is required, especially with the increased threats we face.

I haven't covered every aspect or anecdote from Buncefield and its aftermath, it would take too long; but it is amazing to think it has been twenty years since the incident. Many of the things we learnt there, combined with learning from other major incidents have formed recommendations and procedures that have been developed and implemented to what we have in place today.

I strongly believe the structures, processes and training for major and catastrophic events across fire and partner agencies are much improved. Nevertheless, as we face greater threats such as climate change and wildfires and an unstable world, it would be wrong to not say I'm not concerned about the resources available. In 2005, Hertfordshire had five operational principal officers to maintain the Gold rota. There are fewer now and I know across other services, resources have reduced. We also have fewer firefighters than we had in 2005 as demand on emergency service colleagues in police and ambulance also continues to grow.

However, I remain confident that with the developments since Buncefield and greater focus since the awful and tragic Manchester MEN arena attack, the country can respond in a co-ordinated multi- agency response to a significant incident, but only if that multi-agency training, including JESIP training takes place. Training and operational response remain as important as ever to tackle any major multi-agency incident.

Endnote

[1] *Sadly, Mark passed away in September after a short illness. Mark was my Deputy for five years, we started together as Chief and Deputy Chief Fire Officer in April 2005 and went through a lot in those 5 years. Mark went on to be Chief Fire Officer of Hereford and Worcester Fire and Rescue Service and latterly chair of Herefordshire and Worcestershire Health and Care Trust. He is survived by his wife and daughter and will be missed.*

Acronyms

EA	Environment Agency
ELS	Enhanced Logistics Support
FEIC	Fire Emergency Information Centre
FRSNCC	Fire and Rescue Service National Co-ordination Centre
HVP	Hi-Volume Pump
JESIP	Joint Emergency Services Interoperability Programme
METHANE	Major Incident, Exact location, Type of incident, Hazards, Access, Number of casualties, Emergency services
MHCLG	Ministry of Housing Communities and Local Government
NCAF	National Co-ordination and Advisory Framework
NCC	National Co-ordinating Centre
NCAF	National Coordination and Advisory Framework
NSAT	National Strategic Advisor
NRAT	National Resilience Advisor
SCG	Strategic Co-ordination Group

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Buncefield response

"Aligned but not joined"

Ken Rivers

"How industry responds to incidents such as Buncefield and how the regulators respond on behalf of the public is a measure of our society. A decisive and dynamic response with all parties co-operating is the product of a democratic and advanced society."

Buncefield Standard Task Group, 24th July 2007

Chiltern Air Support

Buncefield was a profound shock. It was a shock to the industry, it was a shock to the regulator and most importantly a shock to the public. No one expected that the overfilling of a storage tank containing petrol could lead to the largest explosion in Europe since the Second World War.

Buncefield has led to profound changes not just in the operational, technical and regulatory aspects of managing major hazards but also in leadership, and the way industry and regulator work together in the UK.

A Major Incident Investigation Board (MIIB) was set up to identify what went wrong, but it took time as much of the evidence had been destroyed. In the meantime, pressure was mounting on all parties to do something. The whole credibility of the industry and the regulatory regime was under fire. We were all in the same boat, all our reputations were on the line and the usual tennis match was not going to give us the answer. Up until then, developments progressed with one party proposing change which would be rebuffed with counter proposals from the other side. Solutions and ideas were battered backwards and forwards across the net to try to "win the point". Buncefield put an end to that.

I am proud of the way the leaders at the time stood up to the challenge. Industry and regulator all shared the view that a Buncefield incident must never happen again. We recognised that by pooling our knowledge, experience and insights, we could deliver better, more effective, more efficient and more timely solutions. And that whilst we might not know what had gone wrong at Buncefield (and there was a commission working on that), we had a clear understanding of what needed to succeed, which enabled us to act swiftly and collaboratively—driving prompt, meaningful change through the Buncefield Standard Task Group

We formulated a new mindset of "aligned but not joined" which recognised that regulator and regulated shared a common goal of preventing major incidents and that it was through open, frank discussion and sharing our different perspectives that we could best achieve that goal. We recognised that we needed more consistent responses to broadly similar risks. Delivery was an essential part of the trust upon which this approach depended and focussed our minds to "say what we do" and "do what we say". Recommendations were translated into real actions. It led industry to becoming more self-disciplined, taking ownership, and it led to a more mature and collaborative relationship with the regulator. It led to leaders across organisations stepping up and holding themselves to account.

The success in working together to identify, develop and deliver real change was subsequently continued and built on by the Process Safety Leadership Group (PSLG) which ensured the effective implementation of the MIIB's wide-ranging safety recommendations. The incidents at Buncefield — and also at Texas City — highlighted and re-emphasised the critical importance of leadership in preventing major incidents. The PSLG went on to define what good leadership in managing major hazards looks like. That work on leadership published in 2009 has had a resounding impact on the UK on-shore process industries and is now embedded in the regulatory framework. It was subsequently embraced by the Offshore Energy Sector and has had a similar impact.

The result from Buncefield of industry and regulator working together has generated better outcomes and a safer environment which in turn builds trust and credibility and creates a virtuous spiral, which manifests itself today in the COMAH Strategic Forum (CSF). The Forum established in 2013 brings industry and regulators together to identify and address matters of strategic importance in the management of major hazards in the UK.

Over the last twelve years, it has helped shape the Better Regulation review into major hazard legislation as well as ensuring the seamless introduction of Seveso III changes. It has gone on to agree a strategic vision which includes creating a thriving safe and sustainable sector with a regulatory regime that supports business growth, high standards and strong compliance. And has identified and is addressing the major challenges to achieving those objectives. One of the key challenges has been "to make good practice into common practice" and CSF has seen leadership and outreach to those currently unengaged as critical. CSF is providing a platform and framework within which the various bodies involved in managing major hazards in the UK can coherently interact. Practical problems can be nipped in the bud and longer term strategic imperatives can be identified and addressed together. CSF's agenda continues to evolve in the face of climate change

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adaptation, net zero, cyber security etc.

Buncefield was a profound shock and it prompted profound change .Buncefield was a defining moment for major hazard regulation. It led to the principles of process safety leadership which have been game changing. The impact of Buncefield remains with us today continuing to stimulate industry and regulator to work together to protect people and places.

When industry works together, when regulators work together and then when industry and regulators work together then transformational change can happen and that is what Buncefield delivered.

Buncefield is a lesson for other sectors too on how to grasp the learning from a major incident and secure a safe and sustainable future.

And for those of us involved in the major hazard sector, I offer a closing & encouraging thought from my time in New Zealand .....

Kua tawhiti ke to haerenga mai , Kia kore e haere tonu
He tino nui rawa ou mahi , kia kore e hmahi nui tonu

We have come too far not to go further.
We have done too much, not to do more...

About the author

Ken is a non-executive director of the Health and Safety Executive and a past President of the Institution of Chemical Engineers. He is also a member of the Industry Safety Steering Group (ISSG) monitoring the progress made by the built environment towards achieving culture change following the Grenfell Tower fire. Ken is a former chair of the Control of Major Accident Hazards (COMAH) Strategic Forum.

Ken's background is in the oil industry. He is a past President of the UK Petroleum Industry Association and chaired the industry/regulator task force in the wake of the Buncefield terminal explosion. He also chaired the government and industry task force, which considered ways of improving the resilience of oil product supplies following a government review.

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Safety practice

Buncefield failures aligned to the hierarchy of risk control

Andy Brazier, AB Risk Ltd, UK

Summary

This paper analyses the Buncefield explosion through an expanded hierarchy of risk control, emphasising that major accidents result from multiple failures rather than isolated errors. It categorises prevention and mitigation measures, highlighting inherent safety principles, engineered controls, and administrative practices. The study identifies deficiencies in design, maintenance, communication, and emergency planning that contributed to the incident, offering lessons for improving reliability, reducing complexity, and ensuring risks remain as low as reasonably practicable (ALARP).

Keywords: Buncefield, risk control, inherent safety, prevention, mitigation

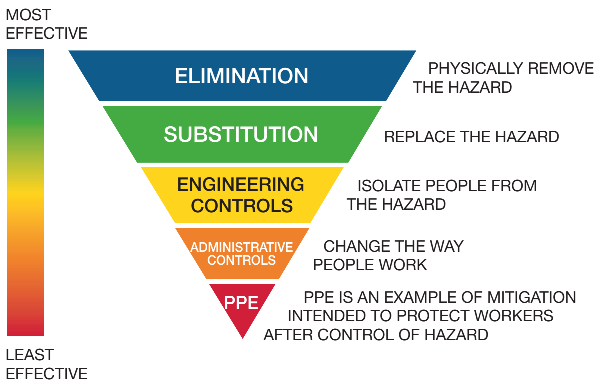

Figure 1 - Typical illustration of the hierarchy of risk control[2]

Introduction

The Buncefield explosion, like all major accidents, was not the result of a single failure. A combination of circumstances came together, leading to storage Tank 912 being overfilled with gasoline. A significant loss of containment created a flammable vapour cloud that found an ignition source beyond the depot boundary.

It is easy to focus on individual failures in the chain of events leading to an accident. At Buncefield, for instance, a faulty level switch meant an alarm did not sound and the automated pipeline shutdown did not function when the tank was overfilled. However, this does not explain why the tank was allowed to reach an overfilled state in the first place. Also, no risk control is ever completely reliable, so occasional failures must be anticipated.

The basis of safety for any hazardous operation should include multiple features that work together to reduce the risk to as low as reasonably practicable (ALARP). The hierarchy of risk controls as shown in Figure 1, identifies different options for controlling risk and indicates that some may be more effective than others[1].

The underlying principles of the hierarchy are well regarded but, in this form, the broad categories defined do not lend themselves to any detailed explanation of how features of a system work together to ensure safety or how failure results in accidents. However, developing it into a more detailed set of risk control types may make it a useful tool[3].

An example of an expanded hierarchy is shown in Attachment 1. It was developed by subdividing the existing categories and integrating concepts of inherent safety and identifying that some controls can be effective for both prevention and mitigation[3].

Prevention controls applicable to the Buncefield accident

Prevention risk controls should ensure a process stays within its safe limits and hazardous scenarios are avoided. For Buncefield, if Tank 912 had not been overfilled there would have been no release of gasoline and the accident would not have occurred.

This section summarises the prevention controls identified in the expanded hierarchy of risk control (see attachment A) when applied to Buncefield depot operations. In some cases, the control was in place and effective. However, in other cases there were deficiencies that allowed the accident to occur. This hindsight view of a past event may provide some foresight to allow others to avoid similar occurrences.

Inherently safer substance – without a hazard there is no risk. The sole purpose of the Buncefield depot was to store hydrocarbon fuels (gasoline, diesel and aviation fuel). Changing the substances would fundamentally change the business and would require customers to find alternative sources. Flammability was the main hazard of the substances being handled. It was beneficial that the Buncefield terminal was not handling substances with other hazards (e.g. toxic, corrosive, reactive).

Inherently safer quantities – a reduced hazard creates less risk. This would have required reducing the number and/or reducing the size of tanks at Buncefield. Managing

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systems and procedures
human factors

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Figure 2 – Pipeline network connecting Buncefield to refineries[4]

inventories without changing the tanks would be viewed as an administrative control, which appears lower in the hierarchy because the inherent storage capacity is not affected. Whilst the total inventory of the depot affected the duration of the subsequent fire and associated environmental impacts, the original release was determined by the flow rate from the pipeline and not the capacity of Tank 912. There is an argument to say that fewer and smaller tanks would increase the likelihood of overfill.

Inherently safer process – operating at ambient conditions minimises the energy to drive hazardous events. The Buncefield depot processes may be considered inherently safer than a system operated at high pressure or temperature, because the substances were stored at ambient conditions. However, the pipelines were at elevated pressures to create required flow rates. It may have been possible to reduce the pressures by adding intermediate pumping stations along the length of the pipeline. For risks to be ALARP the risk reduction from reducing pressure would have to be greater than the risk increased from introducing these extra pumping stations.

Inherently simple process – having few interconnected parts makes it easier to understand and predict how a process will perform. Buncefield was connected to three refineries by two pipelines (see Figure 2). The Finaline pipeline was a direct connection to the Lindsey and may have been considered inherently simple. However, the Thames-Mersey pipeline had several branches, connecting different sites and so was more complex.

The depot was divided into six sites based on ownership (see Figure 3). This introduced complexity for the human operators, which should have been recognised as a contributor to risk.

Using direct pipelines (like the Finaline) and operating the depot as a single site would have reduced complexity but may not have been commercially viable.

Inherently simple system – having few control and safety devices makes it easier to understand how it will react to situations. At the Buncefield depot the main control and safety concerns were tank level. The system may have been considered inherently simple.

Passive engineering (permanent) – suitability of the plant and equipment to contain the hazard. The leak at Buncefield was not the result of any plant or equipment, which was all fully rated for the full range of operating conditions. However, there was an inherent risk because the capacity of the tanks receiving product was limited whilst the pipelines supplying was essentially unlimited. Larger tanks may have reduced, but not eliminated, the potential for overfill. Supplying the depot from road or rail tankers would significantly reduce the likelihood and size of any potential spill but would introduce additional risks of transportation. Also, it would have had a significant environmental impact that had to be considered as part of the cost of changing arrangements when deciding if the risk is ALARP.

Passive engineering (temporary) – physical devices used to physically contain the hazard that are not always present. Valves were used to direct products to the correct tanks. On the day of the accident the quantity of product being delivered required the receiving tanks to be swapped by changing valve configuration. There were no technical failures of the valves and the overfill occurred because valve operations did not take place when required.

Active engineered controls – devices that operate automatically to prevent a hazard from creating a significant consequence. At Buncefield each tank had a high-level trip

Figure 3 – Buncefield depot divided into multiple sites[4]

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installed that would stop flow from pipelines when activated. Errors made during the maintenance of the associated level switch on Tank 912 meant the trip was not initiated. Flow from the pipeline continued until gasoline was released from the tank's overflow.

Active engineered with human action – an engineered control that relies on human actions. Highly Managed Alarms (HMA) may have been identified as an option at Buncefield. They are differentiated from 'normal' alarms and other administrative controls because they require a much more detailed assessment of system reliability taking into account the role of the human operator[3]. No HMA were present at Buncefield because the existing controls were considered sufficient. This is consistent with standards and guidance[5] that specify that HMA should be avoided wherever possible because automating critical actions with reliable systems is preferred to relying on a human response.

Administrative control with engineered support – humans keeping processes within safe parameters using data and controls provided by engineered systems. Flow and pressure of pipelines feeding Buncefield were controlled, but there was no feedback of tank level to the control system. Depot operators were required to monitor tank levels and react when required. However, there were many tanks but, whilst the control system graphics allowed all to be viewed, it did not provide an easy way of seeing them all at the same time. Operators had to select tanks to monitor. At the time of the accident, they were not aware that Tank 912 was being filled and so were not looking at the graphic that showed its level. The tank had a level gauge, but this was known to stick. Also, a high-level alarm that would have notified them of the overfill, but the error made when maintaining its level switch (see above) meant that this did not activate.

Administrative control – competent people performing tasks to keep the process within safe parameters. Operating procedures at the depot defined operating limits, including tank maximum fill levels, and configurations for import and export of product. These were well known and understood by the operators and the overfill was not the result of any deliberate deviation from safe working practices. However, procedures were focussed on individual operations and did not account for multiple operations being performed in parallel or make allowances for inherent complexities in arrangements (see above). Communication failures at shift handover meant the duty operators were confused about which tanks were being filled and meant that they were not monitoring Tank 912. Communication with the refinery and pipeline operators supplying the depot did not address these issues.

Personal health and safety control – minimising harm to personnel. The health and wellbeing of personnel working at Buncefield made no direct contribution to the accident.

Mitigation controls applicable to the Buncefield accident

Mitigation risk controls take effect after a hazardous scenario has occurred and are intended to minimise the consequences. For Buncefield, mitigation should have occurred immediately after Tank 912 was overfilled and escalated as soon as it started to overflow. The aim would have been to minimise the size of release and contain spilt product in a safe form.

This section summarises the mitigation controls identified in the expanded hierarchy of risk control (see attachment A) when applied to Buncefield depot operations.

Inherently safer location for people – knowing the hazardous extent of potential scenarios when deciding where people may work or live safely. The occupancy of the depot was normally low. However, the accident caused significant offsite damage to buildings that would have been occupied had it been a working day. Because tanks and pipework were located in open air it may have been assumed that an explosion like the one occurred was not possible. One learning was that features such as walls and hedges can influence the spread and overpressure a flame front, significantly increasing blast pressure.

Passive engineered item (permanent) – physical items that contain a hazard after initial control has been lost. All tanks at Buncefield were bunded to prevent spilt liquid from spreading. They were effective before the explosion, although subsequent damage contributed to the fire and associated environmental impact. However, another passive element of design was the roof vent on Tank 912. This was point where containment was lost. The arrangement of the vent led to the gasoline being vaporised and mixed with air to form a large, flammable cloud that was able to find an ignition source a significant distance from the tank.

Passive engineered item (temporary) – physical items that are not always present or have features that mean they are not always effective. None of these were relevant for the Buncefield accident.

Active engineered item – systems that act automatically when a hazard occurs to mitigate the consequences. There was no effective leak detection at Buncefield, so it was not possible to automate any shutdown or other mitigation when gasoline was released.

Active engineered item with human action – systems that prompt people to act when a hazard occurs. Because there was no leak detection the depot operators were not aware of the release until members of the public phoned to say there was a visible vapour cloud. However, even if they had known about the leak earlier they could not have stopped the supply to site directly because they did not have control of pipeline. They were reliant on the pipeline operators, who did not have visibility of the site. Stopping the flow quickly would have prevented the formation of the cloud or significantly reduced its size. This should have been considered into the arrangements for operating the depot and pipeline.

Administrative control with engineered support – action taken by a person that is initiated or supported by an engineered system. The Buncefield operators could have quickly and easily requested the pipeline to be shutdown at any time. They may have done this as soon as they realised the tank had been overfilled, before any product had been released. However, they were not aware of any problems until the hazardous vapour cloud had been formed.

Administrative control – emergency response procedures and practices enacted after a hazardous event to mitigate

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consequences. Once the vapour cloud had ignited, the main safety hazard had occurred and passed. The subsequent fire had significant environmental impacts but the risk to people was much less. An incident of this scale and nature had not been properly considered in emergency planning. This meant that issues, particularly fire water run-off, had not been properly considered in advance.

Personal health and safety control – protecting people from hazards. Given the scale of the accident the number of injuries experienced was relatively modest. There are very few options to protect people from an explosion like the one that occurred. However, there were many opportunities for people to be harmed during the subsequent firefighting operation. The products handled were non-toxic, and fire-fighting equipment, including breathing apparatus, was sufficient to protect personnel.

Conclusion

Applying an expanded version of the hierarchy of risk control has highlighted a number of factors related to the Buncefield accident that may be applicable more widely. The table below summarises some of the main ones.

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Potential learning	Buncefield relevance
Even when a business fundamentally relies on handling hazardous substances, it is important to ensure hazards are properly risk assessed. Also, to avoid introduction of and any supplementary or unnecessary substances.	The depot handled flammable fuels. There were no substances with other hazards (e.g. toxic, corrosive, reactive).
Complexity is often the result of commercial factors. Simplification is inherently safer, but if it is not possible, complexity has to be recognised as a risk that must be controlled.	Branching of the Thames-Mersey pipeline and division of the depot into multiple sites added complexity for the depot operators. The risks were not adequately addressed in the design of control system graphics or operating procedures.
Transferring products from a source with a large capacity into a receiver with smaller capacity introduces a significant risk of overfill.	The tanks at the depot had a fixed volume whilst the supply via pipelines was much greater. Overfill controls had to be much more reliable than may be required for other supply routes (e.g. road or rail tanker).
Reliability of active engineered controls relies on effective maintenance, inspection and testing.	The high-level switch on Tank 912 was left inoperable due to errors during maintenance. This meant the associated alarm and trip were unable to operate. The reason it was inoperable was that it was unreliable, which was unacceptable given its criticality for safety.
Control systems should have feedback loops from all critical plant parameters.	Pipelines had flow and pressure control, but no direct feedback from tank levels. The depot operators were responsible for managing tank levels.
Control system graphics should present data in a way that it is useful to the operator. It is not good enough to just make the data available.	There were graphic displays for each tank that showed level, but no overview display. Because the operators were not aware that Tank 912 was being filled, they were not actively looking at the data and it was hidden from view by other displays being monitored at the time.
A procedure describing a single task is less effective if multiple tasks are performed in parallel.	Procedures described how to conduct individual transfers from pipeline to tank, but operators were responsible for multiple transfers at any time.
Communication is an error prone activity. Shift handover is a particularly critical activity.	Depot operators were confused after shift handover and did not realise that Tank 912 was being filled. This meant they were not monitoring it. The poor control system interface and high-level alarm failure meant they were not aware until after the release occurred.
Low occupancy and open-air layouts may mean most releases do not result in significant harm but barriers like walls, off site features and populations can dominate the risk to people.	Industrial buildings near to the Buncefield site were very badly damaged. On another day many people were likely to have been serious injured or killed.
The route of a liquid from tank overflow to secondary containment bund can have a significant effect on hazard.	Gasoline being released from the overflow on Tank 912 was physically disturbed in a way that increased vaporisation and mixing with air. This had not been recognised in the design of the overflow.
Effective leak detection can allow interventions that may not prevent a release but can significantly reduce the consequences.	There was no leak detection. This meant there was no way of automating pipeline shutdown and no indications to the operators that a spill had occurred. The depot operators only knew that Tank 912 had been overfilled and gasoline was being released when members of the public phoned the control room.

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Attachment A – Proposed hierarchy with examples in hierarchical order[3]

Type	Examples – prevention	Examples – mitigation
Inherently safer substance	• Low hazard substances • Naturally low concentration of hazardous substance. • Stable form (e.g. solid not gas) • Naturally conspicuous hazard (odour, visible, detectable)	Not applicable
Inherently safer quantity	• Small fixed volume of hazard. Tanks, vessels, pipework (length/ diameter)	Not applicable
Inherently safer process	• Process sub-steps eliminated • Pressure / temperature near ambient at source (i.e. not achieved by a control system)	Not applicable
Inherently simple process	• Parameter changes have few and predictable outcomes	Not applicable
Inherently simple system	• Minimum of add on control /safety devices	Not applicable
Inherently safer location for people	Not applicable	• People located outside of the hazardous zone • Natural, permanent obstacle between hazard and people. • Natural ventilation prevents hazardous concentrations forming • Remotely operated or autonomous mechanised devices (robots in hazardous area)
Passive engineered item – permanent	• Pressure envelope rated for the full range of operating conditions possible – without joints. • Pressure envelope rated for the full range of operating conditions possible – with joints. • Bridge over road or rail track	• Created permanent obstacle between hazard and people. • Secondary containment with no breaches (double walled tanks) • Tertiary containment with no breaches (bunds, dykes) • Permanently installed passive fire protection
Passive engineered item – temporary	• Pressure envelope rated for the full range of operating conditions possible – using temporary connections (hose, loading arm) • Positive isolation (blank flange, spade) • Valve isolation • Physical obstacles that could be removed (machine guards, dust hoods, road barriers)	• Secondary containment with breaches (double walled tanks with drain valve) • Tertiary containment with breaches (bunds, dykes with drain valves)
Active engineered	• Physical obstacles deployed automatically (train level crossing) • Pressure safety valve / bursting disc • Hazard removal (local exhaust ventilation, after burner) • SIL rated safety instrumented function • Non SIL rated trip	• Automated blowdown • Automated active firefighting (deluge, water mist, water curtain) • Shutdown initiated automatically by fire and gas detection
Active engineered with human action	• Highly managed alarm	• Protective system alarms (fire, gas spill). • Manually operated active fire fighting • Decontamination devices (safety shower)
Administrative control with engineered support	• Tightly controlled process keeping hazard within boundaries (minimum gassing off, no over-spray) • Fixed physical device forcing an action (valve minimum stop, slow acting valve) • Active physical device forcing an action (Valve sequence fixed by key trap interlock) • Automated actions initiated by a human (Automated sequence via BPCS) • Automatic process control • Process alarm • Beacons, light-up signs triggered by a condition.	• Shutdown initiated manually • Exclusion zones around hazardous areas • Reaction quench / kill

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Type	Examples – prevention	Examples – mitigation
Administrative control	• High performance HMI for operator situational awareness • Created low concentration of hazardous substance. • Created conspicuous hazard (odour, visible, noise) • Hazard segregation • Defined operating limits (tank level, operating temperature / pressure). • Control of work procedure (permit to work) • Safety critical operating / maintenance procedure • Plant patrol with effective checklist • Competence management system • Operating / maintenance procedure • Signs and labelling • Communication supported by a relevant tool (shift handover with formal log, permit to work)	• Emergency response procedures • Emergency response practice (emergency exercises, desk top scenarios) • Emergency response training (classroom) • Reduced occupancy
Personal health and safety control	• Ergonomic design • Mechanical aids (avoid manual handling) • Personal monitors with alarms • Health screening • Hazard exposure surveillance	• Collective PPE (safety net) • PPE used routinely (safety glasses) • PPE used during emergency (escape BA)

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Buncefield – Reflections from a regulator

Wayne Vernon, Strategic ALARP, Australia

I got involved in the Health and Safety Executive's investigation into the causes of the Buncefield explosion when I provided holiday cover for the Principal Inspector leading the technical aspects of the work.

I knew that the part I had played in the investigation was a small one, but it was some years later that I found out just how small. I wanted to give the senior leadership of an Australian regulator I was working for at the time an idea of the resources needed to investigate a major incident of this scale, so I made a freedom of information request to the HSE to get the numbers.

I was one of 62 inspectors who, between us, spent almost thirty thousand person-days finding out what happened and obtaining evidence for subsequent prosecutions. Most of the inspectors spent months on the case; some worked on it for years. I was only there for a few weeks.

When I first arrived at the site, months after the explosion, the extent of the damage to the site and its surrounds was shocking. Nearby trees were stripped of branches, adjacent buildings had their external facades ripped away to reveal crumpled support structures. The devastation resembled a war zone.

During a casual chat with a predictive risk assessor who worked for what was then called the Health and Safety Laboratory, I mentioned that it was lucky no-one had been killed. He nonchalantly dismissed such an alarmist view by pointing out that the explosion could only have happened in the early hours of a winter's morning, so the zoning of the area as light industrial meant that it was unlikely anyone would be present in the event of an explosion.

Figure 2 – Damaged building near the Buncefield storage depot

My role in the investigation was to provide technical and operational oversight of the examination of the electrical and control systems used to manage the flow and storage of product in the tanks.

The site had originally been operated by a single organisation, so the control systems were designed accordingly. Over the years, sections of the process and equipment had been sold to different organisations, which meant the control loops sometime had sensors owned by one company, logic solvers by another, and the intervening cables by a third.

If it wasn't hard enough trying to trace cables and signals

FOI Request for Information on the Buncefield Explosion Investigation.

HID – to end of May 08

	No.	Days spent 05/07	Days Spent 07/08	Days Spent 08/09	Total Days
No. of Inspectors (inc HSE Technical Specialists	62	28,123.09	591.04	114.70	28,828.83
No. of Admin	7	568.32	41.52	5.00	614.84
No. HSE Managers	2	191.00	161.00	25.00	377.00
				Grand Total	**29,820.67**

*** The investigation has been very complex. We are confident that these are the best figures we can obtain at this stage.**

Figure 1 – HSE Freedom of Information Response July 2008

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Figure 3 – The post-apocalyptic landscape we were trying to obtain evidence in

through a post-apocalyptic landscape, by this time, every duty holder involved had engaged lawyers to wage an intense liability-avoidance war.

Usually, safety regulators don't get involved in such squabbles, but the financial stakes were so high on this occasion, that one of the combatants persuaded HSE's investigation team to try to prevent the opposition from getting advanced notice of the direction of the enquiry. They asked for it to be conducted in a way that didn't reveal exactly what circuits and equipment we were looking at. This led to the farcical situation of the investigators conducting tests using coded statements rather than plain speech. So instead of saying, 'I'm checking the continuity of cable X leading to switch Y' over the radio, we had to write each testing step down individually, and refer to them by number. "The result of step 4.2 is positive."

I suspect that we were the first people to have fully traced these safety-critical loops in a decade or more.

I have strong recollections of conversations with the operators of the site who were engaged as liaisons assisting the ongoing investigation and recovery operations. The incident had clearly been devastating for them. They recounted a tale of constant resource-cutting and efficiency drives prior to the explosion that had led to fewer and fewer of them working on the site. One of them had a sense of guilt that maybe there was something they could have done to prevent the explosion.

I don't know what the owners of the site had saved over the years, but I bet it was a lot less than they lost in the explosion.

The failure of a level switch to stop the flow of petroleum into a storage tank proved to be a key factor in the subsequent formation and detonation of a petroleum vapour cloud. The owner of the tank at the heart of the explosion had not ensured that a handle had been padlocked into place to allow the unit to function properly.

One day, I inspected one such switch on a surviving tank operated by the same company. It had no padlock in place. Nearby, separated by a chain link fence, were some other tanks, operated by a different company. Each of their level switches had the necessary padlock. I have yet to encounter a more graphic physical demonstration of the effectiveness of safety culture in preventing major incidents.

About the author

Wayne Vernon was a Principal Specialist Inspector with the UK's Health and Safety Executive at the time of the investigation of the Buncefield Explosion *(pictured)*. He subsequently went on to establish New Zealand's onshore major hazards regime.

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Buncefield response

The German response to the tank fires and explosions in Buncefield

Mark Hailwood, LUBW, Germany

The explosion and subsequent fires at the Hertfordshire Oil Storage Terminal (HOSL) tank storage depot on 11 December 2005 was the largest explosion in Europe since the Second World War and had effects over a great distance including a smoke plume that drifted across France, eventually reaching Spain. Economic impacts were experienced across parts of Europe as a result of the restrictions to the fuel supply for London's airports and the need for flights to land elsewhere to refuel.

If anything is to be learned from catastrophic events such as Buncefield then it is not sufficient to just investigate and publish reports[1] — it is necessary to analyse how the facts and any new knowledge and understanding apply to one's own situation and to work out which measures need to be applied to avoid a repetition.

In Germany, the Federal Environment Minister Sigmar Gabriel requested on 13 October 2005 that the Commission for Plant Safety (Kommission für Anlagensicherheit – KAS) provide a position paper as to whether the events in Buncefield should lead to measures to be taken with respect to German tank storage depots. In particular it should be considered whether the legal framework and technical regulations were sufficient or whether additions were possibly required.

The Commission for Plant Safety set up a working party on tank storage. The membership of the committee was drawn from academia, industry, technical inspection bodies, public authorities and institutions as well as environmental NGOs. From its start the working party established a close contact with the authorities in the UK so as to be able to follow the developments and the release of information as closely as possible.

The urgency of the Federal Environment Minister was possibly in part motivated by claims by a tank storage inspection expert in the media, that Buncefield could not have happened in Germany. A claim made at a time when the Buncefield site was still covered in water, foam and petroleum products and the investigation team of the Major Incident Investigation Board (MIIB) had not yet had access to it.

Early on it became clear that the operation of tank storage fuel depots in the UK was substantially different to the way that they were operated in Germany. Whereas the UK has a pipeline network connecting refineries with the fuel depots, Germany generally has large fuel storage tanks at the refineries with distribution to remote depots via river barge, road tanker and rail tank-cars. There are a few cases where refineries distribute to a remote fuel storage depot by pipeline, however these operations are in the hands of one operator and should therefore be simpler to manage. This does not mean that an overfilling of tanks is not possible. Any situation in which the quantity of fuel to be transferred exceeds the free capacity in a tank has the potential to lead to an overfill.

The working party met eleven times, the last time on 12 October 2009 and published two interim reports. The first report was released by the KAS at its meeting on 22–23 June 2006, the second report was released in November of the same year and was followed by three further updates as more information became available. The final report was published in November 2009[4].

The conclusions and recommendations in the final report were grouped under the headings:

- prevention of an overfilling
  - – technical measures
  - – organisational measures
  - – testing of over-fill protection
- leak detection and product retention
- prevention of turbulence and other critical transport effects
- measures for limiting the consequences (safety distances, emergency response, firefighting and emergency planning).

In the preamble to the conclusions and recommendations it

> The Commission for Plant Safety is a body established under Paragraph 51a of the Federal Pollution Control Act[2] with the task of advising the Federal Government and the Federal Environment Ministry on matters related to process safety. The membership of the KAS is multipartite covering a wide range of stakeholder groups including federal and state authorities, academia, industry, third-party experts and inspection bodies as well as environmental NGOs. The KAS does not itself investigate accidents and has no enforcement responsibilities. A particular role is providing advice on the "state of the art of safety technology" (Stand der Sicherheitstechnik) and where necessary to formulate technical regulations.
>
> The "state of the art of safety technology" is a particular terminology anchored in Paragraph 3 of the Major Accident Ordinance (Störfall-Verordnung)[3], the German implementation of the Seveso Directive, since 1980 as a requirement on operators of major hazards establishments to construct, operate and maintain their operations to this standard. The standard is defined in Paragraph 2, No. 10 of the Ordinance as being the development status of advanced processes, installations and operations, which appear with certainty to be practically suitable as a measure for the prevention of a major accident or the limiting of the consequences. Thus, this standard is not fixed but is dynamic and requires that operators of major hazard establishments continually assess the status of their safety measures and take the necessary measures to improve.

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was clearly stated that tank storage facilities are not constructed to survive such massive fires and explosions as occurred in Buncefield. The German technical regulations for storage tanks for petroleum presumed that the maximum extent could be a leak and fire involving one tank. This underlines the importance of prevention, i.e. the left-hand side of a bow-tie diagram.

This meant that the following requirements were placed on the technical measures for the prevention of overfilling:

- Overfill protection should have a high reliability. This may be through the use of redundancy or through the use of self-monitoring overfill protection devices.
- A warning should be given before the main alarm level is reached. These are known as Hi-Alarm and Hi-Hi-Alarm.
- Overfill protection systems should stop the filling process sufficiently early before the maximum fill level is reached and trigger an alarm. The function of the remotely operated valves should be signalled to the control room. On closing the inlet valve the pump must be switched off.
- Failures in the function of the level indication, the overfill protection and the relevant valves should be detected quickly, with certainty, and reliably. In such situations operators should be instructed not to commence filling or to stop the filling operation.
- For emergencies, the function of at least the safety relevant elements of the process control system are to be supplied with a sufficiently sized, non-interruptible power supply, unless their safety is guaranteed by a "fail-safe" design. "Fail-safe" in this context means that the component fails to a safe mode, in the event of a power failure.

These criteria effectively make mechanical over-fill protection devices, as implemented in Buncefield, unacceptable in German petroleum fuel depots.

The organisational measures described in the final report are based on the fact that fuel depots are generally Seveso establishments of the upper tier, with requirements to produce a safety report and to develop a safety management system. The organisational measures are targeted towards ensuring that the quantity of fuel which is to be transferred to the depot is not greater than the available free capacity. In addition, requirements are to be placed on the definition of alarm levels, maximum fill-levels as well as on the maintenance and testing of the overfill protection system.

The overfill protection systems are to be regularly inspected within the requirements of the Technical Regulations for Operational Safety. Petroleum tanks storage facilities fall within the equipment and plant to be regularly inspected by authorised inspection bodies. The authorised inspection bodies were recommended to establish guidelines for the extent and frequency of the testing and inspection of overfill protection systems.

The Commission for Plant Safety recommended that operators of petroleum storage tanks consider, within their overarching safety concept, the installation of leak detection devices which would at least lead to an alarm signal. If appropriate this could be coupled with interruption of filling operations. The Commission for Plant Safety also found that the retention systems such as bunds should remain intact for an appropriate amount of time in the event of fire and the relevant bodies were recommended to draw up standards to this effect.

One of the key consequences for the emergency planning which followed Buncefield was the realisation that no single operator would have sufficient firefighting foam to be able to deal with a large-scale fire. Thus, a network was established between the refinery operators, fuel depot operators and others to be able to share foam in an emergency. Firefighting foam has a limited shelf life and this improves the efficient use of resources. This network has recently been a subject of discussion, due to the legal requirements on the use of PFAS- and PFOA-free foam. It is therefore essential that industry ensures that the foams are compatible and that the network can continue its operation. This cooperation has recently been achieved.

As the Commission for Plant Safety released its interim reports and eventually its final report it was the responsibility of the operators and the authorities of the German States (Länder) respectively to implement, and to oversee the implementation of the recommendations. One of the earliest enforcement activities was to identify the relevant petroleum storage facilities and to assess their overfill protection systems. In addition, discussions with operators were necessary to consider which measures were to be implemented and within which time frame.

It can be seen that the fires and explosions at the Buncefield fuel depot were considered intensely in Germany and that measures were identified and implemented to ensure that tanks are fitted with reliable overfill protection systems and that petroleum storage facilities are operated and managed in a manner that ensures that fuel transfer and storage is carried out as safely as possible.

However, Germany is only one jurisdiction in Europe. What happened in the other countries? Were changes made to operating practices? Were there recommendations on the standards and quality of overfill protection systems? Whilst it is recognised that it is the operator's responsibility to construct and operate their establishment in a safe manner, it is also known that if the authorities do not declare what their expectations are, there is a drive towards the lowest level of acceptance. Major accidents are low frequency, high consequence events, thus it is necessary for operators to take all measures necessary to prevent such events and to reduce the consequences as far as possible.

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Buncefield response

CDOIF environmental guidance — a welcome consequence of the Buncefield disaster

Dr Ken Patterson

Back in 2009 I wrote a paper about learning from accidents for Hazards 21[1]. In it I compared the speed at which the inquiry into the Tay Bridge disaster, in December 1879, had completed its work so it could report to Parliament within six months (in June 1880); with the delay in information coming out of the Buncefield incident — then already three and a half years prior to the conference. However, hindsight gives a somewhat different perspective. I would still contrast the speed of the two enquiries — the enquiry team for Tay Bridge was assembled and travelled to Dundee within *six days* of the incident (despite Hogmanay intervening) — but the learning from Buncefield for Process Safety (PS) practice has probably been more significant than from any other recent incident.

The investigation of most accidents, even major accidents, generally turns up a depressingly familiar set of causes — poor safety awareness, sloppy practice, poor safety analysis, etc — and they existed at Buncefield too. However the investigation of Buncefield gave us some important insights into the *practice* of PS analysis. Before Buncefield we knew that congestion could cause a burning vapour cloud to transition to detonation but PS practitioners (me included) would generally have dismissed the chance of it happening in an open area like that around the terminal, despite the trees and undergrowth. The work by Gexcon[2] and FABIG's technical conference on Buncefield[3] showed us the gap in our understanding. Similarly, the work by the investigation board[4] into the sharply different results of Layer of Protection Analyses (LoPAs) done by different teams[5] has hopefully pushed us into improving our practice and getting our teams into a better state of training, understanding and LoPA performance.

That said the biggest impact was probably in the area of environmental assessment of major hazard risks. The terminal is operating again and the surrounding area largely rebuilt. But the eco-toxic runoff from the fire and firefighting has polluted underground aquifers and the effects are likely to be felt for hundreds of years, that is — it is likely to be hundreds of years before the aquifers can be used for drinking water abstraction again. The quantity of firewater overwhelmed the site defences and ran off into unprotected surrounding areas, then percolated down into the aquifers, carrying with it the chemicals (PFOS) used to produce the vital firefighting foam.

The response of the UK Regulators (principally the Environment Agency) was, quite understandably, that this must never happen again. They initially asked for complete, impermeable bunding around *and under* all storage tanks, together with tertiary containment for fire water, so that it could not escape from any similar storage depot or other installation. Very few, if any, existing sites achieved this standard. And the costs would have been prohibitive. How do you put down an impermeable layer underneath an existing 100,000 m^3 tank? The request was greeted with horror by the CIA and the Tank Storage Association, and there were a couple of tense meetings. To the regulators' credit they understood the operators' concerns and a dialogue started which recognised that if had been possible to define "intolerable" and "broadly acceptable" frequencies for human deaths at work (in R2P2[5]) it should be possible to read these ideas across to environmental harm.

Chiltern Air Support

The outcome was the CDOIF (Chemical and Downstream Oil Industries Forum) guidance on the assessment of environmental accidents on major hazard sites, first published in 2013 and revised in 2016[6]. The guidance built on previous work[7] and accepted that there was a "tolerable" frequency for environmental incidents but that that frequency would be dependant on: the size (extent) of the pollution from the incident and the material involved; the environmental importance of the flora and fauna affected; and the likely time

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it would take the environment to recover from the insult. This provided a "read across" from the ALARP triangle used by HSE for human accidents, to environmental incidents. The guidance provided a broadly similar way to approach both human and environmental accidents; and gave guidelines which could be used by regulators and the regulated industries alike.

The guidance and its use have been widely discussed, notably in a number of Hazards conferences[8], but that is beyond this brief note. None the less it has provided another example of learning from accidents — even if somewhat slower than the Victorians managed! It represents a significant improvement in the way PS practitioners can approach the assessment of environmental risk. If you don't have, and use, the CDOIF guidance (free download from ref 6) in the production of your Major Hazard Safety Reports, you should.

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Letter

When good intentions go up in flames — the forgotten warnings

…. Or how overlooked research and well-meaning decisions set the stage for Buncefield

Chekov once famously declared "If in the first act you have hung a pistol on the wall, then in the following one it absolutely must go off."

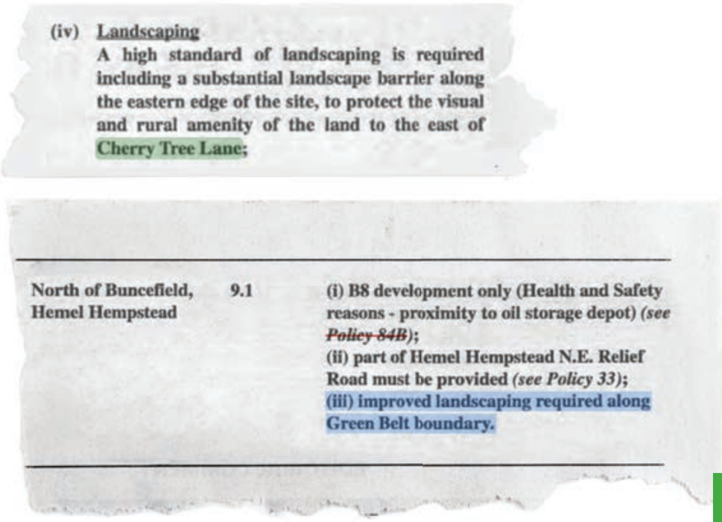
Accordingly, the curtain might go up on Act 1 of "The Buncefield Blast" to show the St Albans DC planning committee in front of a district map on the wall, debating whether the site should be screened by lines of trees, "in order to protect the visual and rural amenity" of the neighbouring land … (see Figure1).

Then, following a somewhat protracted intermission of about 21 years, Act 2 would roll inexorably forward, via all the mishaps and mis-steps laid bare in the Buncefield Major Incident Investigation Board (MIIB) reports, to the instant where the [vapour fire crossing the] treeline "absolutely goes off".

Viewed thus, what lends the drama its poignancy is the good intentions of the planning committee; less so the embarrassing ignorance of nearly[2] all of us professionals taken by surprise — regulator, industry and fire & explosion community.

According to the MIIB, "One important aspect of the incident was that a severe explosion took place, which would not have been anticipated in any major hazard assessment of the oil storage depot before the incident[3]." However, literature searches quickly revealed several unnervingly similar precedents, for example in Newark, New Jersey (1983), in Naples (1985) and in Saint Herblain, near Nantes (1991). Each of these had been reported in detail in high impact journals, one as recently as 1999.

In September 2007, the Explosion Mechanism Technical Group of the MIIB presented the results of its investigations at a meeting of explosion specialists[4]. The blame for the violence of the explosion was correctly pinned on the congestion offered by branches, twigs and foliage of the trees bordering the Buncefield site. However, the MIIB might have spared themselves some labour – and an illusory eureka moment – had they been aware of modelling results, published the very year before Buncefield, which set out the explosion mechanism they now proposed[5]. Neither the journal (Journal of Loss Prevention in the Process Industries) nor the title of the paper ("Do tree belts increase risk of explosion for LPG spheres?") is in the least obscure. Yet no one at the meeting recalled having seen this paper.


(iv) Landscaping
A high standard of landscaping is required including a substantial landscape barrier along the eastern edge of the site, to protect the visual and rural amenity of the land to the east of Cherry Tree Lane;

North of Buncefield, Hemel Hempstead	9.1	(i) B8 development only (Health and Safety reasons - proximity to oil storage depot) *(see ~~Policy 84B~~)*; (ii) part of Hemel Hempstead N.E. Relief Road must be provided *(see Policy 33)*; (iii) improved landscaping required along Green Belt boundary.

Figure 1 – Extracts from 1994 St Albans District local plan review[1]

How could it have been forgotten so quickly – and then overlooked by the MIIB Technical Group?

Prof Trevor Kletz coined the phrase "corporate forgettory". But from the above, it seems that many reports relevant to the understanding of major accidents never get a chance to be forgotten about – because they are not read in the first place. Or, even if read, not digested.

Ivan Vince

[1] *https://www.stalbans.gov.uk/sites/default/files/documents/publications/planning-building-control/district-local-plan-review-1994/District%20Local%20Plan%20Review%201994%20Saved%20and%20Deleted%20Policies%20Version%20%5BJuly%202020%5D.pdf.*

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Buncefield – the human factors

Professor Fiona Macleod, IChemE Safety Centre

When did you last visit the control room of a major hazard installation? What questions would you ask if you noticed a new alarm clock* on the desk of a supervisor?

The cynic might suspect staff of taking naps on the job, using the alarm clock to wake themselves in time to avoid detection. You could rant and rave and confiscate the alarm clock...or ask further questions.

What if you discovered that:

- workers were coping with a fourfold increase in workload
- with overtime – it was common practice to work 84 hours in a seven-day period
- no fixed breaks were scheduled
- breaks could only be taken when operating conditions allowed.

And that in addition to filling road tankers, staff were monitoring three incoming pipelines which filled multiple tanks at variable filling rates and, over two of which, staff had no control and the only way to stop the flow from those two pipelines was:

- by a telephone call to another terminal
- operation of an independent high-level switch (IHLS) or
- activation of a manual call point on an adjacent site.

And that the design of the automatic tank gauging (ATG) system meant that the status of only one tank could be fully viewed at a time, on the single screen provided. The operating staff didn't trust the level readings.

- there had been 14 call-outs in three months to address a single sticking level device
- resolution was only ever temporary
- staff had given up logging the regular faults.

Would you be reassured by the fact that the contract maintenance personnel had scored well in a recent site performance evaluation? An evaluation that focussed on whether they wore the right PPE.

What if you also discovered that staff had no confidence in the independent high-level switch meant to automatically close the tank feed and that:

- tanks had been allowed to operate for months without working independent high-level switches (IHLS)
- a new type of IHLS had recently been fitted, without any management of change assessment
- maintenance tests said it worked, but operating staff said otherwise
- nobody really understood how the new IHLS worked
- nobody really understood the purpose of the missing padlock.

** an alarm clock was a mechanical device used before mobile phones.*

And what if you discovered that senior management decisions were taken by

- a board with no employees
- a group that met twice a year
- a group that had never scrutinised the 'aspirational' safety case it had hired a contractor to write
- a group that allowed audits to check the paper version of procedures rather than their application in practice.

The alarm clock was a cry for help. It was being used to manage the single filling line over which staff had some control. Based on the ullage and filling rate, they set a timer to ring when the tanks should be approaching full capacity, because they couldn't trust the level gauges and suspected that the independent high-level switches would not stop the flow.

According to the HSE, the explosion and fire at the Buncefield oil storage depot in 2005 resulted from 'slackness, inefficiency and a more-or-less complacent approach to matters of safety'. Had the same event occurred during weekday hours (instead of a Saturday to Sunday nightshift), hundreds of people could have been injured or killed. The lessons we can learn from revisiting the Buncefield accident go deep into the heart of human factors in high hazard management.

The final HSE Buncefield Report (2010) is a model of clarity — I recommend you take the time to read it. https://www.icheme.org/media/10706/buncefield-report.pdf

Then pop down to the nearest control room and ask people at the sharp end what's not working.

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Incident

HSE process safety communication – explosion in an anaerobic digestor plant

Karen Camplin & Rhiannon Thomas, HSE, UK

Summary

This paper details a catastrophic explosion at an anaerobic digestion plant, caused by the ignition of flammable gases in a buffer tank during hot work. The incident resulted in life-altering injuries to two workers and highlighted serious deficiencies in hazard identification, risk assessment, and contractor competence.
Key failures included an inadequate DSEAR assessment, outdated process diagrams, and poor management of change. The report emphasises critical lessons for the anaerobic digestion industry and broader sectors, including the need for accurate hazard studies, robust safety systems, and active operator engagement in risk management.

Keywords: Anaerobic digestion, flammable gases, DSEAR risk assessment, hot work, process safety management.

Description of the incident

The company operated an anaerobic digestor to recycle food waste in Colwick, Nottingham. In September 2017 a blocked pipeline was being removed with a grinder by two employees in a mobile elevated working platform (MEWP). Both suffered life changing injuries as a result of the basket being violently bounced when the flammable atmosphere in the buffer tank ignited and it lifted, contacting the basket. One worker lost his leg and the other spent two months in hospital.

Figure 1 illustrates the anaerobic process. The liquid being recycled back into the process was essentially reseeding the slurry, and beginning the digestion process earlier than anticipated (the initial phases of the digestion process can lead to hydrogen being evolved as well as methane). This is common practice to save on fresh water, and acceptable if flammable hazards are included in the risk assessment.

The buffer tanks, which had atmospheric vents, had not been emptied prior to the incident: Figure 2 illustrates the buffer tanks and ingress of air.

Issues identified included:

- process diagrams were not accurate
- a hazard study failed to identify flammable hazards upstream of digester
- the DSEAR risk assessment was inadequate, and
- a Safe System of Work for hot work was inadequate.

When the grinder sparked, ignition of the flammable gases occurred and the expanding ignited gases forcibly ejected the slurry out of the bottom of the tank (see Figure 3) where the clamp arrangement, the weakest point of the vessel construction, had given way (Figure 4). The buffer tank remained in the air for nine seconds before landing on the electrical board building (Figure 5). It was fortunate that the tank did not hit other people or process plant.

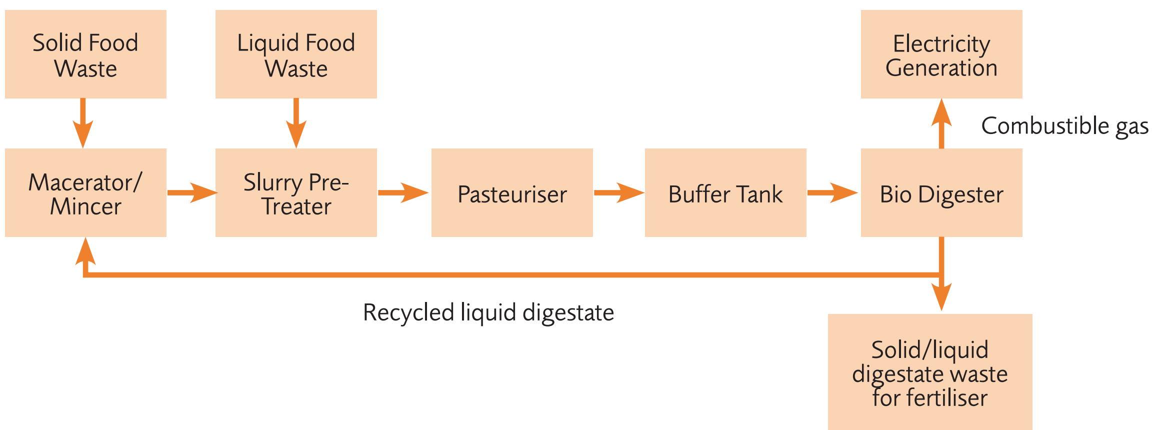

Figure 1 – Outline of the anaerobic digestion process

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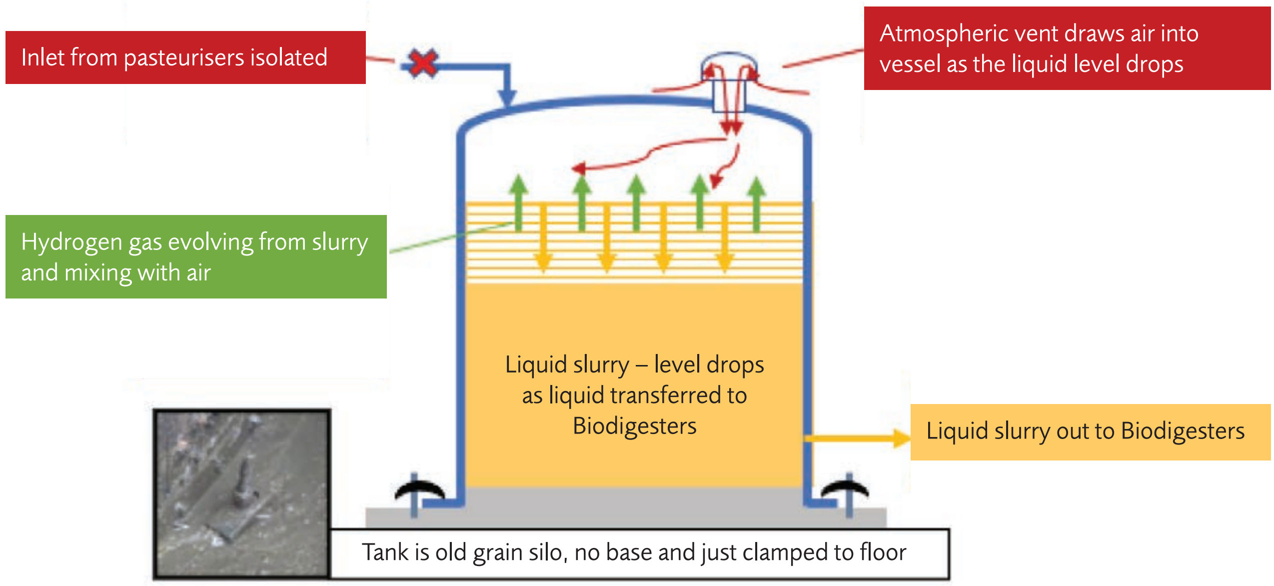

Figure 2 – The buffer tank, once isolated, now showing ingress of air

Causes of the incident (direct and safety management systems failures)

Failure to identify hazards

The risk assessment carried out by a consultant failed to identify flammable hazards upstream of the digester. Consequently, the company did not know that flammable gases existed in the buffer tank. As a result, the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) risk assessment was inadequate and the Safe System of Work (Permit to Work) for hot work was not considered or used. Inadequate risk assessments or DSEAR assessments effectively allowed gaps and failures to remain undetected in a system i.e. latent failures. This meant that an incident became likely because no-one was aware of these gaps and deficiencies.

Competence

The DSEAR assessment was carried out by a consultant, but the assessment had a range of serious deficiencies and was not fit for purpose. The consultant had only undertaken a one-day training course (Introduction to DSEAR) and was not experienced in identifying the flammable risks at a site using microbes to generate large quantities of biomethane. The company failed to manage and challenge the consultant on their assumptions and assertions, i.e. be an intelligent

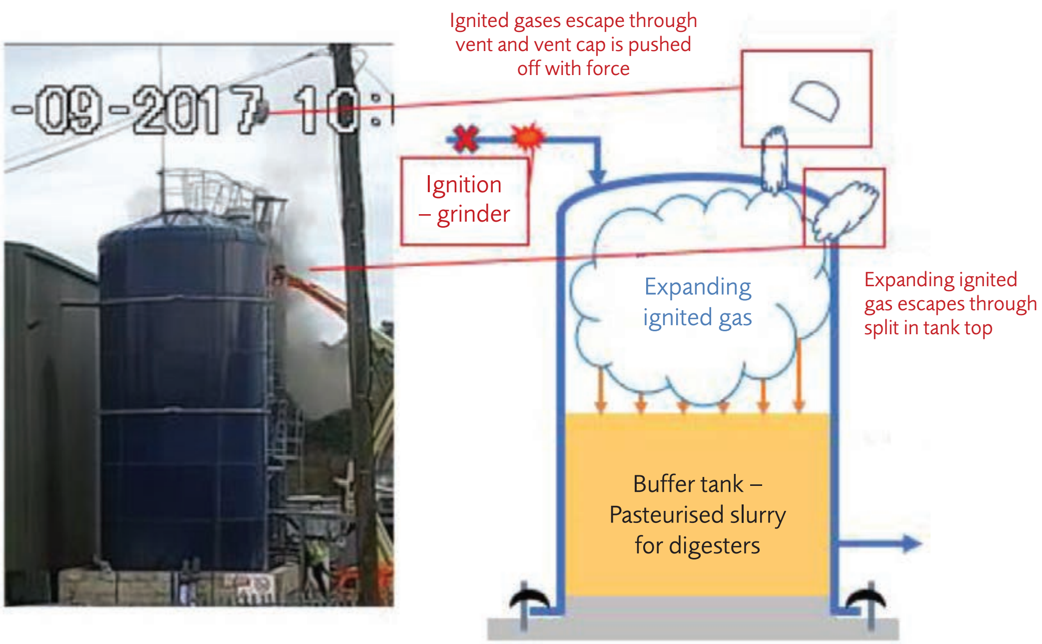

Figure 3 – The buffer tank – flammable gases ignited & expanding internally

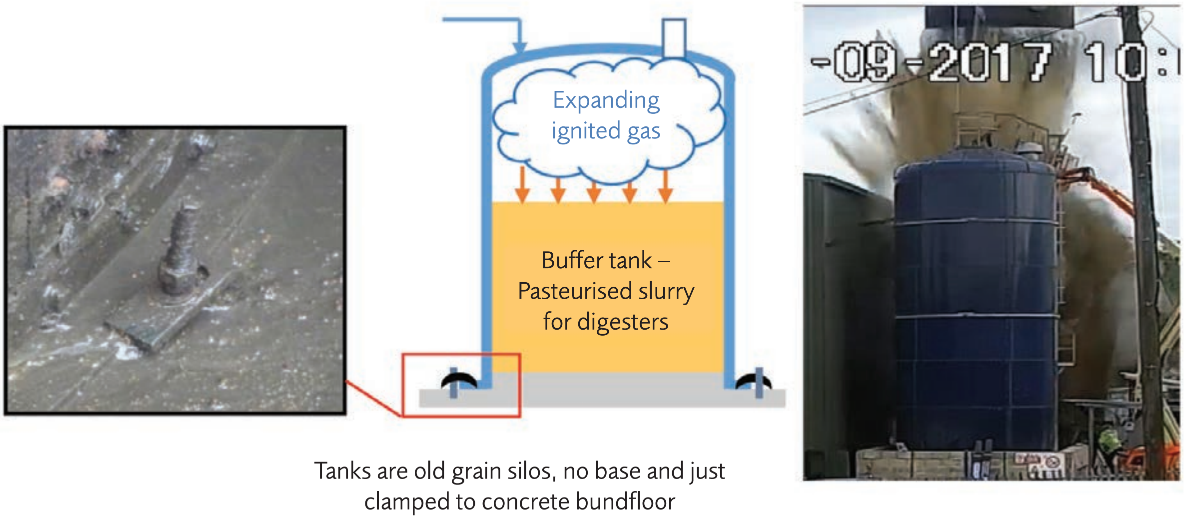

Figure 4 – The buffer tank 'take off'

customer. Site operators should not take things on face value — the legal duty to ensure safe site operations remains with the site operator and cannot be passed to consultants. HSE guidance *Managing contractors: A guide for employers HSG159* is aimed at small to medium businesses in the chemical industry and has a checklist of questions to ask contractors or consultants.

Lessons to prevent a reoccurrence

Lessons specific to the anaerobic digestion industry

- **Flammable atmospheres can occur in vessels and pipework other than the digester itself e.g., pre and post digester.**
  Always assume there is the potential for transfer of flammables when vessels are connected to each other, and methane is known to be present in at least one. A cautious approach should always be taken to make sure the atmosphere is safe. Do not assume a pipe / vessel is gas free — always check before carrying out work. This is essential if the work involves heat or other potential sources of ignition.
- **Methane is not the only flammable gas generated in the AD process.**
  Post incident testing of material from the buffer tank showed that the predominant gas initially produced by the bacteria in the tank was hydrogen, not methane. Hydrogen is lighter than air and is more likely to accumulate near the top of any vessel. Hydrogen has a wide flammability range (typically 4-77% by volume). When ignited hydrogen shows higher overpressures, faster flame propagation and is more prone to detonation than methane. In other words, hydrogen presents a higher risk which is harder to control than the risks from biogas (predominantly methane). These considerations should have formed part of the DSEAR assessment.
- **Use of 'black water'.**
  Recycling the 'digestate' liquid (black water) back to the start of the maceration process is acceptable, provided the site operator understands the possible impact of this process (e.g., the potential for reseeding the reaction). A suitable and sufficient risk assessment should have considered the likelihood that black water can accelerate the reaction processes and that flammable substances are more likely to be present early in the process.
- **Pre-digestion pasteurisation.**
  It was assumed by the site operator that pasteurisation would greatly reduce the microbiological activity within the degrading food waste in the tank, making it safer to keep it there in a holding tank ahead of main digestion. In fact, pasteurisation is intended to reduce the levels of pathogenic microorganisms in the feedstock and not to eradicate all microbiological components. Post incident tests on the feedstock slurry from the buffer tank detected vast numbers of viable microorganisms (both aerobic and anaerobic bacteria). The waste had remained extremely bio-active, even after earlier heat treatment at 70°C.

Lessons applicable to all industries

- **Management of Change.**
  The buffer tank was a repurposed grain silo bolted to a concrete base. Where vessels are repurposed, risk assessment should determine that they are fit for purpose and whether any modifications are required, such as fitting pressure or fire relief.
- **Reviewing and updating plant design records.**
  The risk assessments were also undermined by outdated process and instrumentation diagrams (P&ID) which did not reflect the plant "as built". The risk assessment and DSEAR assessments were based on a plant layout which did not exist. Operators must ensure that diagrams and process documentation is kept up to date and reflects reality.

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Figure 5 – The final landing position of the buffer tank at the site

- **Hot work.**
  This is a high-risk activity in all industries with flammable substances, including AD plants. This is made clear in paragraph 321-322 of the DSEAR Approved Code of Practice (ACoP): "Hot work on or in any plant and equipment (including containers and pipes, e.g. storage tank, drum, cylinder, silo, pipeline, fuel tank etc) remaining in situ that contains or may have contained a dangerous substance is classified as high-risk activity and will require a Permit to Work system to be put in place."
- **Use of inert atmospheres.**
  A suitable safe system of work for carrying out hot work should include appropriate methods for making the tank gas free or inerted. Schedule 1, Regulation 6(8) of DSEAR outlines the general safety measures that ought to be considered, including use of inert atmospheres. The option chosen will depend on the risk assessment. Standards exist for cleaning vessels/tanks containing flammables; although these are aimed at the petroleum type sites, with large storage tanks (Energy Institute Model Code of Safe Practice IP16), the same principles will apply. Typically, the vessel is emptied, washed down/filled with an appropriate cleaning fluid (e.g. water) and emptied, then gas tested to ensure the flammables are removed, with ongoing monitoring because material can be held upon the internal walls even after washing.
- **Site operators must genuinely engage in the risk assessment process.**
  Whilst there were deficiencies in the competence of the consultant to undertake the DSEAR and HAZOP assessments, the quality of the resulting reports was further compromised by a lack of engagement by the site operator in the assessment process.
- **Obtaining regulatory approval prior to alterations.**
  Modifications to the process were not clearly communicated to the Environment Agency, and permission was not sought or obtained for deviations from the original design and operation of the plant as authorised by the environmental permit.
- **Maintaining permit compliance.**
  Whilst the operator had an environmental management system and associated operating procedures, these were not being followed, audited or reviewed and updated.

Enforcement outcome

Two Prohibition Notices were served immediately, with multiple Improvement Notices and Notices of Contravention for occupational safety issues.

The UK Health and safety Executive undertook a joint investigation with the Environment Agency (breach of permit conditions). On 22 November 2024, BioDynamic (UK) Limited were fined £304,500 (HSE Fine £297,500) costs £229,988 awarded (HSE costs £57,900).

In conclusion

This incident is a clear reminder of the importance of ensuring that key elements of a process safety management system are in place and functioning well. Without effective identification of hazards, sites will be unlikely to properly provide the necessary controls for safe work. Without good management of change procedures, process changes can bring unforeseen hazards which can subsequently bring vulnerability to sites. Without good competency management, mistakes can be made which have tragic consequences. The incident details, prosecution and sentencing outcomes in this case are shared here to encourage learning across industry for prevention of future related incidents.

References and Guidance

1. *DSEAR Approved Code of Practice (ACoP) L138 – available to download for free from the HSE website*
2. *Managing contractors: A guide for employers HSG159*
3. *Energy Institute Model Code of Safe Practice Part 16 – Guidance on tank cleaning.*
4. *'The Practical Guide to AD' – Anaerobic Digestion and Bioresources Association*
5. *BS ISO 19388:2023 – Sludge recovery, recycling, treatment and disposal – Requirements and recommendations for the operation of anaerobic digestion facilities.*
6. *BS EN ISO 24252:2022+A11:2023 – Biogas systems – non-household and non-gasification.*
7. *'Guidelines for the safe use of biogas technology' – German Biogas Association, www.biogas.org*

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Layer of Protection Analysis
21–22 April, Manchester, UK
www.icheme.org/lopa

Bowtie Analysis and Barrier-based Risk Management
22–23 April, Rugby, UK
www.icheme.org/bowtie

HAZOP Study for Team Leaders and Team Members
28–30 April, Reading, UK
www.icheme.org/hazop-team

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From 10 February, 09:30–12:30 GMT
www.icheme.org/advanced-ammonia

Layer of Protection Analysis
From 17 March, 10:00–13:00 GMT
www.icheme.org/lopa

Safety Instrumented Functions
From 26 March, 10:00–13:00 GMT
www.icheme.org/sif

Fundamentals of Process Safety
From 31 March, 10:00–13:00 BST
www.icheme.org/fundamentals

Advanced Process Safety Considerations for Hydrogen Projects
From 31 March, 14:00–17:00 BST
www.icheme.org/advanced-hydrogen

Delta HAZOP
16 April, 14:00–17:00 BST
www.icheme.org/delta-hazop

Fundamentals of Process Safety
From 1 May, 09:00–12:00 AWST
www.icheme.org/fundamentals

Asset Integrity Management
NEW
From 12 May, 10:00–13:00 BST
www.icheme.org/asset-integrity

Process Safety Performance Indicators
From 13 May, 14:00–17:00 BST
www.icheme.org/performance-indicators

Bowtie Analysis and Barrier-based Risk Management
From 14 May, 10:00–13:00 BST
www.icheme.org/bowtie

HAZOP Study for Team Leaders and Team Members
From 14 May, 14:00–17:00 BST
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