Investigation – what does good look like and does it really have to be complicated?

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Investigation can be a difficult process and activity for many people, whether they are investigation leaders, regular or occasional investigation team members or even those charged with implementing the subsequent recommendations. Opportunities for most people are limited either by the availability of incidents or by the time and resource made available to devote to them (and few companies have permanent investigation teams). So gaining experience, and maintaining and improving investigation skills and knowledge is a challenge. Investigation methods used by companies vary widely too and are often changed for perceived benefits such as better and more detailed root cause identification or apparent improved validity and reliability. Investigation training is often classroom based and not necessarily consolidated by structured on-the-job training or other effective consolidation. Furthermore the extent to which human and organisational factors (HOF) is included in training and in methods is also very variable e.g. many methods make claims for such inclusion but this is not supported by research or experience. In practice even the best methods – with HOF fully integrated, and they are very few – are very reliant on the investigators' own HOF understanding and experience, and of course effective implementation of related recommendations is too.

While organisations may have an appetite to investigate lower level incidents and precursors to major incidents there may be barriers such as their internal classification system which may only permit a site to deploy very basic capability to investigate and for a very short time. The outcomes then usually lack depth and rigour and may simply result in more and longer procedures, re-training, reluctance to improve design or other measures higher up the hierarchy of control, and very little HOF analysis. Investigators can only find what they look for or are permitted and prepared to look for.

The other area of difficulty for sites is that investigation depth means contributions from others can play a greater role. Potential recommendations / actions can be challenged and played down during review and discussions. Lead investigators may feel they cannot push findings if e.g. they may be perceived as pointing to site leadership.

This paper offers the views of two very experienced ex-regulatory investigators rooted in a largely non-methodological approach. They introduce a project which changed BP's methods and approach significantly, and this is illustrated by a case study for one incident. Experience from a wide range of industries and other regulators is also offered with a view to providing pragmatic advice and guidance to industry investigators. Learnings and experience for investigators are offered on investigation method selection, training and practice. Some of the pitfalls of the more theory-driven methods are discussed. Wider experience on improving organisational learning from incidents and more widely are also offered.

Introduction

Incident investigators can often have a tough time investigating. They may be hindered by time, resource and other pressures and constraints. Training and opportunities to practice may be limited. There is often a shortfall in investigation methods and processes, usually with an over-focus on the technical and engineering aspects. This is equally true when it comes to identifying actions and making recommendations. What is often missing or inadequate is the human contribution. (HOF) - for supporting evidence see (Energy Institute 2008) . This paper argues that good incident investigation requires an integrated and proportionate human and organisational factors (HOF) approach, and that this is not a 'nice to have' or an add on. Where there is a key human behaviour of interest then it makes sense that such an approach is taken. If the behaviour is not properly understood then it is unlikely that effective recommendations will be made.

A key success factor for effective investigation is establishing an adequate narrative (story) of the event and what led up to it. This process starts with piecing together a reliable timeline of the events followed by effective analysis. Key factors in the analysis include: looking for and identifying key performance influencing factors (PIFs – those job, personal and organisational factors which make error more or less likely), the contribution of human failure (errors and workarounds) and organisational failures. It can be more challenging to link human failures to organisational ones but if this is not done then those same organisational factors are likely to contribute to further incidents. The main focus here is on practical help for investigators. A BP case study illustrates a practical HOF approach to investigation.

Methods

One useful way of thinking about investigation is to see it as the mirror image of the hazard identification / risk assessment process. But instead of 'looking through the windscreen' (as if you were driving a car and looking at the road ahead) it is about 'looking in the mirror' i.e. at the road behind. Some methods reflect this quite directly e.g. Human Factors Analysis Tools (HFAT®) (The Keil Centre 2007) and TRIPOD (Stichting Tripod Foundation, 2015) which have adapted such prospective tools. In a nutshell if there is a human behaviour of interest in an incident (and there usually is!) then using a HOF approach is essential to understanding this fully and preventing a recurrence. HFAT® uses specific tools to categorise the behaviour of concern as intentional or unintentional and then to consider error types (for unintentional) and other solutions (for intentional). HFAT® is a method used alongside a mainstream investigation method. It does the behaviour analysis more thoroughly and matches likely solutions to the behaviours and sub-types. Without this careful analysis the

behaviour(s) of concern is unlikely to be fully understood and effective solutions are unlikely to be reliably identified or implemented. TRIPOD "…is an incident investigation and analysis methodology designed in line with the human behaviour model. It was explicitly created to help accident investigators model incidents in a way that allows them to understand the influencing environment and uncover the route organisational deficiencies that allowed that incident to happen." (Stichting Tripod Foundation, 2015). Other methods vary widely and generally offer less (Energy Institute 2008). The default for many available methods is to provide lists of HOF causes to choose from.

Safety-2 and Systems' Thinking

A current hot debate in the safety literature is about the new 'Safety-2' approach where existing safety approaches are seen as 'Safety-1' i.e. out of date. (see e.g. Holnagel 2014) Safety-2 takes a systems' approach and tries to avoid traditional decompositional investigation methods i.e. most of the existing ones. Modern industrial / work systems are increasingly complex and interconnected i.e. they are not linear, but 'decompositional' implies that a linear approach to causation is taken. Such systems also have emergent properties - they can surprise designers and users because parts of the system can interact in ways that are not predictable. This is why high reliability organisations (HROs) are said to show 'chronic unease' – they are vigilant for signs of disturbance or difference in their systems and prepare for the unpredictable. In practice this may mean helping staff make optimal decisions under conditions of uncertainty, and not just for pre-prepared scenarios.

There are newer investigation methods around that claim to offer such a systems' approach but these have yet to be applied widely or to have built much of an evidence base so far. STAMP (Systems-Theoretic Accident Model and Processes, Leveson 2011) and FRAM (Functional Resonance Analysis Method, Hollnagel 2012) are two examples (from the systems' engineering and resilience engineering perspectives respectively). Such methods aim to model systems complexities more realistically. For example, FRAM focuses on what people usually do i.e. they usually succeed at work. When they fail they are almost always doing what made sense to them at time (the 'local rationality' principle) and so their behaviour needs to be properly understood in that context. So these methods aim to take account of system complexities, emergent properties and hindsight bias (extrapolating backwards in a linear way from selected outcomes i.e. usually what has gone wrong) among others. (for hindsight bias see e.g. Dekker 2015, p28)

Selecting a method and avoiding bias

What can be said about this debate in practical terms and the implications for investigation method selection? Whatever method(s) are used, they need some basic qualities – and one of the best is simplicity. So, any investigation method needs to allow the piecing together of a ***timeline*** to make initial sense of the events and then to facilitate an ***analysis*** stage. Whatever story finally emerges, it needs to be tested (does it hang together?) and a check made that that there aren't other competing stories that may explain the events better. So any investigation method needs to understand that story through the timeline and subsequent analysis of events, and ideally supported throughout by at least one reliable source of evidence, and preferably corroborated by more.

For the analysis of contributory and root causes the method(s) selected can provide structure and support but will also require an experienced investigator (see below under 'Training and Competence'). What should therefore drive the choice of an investigation method? Well, simplicity as already said above coupled with usability and a better focus on giving investigators and their teams an overview of HOF - as a starting point knowing what PIFs to look for, how to identify and understand key behaviours (errors or workarounds), and how not to bias an investigation through poor or selective interviewing and evidence-gathering techniques. Whether the method is a decompositional (traditional) one or a newer systems' one is less important than the investigating team's understanding. If they know the limitations and capabilities of their chosen method(s) – and of people and their behaviour – then success is much more likely. Choosing a complex and not well understood method is likely to end up with the method tail wagging the investigating dog. The organisation concerned also needs to show both that it values organisational learning (including the investigation process, and going beyond just assigning blame or frontline error attribution) and that it will deliver the necessary time and resources to enable this to be done properly.

Experienced investigators tend to be pragmatic in their use of methods i.e. they pick and choose what to use and when to use it. Very simple or complex incidents can be problematic for formal methods. Even the newer 'systems thinking' methods can produce odd outcomes in less experienced hands. For example, the increasing use of 'loss of situational awareness' as a root or contributory cause (Dekker 2015, p69). Situational awareness is neither a cause nor an explanation. At best it describes something. Identifying it as a cause is the systems' equivalent of using hindsight to blame the frontline operator. The operators' behaviour made sense to them at the time and clearly they didn't know what they didn't know.

Human beings are hard-wired to want to make stories out of events, to make sense of the world. But there are some shortcuts in that hard wiring – often referred to collectively as 'cognitive biases'. From an evolutionary viewpoint these are generally useful and produce 'good enough' outcomes. The hindsight (see above) and confirmation biases are two well-known ones that can affect investigations. Confirmation bias is looking for evidence that supports what is expected. For example, what an investigator initially suspects has gone wrong. This can lead to prioritising evidence that confirms this against neutral or contrary evidence, and also to stopping the investigation process once such confirmation has been found. One other key bias is the fundamental attribution error (e.g. see Reason, 1997; Strauch 2004). People are initially more likely to attribute others' behaviour in an accident to a personal / character failure but when explaining their own will appeal first to external and environmental factors. So investigators need the time, evidence and understanding to develop a balanced view – the truth usually lies somewhere in-between. Individuals have privileged knowledge of what might explain their own behaviour and can more readily assemble external and environmental explanatory factors – doing the same for others requires more time and effort.

Training and Competency for Investigators

So investigators need a good awareness and understanding of the potential for cognitive biases, and they need to understand the strengths and weaknesses of the method(s) they are to use. They also need to understand the pre-incident events from the viewpoint of those involved – what made sense to them at the time – and how to identify and analyse key behaviours of interest. Given that most mainstream investigation methods do not deal with the HOF issues fully or in an integrated way, any method(s) selected will likely need to be supplemented to support the behaviour aspects. Investigation is also usually a team activity and requires a softer and more process-based skill set to i.e. how to do it and so training needs to reflect these practicalities too, as well as the softer team skills required (communication and so on). Deploying a team can help offset some of the risk of bias. Otherwise the resulting findings can be the old chestnuts such as modifying and extending the procedures, re-training frontline staff, restating responsibilities / accountabilities, and allocating blame to the frontline.

So although method selection and appropriate training courses are a starting point it is also important to select the right people at the right stage. If they are trained without investigation experience then the method(s) processes may take over and drive the outcomes. So some experience of assisting an investigation team first is best. Consolidation after a training course can be problematic in terms of opportunities and in practice this can often be unstructured. So if incidents are not available then it is also possible for investigators to work through for example: selected 'cold cases', near-misses, quality-related incidents or equipment / plant failures, and identified problem behaviours so that they can practice more consistently and reliably, and under less pressure than might result from immediate involvement in a significant process safety or personal injury incident. This is particularly the case for practising their HOF skills and methods initially. They can also be encouraged to apply the same skills and methods prospectively (as part of ongoing auditing of the safety management system for example) to help consolidate their training and develop / maintain experience. Such auditing can be structured through selective use of critical procedures to walk and talk through with those that perform them, and with an eye to key PIFs. Wherever the reality departs from the procedure (and it usually will, and quickly) then there is either an improvement (learning) point or something to fix. Usually people are working around some constraint, change or other real-world issue and so this prospective approach adds value. After an incident the focus is on what went wrong on this occasion, and not on all the times the work got done successfully prior to that (and no one checked).

Performance Influencing / Shaping Factors (PIFs / PSFs)

Understanding errors in context requires reliable identification of the PIFs (PSFs are exactly the same) – those factors which, on the day, make errors more (or less) likely - see e.g. (HSE (undated)) for a basic list. These are a range of factors, internal and external to the individual which affect human performance, either for the worse or better. If we can optimise these beforehand then errors are simply less likely, and with good error management we will know where the vulnerabilities remain and can at least monitor for these prospectively. There are various lists or taxonomies of PSF /PIFs available but these need to be used with understanding and by focusing on the higher-level categories first ('What pool am I fishing in here?') otherwise investigators can be overwhelmed. Equally the use of multiple drop-down menus (on-line or in hard-copy) with multiple PIFs (or HOF causes) can drive bizarre results. Where such lists are used then good supporting training and guidance is required for consistent and reliable usage.

A simple subdivision is into personal, job and organisational factors. Less effective investigations tend to identify the personal and job factors better and may neglect the organisational factors. Why? The organisational factors are often seen or experienced as "the wallpaper' (Wilkinson and Rycraft 20xx) i.e. 'The way things ARE round here' (not 'The way we DO things round here' as in one common safety culture definition). …). So even if they are identified reliably and appropriate recommendations made (and they may not be) there are often barriers to implementing these effectively, either perceived or real (and often in practice both)

Organisational factors are not only important in investigations, they also set the tone, resources and general landscape for investigators and for the value of the investigation process. Even though an organisation may say it wants quality investigations if in practice investigators do not have the time or resources – and if the organisation focuses on quick resolution of investigations, development of recommendations and close-out – then the outcomes will likely be disappointing. So the more challenging HOF issues may simply be avoided to enable such speedy resolution and to avoid a 'deeper dive' into the investigation.

Case study

This case study illustrates one major oil and gas company's investigation journey, and a shift towards simplicity and usability in its mainstream methods, and the selective use of a specific HOF investigation method alongside these.

Development of BP investigation method

BP recently issued new group-wide incident investigation requirements. The intent of the changes was to further improve investigation quality by managing the development of and maintaining investigation leader capability and by using a different and reasonably simple investigation method ('Logic Tree') for higher severity incidents. Prior to this BP used its own Comprehensive List of Causes (CLC) methodology in association with selective use of HFAT® for key behaviours, however it was considered that a combination of this methodology and variability in investigator capability sometimes encouraged a 'reverse engineering' approach. It was found that investigations sometimes involved discussions on how best to fit the available evidence to the CLC options. A criticism of the CLC approach was that investigators were coaxed into hindsight and confirmation bias. Hence, it was identified that investigator competence required greater focus along with a different method that prompted a more open minded / unblinkered outlook, and where the method did not bias the investigation. Using HFAT® to analyse specific behaviours of concern in selected incidents was found to work well but was

underused for various reasons, e.g. capability and confidence of investigators and difficulty in integrating with the CLC method. BP therefore looked for a more straightforward and user-friendly approach that would complement HFAT® better and lead to more challenging outcomes and organisational learning. This was a substantial project which has transformed the investigation process in BP. The transition has involved the training and certification of in excess of 400 investigators (at Master and Skilful Levels) taking over 3 years to complete.

The new BP method for investigation of complex incidents

BP utilises a 'logic tree' method for analysis of higher severity incidents and HFAT® for human factors analysis. The logic tree (think of it as a type of why / because analysis, similar to fault tree without the logic gates) is developed by the team using their choice of off-the-shelf mindjet software, excel, or visio. It is a free-flowing method that involves early development prior to significant evidence collection – this way hypothetical causes or contributory factors can be identified. The advantage of doing this is that the analysis tool can be used to frame lines of enquiry for investigation. The logic tree is then revisited and hypotheticals ruled in or ruled out. There follows a fresh round of hypothesis development and this cycle continues until sufficient depth is realised. BP uses the logic tree to drive identification of lines to follow, and to capture and map causes and contributions. The completed tree then reflects all the causes identified and ruled in, ruled out or unverified. It therefore helps the investigator maintain a record of the breadth and depth covered. The logic tree approach explicitly aims to address physical, human, management system and organisation / leadership factors. In addition, the method requires the investigator to look across the whole logic tree beyond the 'linear' cause and effect relationships. The logic tree do**es** not integrate seamlessly with HFAT® but the principle is to use logic tree to help identify key behaviours for possible HFAT® analysis and for output**s** (PSFs, antecedents and consequences) **to be identified**. These are then pulled back into the logic tree for the organisational factors supporting these PSFs etc. to be investigated / understood. BP has worked with Keil Centre to improve the usability of HFAT® and increase linkage to the logic tree method. The relationship of logic tree to HFAT® within the investigation process is shown in Figure 1.

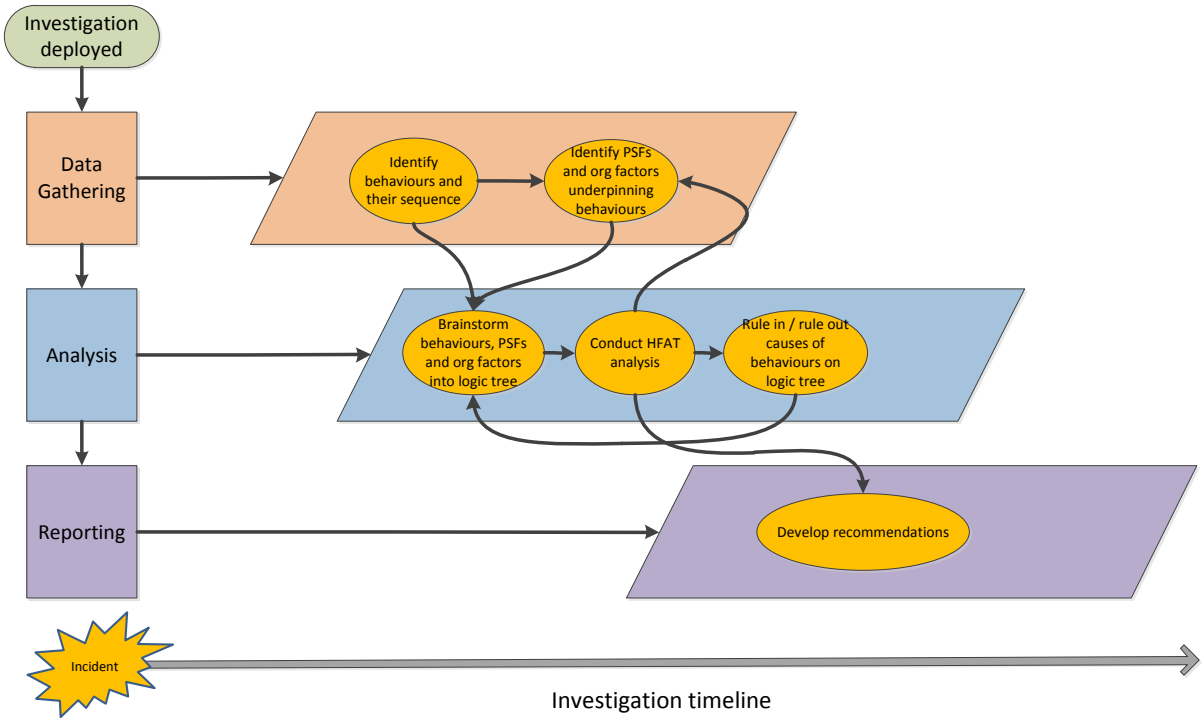

Figure 1: How human factors fits into the BP investigation method.

BP Master Level Investigators are pre-selected individuals identified by their business or segment as having the necessary skills and experience to lead complex investigations. They are provided with investigator training (4 day residential class) with the assessment of certain skills (e.g. interviewing). A brief HF session is provided and behaviour identification is woven into the practical exercises. The need for investigators to put themselves 'in the shoes' of the people involved in the incident is an important part of the training program, aligned with interviewing and logic tree analysis. HFAT® training is available as an optional additional session that is delivered at the business / segment level. The investigator then goes through a period of certification on a live investigation. They are followed up closely by coach assessors (a small number of expert investigators) as the investigation progresses. There is a competence interview framed around a competence assessment record and then QA/QC assessment of the final investigation report. Application and knowledge of HF is a key area that is included in the assessment process. Successful candidates are then certified and added to the database. For recertification (after 2 years) the investigator needs to undertake suitable continuing professional development and incident investigations.

Use of the new methods has confirmed that this is a more user-friendly approach and matched with a capable lead investigator it enables the team to drive to appropriate breadth and depth in investigation. Findings tend to fall out of the

approach more readily and this makes it easier to record recommendations to help prevent recurrence. Logic tree is proving to be a good fit with HFAT® but investigators have identified a need for more training to bridge perceived gaps in competence and / or confidence in applying the HFAT® tools. BP is working on this with its cadre of lead investigators via a range of capability building measures such as HF coaching during investigations, provision of training, discussions in investigator community forums and by deploying HF expertise as part of investigations with a critical behavioural theme.

Case Study: Petrochemicals incident

In February 2015 there was a release at a Petrochemicals site of 25m³ of an acetic acid solution during the process of filling the process plant after routine maintenance works. The temperature of the solution released was 67°C, marginally above flashpoint. The solution was released into the unit sewer system and captured at the waste water plant. Given the quantity of the release and the potential flammability of the acetic acid solution the incident was classified as High Potential requiring a thorough incident investigation. Nobody was injured in the incident and there was no release to the environment. In BP this level of investigation involved the deployment of a Master Level investigation leader and the utilisation of the logic tree incident investigation methodology (Figure 2 shows a portion of the logic tree developed).

The sequence of events that led to the release was as follows:

- The process system was washed out (planned maintenance)
- On completion of the washing the system was drained using three drains
- The unit was handed over to the incoming shift team who were told the ‘drains are open’
- The shift team began execution of the start-up procedure
- Two of the drains at ground level were closed in preparation for introduction of the acetic acid solution
- Drain 3 (Figure 3) at the base of a vessel was left open
- Acetic acid solution was introduced (0900)
- Acetic smell was reported on the unit
- Troubleshooting began
- Leak believed to be a through valve leak at Drain 1
- True location of the release identified and Drain 3 closed (1030)

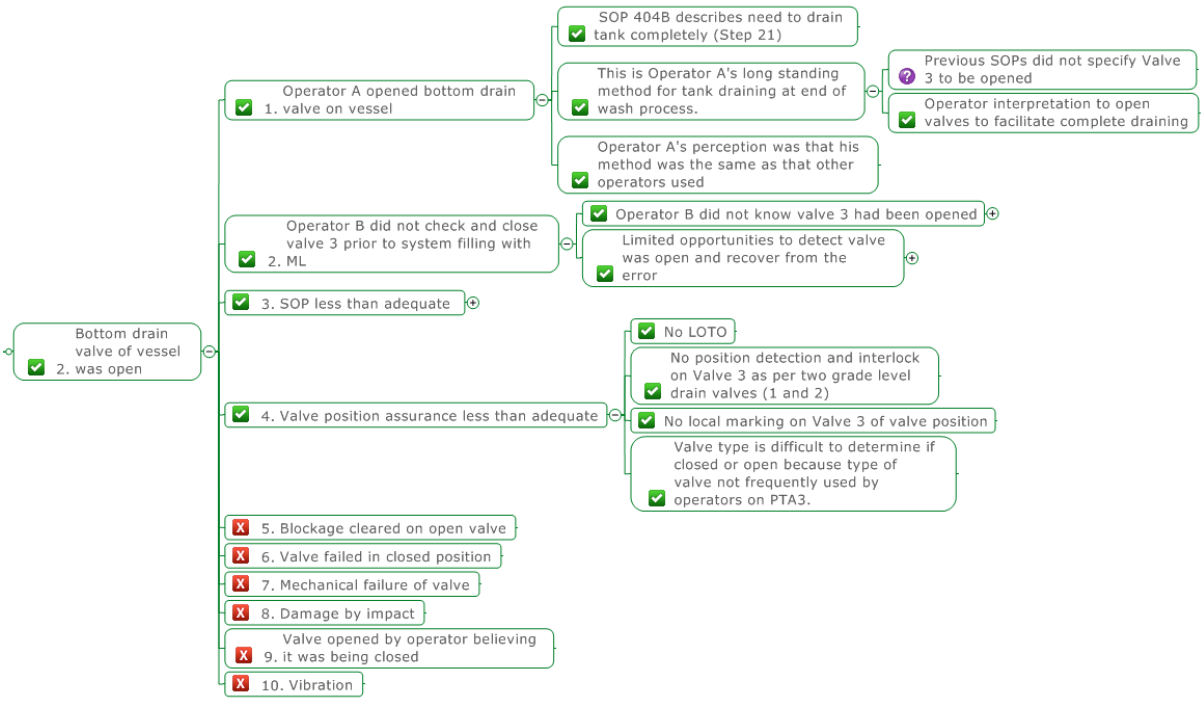

Figure 2: Example section of logic tree related to the valve being left open. HFAT® output was used to inform the behaviours of Operator A opening the bottom vessel valve and Operator B not closing the bottom vessel valve.

Much of the investigation involved understanding why the valve on the bottom of the vessel was left open. Note, weaker investigations might find the temptation to stop too great once they found the drain was left open and an individual accountable for closing it was identified!

However, rigorous investigator behaviour combined with effective use of the tools and methods identified:

- The outgoing operator opened all 3 drains to drain the cleaning material. This was a long standing method for draining that was used by this operator.

- The incoming operator closed drains 1 and 2 but did not close drain 3. He followed his habitual method closing only the drains he normally used when draining the system.
- The SOP in use was imprecise (e.g. close all drains), not written with sufficient input of operator, and updated frequently without the right communication with procedure users.
- Unit leadership recognised variation in the execution of the procedure for draining the system and did not reinforce expected use or verify conformance to the SOP.
- Previous opportunities to close the loop were missed.
- Then there was the troubleshooting…

Areas for recommendations focused on: procedure development, valve position assurance, supervisory oversight and non-technical skills development.

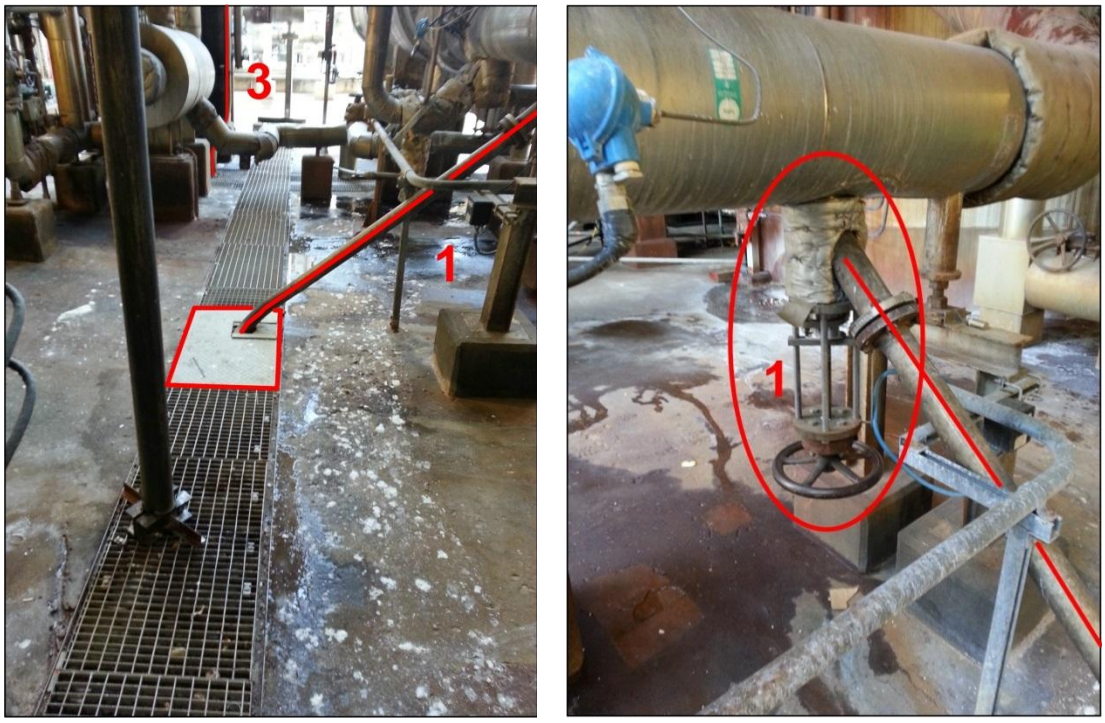

Figure 3: Selected images of the drains involved in the release.

Above: shows the outlet pipes, splash plate and sewer. Note, the outlet for drain 3 is upstream of drain 1. Drain 1 shown believed to be leaking, fitted with position detection (blue cable).

Left: the valve at the bottom of the vessel that was left open.

The Way Forward

While method selection should be done carefully, there is no perfect method out there (see the Energy Institute, 2008 guide which shows what a range of these methods actually cover) and none are suitable for all applications. Major incidents may make the use of any single method problematic and then their role may be more helpful in periodic checking of the investigation process for progress and completeness. It is important that any method does not simply drive the investigation (the tail wagging the dog) but offers a supporting framework and guidance through an often-difficult team process. It can also – if it is well chosen – help to sense-check other possibilities as you move through the investigation i.e. make explicit those factors and issues that just might be relevant, as a check.

Start with a method that is reasonably simple and don't be seduced by apparent desk-top simplicity followed by a tidal wave of huge drop-down menus or picklists which users will often struggle to understand or select appropriately. To understand key behaviours in detail and reliably then don't be afraid to use separate or add-on ways of doing this whether bespoke like HFAT® or integrated like TRIPOD, or through less formal means where the experience and background is available to do this i.e. this generally means having some HOF experience in or available to the investigation team. It makes sense to consider a 'toolkit' of investigation methods so that for e.g. simpler events the corresponding method is simple, and more sophisticated methods are deployed appropriately.

Although training in the method(s) selected is important it is equally important to practice. Remember that this practice can be done by utilising investigation principles and the factors normally looked for in an investigation, and using them in more routine and regular prospective activities like monitoring, audit and review, and through hazard identification and risk assessment processes. The use of police-type interview techniques is very helpful in neutrally eliciting the facts and giving witnesses and others the best chance to state what they think happened in a safe environment. There are some basic psychological facts about the limits of what people are likely to reliably commit to memory during an event, and it helps to make sure that witnesses are given the best chance of recall e.g. through walking and talking through the incident and providing aids like diagrams and photographs or documents so they have some context for this. It is also possible to adopt a more neutral 'debriefing' approach to eliciting information initially i.e. one that side-steps the issue of allocating blame or responsibility - see e.g. (Dekker, 2015 p46) for an overview of how this latter approach might work.

Make sure that the emerging story is coherent (it hangs together) and check that it isn't the only explanation for what happened. The best story of events will explain something and not just describe it. People do have a tendency to 'join up the dots' i.e. to complete a story, but it is vital to corroborate evidence and check that there are not other equally valid stories.

When looking at compliance issues make sure the real background or baseline for such apparent anomalous behaviour is established – is everyone doing this, just that shift or team, or just one person? Rarely is it just one person. What is the norm (what has become normalised through custom and practice and in such cases what are people working around? E.g. poor design, reliability, resourcing…? One very powerful way of finding this out is to walk / talk-through the procedure in question with either the person directly involved or another person who does this task. This will produce a clearer picture of the baseline and of the task and environment, and will generate better questions for the subsequent interviews.

Making Recommendations

Making effective recommendations is difficult and of course depends on how the investigation process has been undertaken. It is best to aim to influence groups of people, not one individual and to consider whether the need for the unwanted behaviour can be eliminated e.g. by influencing the system – how work is designed, organised, managed or – for workarounds particularly – considering what behaviour is actually wanted. This means moving on from analysis of what isn't wanted – which will likely produce a more limited and narrow set of recommendations – to what is wanted. And then make recommendations to support this wanted behaviour and reinforce it. Finally it is important to make sure that the culture and understanding are present for recommendations to be effectively implemented. This last step is often overlooked and the result is that the same kind of incident will recur there or somewhere else. Sometimes the focus is then more on pleasing the action tracking system to achieve close-out but if the real understanding is lacking then this will not result on effective implementation that is sustainable.

Conclusion

This paper offers pragmatic advice based on BP and investigator experience. It would make a useful starting point for ongoing review of existing investigation processes, and for improvement. There is no single magic method out there but understanding the limitations and capabilities of the methods used or selected will help offset this and 'one size may not fit all'- an investigation 'toolkit' approach may be more practical. Making sure that relevant human behaviour in an incident is as rigorously approached as the technical and engineering aspects will produce better investigations, recommendations and learning. In practice this means appropriate consideration of HOF issues both in the methods sued and in the investigation process itself.

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