Transient contractor and supplier risk management and assurance during shutdowns, outages and turnarounds

TRANSIENT CONTRACTOR AND SUPPLIER RISK MANAGEMENT AND ASSURANCE DURING SHUTDOWNS, OUTAGES AND TURNAROUNDS

1st edition

March 2018

Published by
Energy Institute, London
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Registered charity number 1097899

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The EI gratefully acknowledges the financial contributions towards the scientific and technical programme from the following companies

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Valero
Vattenfall
Vitol Energy
Woodside
World Fuel Services

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ISBN 978 0 85293 874 4

Published by the Energy Institute

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Shutdowns, outages and turnarounds (SOTs) of major accident hazard (MAH) sites are challenging. The SOT requires a lot of disparate repair and upgrade work to be done in a short period of time. Operators typically do not carry the staff or other resources to do this, but plan the work and engage one or more specialist contractors to carry it out. Often this involves the employment of a large number of contractor staff for relatively short periods of time. The contractors may be unfamiliar with the site and often will be undertaking non-routine tasks. A number of significant issues have causes or solutions related to human factors (HF).

This publication aims to identify pertinent areas where HF plays a role in the success or failure of a SOT programme. It is structured around a select number of issues, with an explanation of the HF issue and, wherever possible, guidance, checklists and case studies demonstrate how this issue can be addressed. The guidance provided is of relevance to SOT projects, as well as shorter projects lasting from a few days to a few weeks in length.

The subjects covered in this publication have been shaped by past incidents, therefore, there is a strong focus on work control, supervision and competence. Additionally, a number of other issues have been included that occur less often in the incident and safety literature and that are more specific to SOTs: examples include tools, spare parts and consumables. Issues related to these are often underrepresented in guidance on major hazard safety; however, some very significant incidents have occurred when spare parts, stores or equipment have not been managed carefully.

This publication is intended to be used by anyone who can make use of the guidance given. Some issues will require a significant degree of HF specialism, others can be addressed by anyone familiar with work on a major hazard site. It is not necessary to read this whole publication cover-to-cover. It is intended to be used like a toolkit, making use of relevant sections and guidance when needed.

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ACKNOWLEDGEMENTS

Transient contractor and supplier risk management and assurance during shutdowns, outages and turnarounds was developed by Rob Miles (Hu-Tech Risk Management Services Ltd) and produced by the EI Human and Organisational Factors Committee (HOFCOM). At the time of publication, HOFCOM members included:

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Management of this project and technical editing were carried out by Stuart King (EI).

Formatting was carried out by Jack Keaney (EI).

The EI also wishes to acknowledge the following individuals who contributed to the development and/or review of this project:

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1 INTRODUCTION

1.1 OBJECTIVES

The guidance contained in this publication is intended to be of use to operators planning, managing and undertaking shutdowns, outages and turnarounds (hereafter referred to as SOT) activity. This is the planned shutdown of some or all of a petrochemical process plant, refinery, power station or offshore installation[1] for a period of concentrated maintenance, where this maintenance is predominantly undertaken by staff brought on to the site for a defined period and who leave the site again once the work is complete. In general, these staff are employed by a third party contractor company, but they could be a dedicated campaign maintenance team employed directly by the operator.

This publication is intended to be used alongside existing relevant guidance rather than replace it. The content of this publication contains overlapping guidance on many specific topics (for example shift work, safe isolations and permit-to-work) and the user of this publication is expected to be familiar with other relevant guidance and regulations – there are many technical and legal matters that are beyond the scope of this publication but remain critically important to safety and regulatory compliance.

The mobilisation of a large number of contractors to SOT a plant, along with safe hand-over from, and hand-back to, the operator presents many challenges. Staff numbers increase significantly and many workers and supervisors arrive who, while experienced, are often unfamiliar with the site and the site operator's safety management system (SMS)[2] and working practices. A number of important issues, including competence, change from a procurement issue prior to mobilisation to an assurance and monitoring one during the SOT. 'Ownership' of supervision, and coordination and the control of work become very important during the time and resource-constrained environment of an SOT.

1.2 BACKGROUND

SOTs are an inevitable part of operating a major hazard site. It is not feasible, nor may it be safe, to shut down the plant each time maintenance is required or for each and every element that degrades over time. The solution is to run the plant for defined periods, typically one or more years, while aggregating all of the faults and applying operational risk assessments to continue operations safely up until the SOT. The SOT therefore requires a lot of disparate repair and upgrade work to be done in a short period of time. Operators typically do not carry the staff or other resources to do this, but plan the work and engage one or more specialist contractors to carry it out.

Delivering an SOT safely is a major challenge and a number of serious incidents have occurred during SOT programmes or shortly afterwards as a result of sub-standard work.

The process of operating with degraded safety defences is outside the scope of this publication; however, concurrent operation is considered throughout.

1 These are the intended applications but readers of this guide are encouraged to find other situations in which the material here can improve safety.
2 SMS is used to denote the elements of the operational management system that ensure safety, principally by ensuring safety critical elements (SCEs) are effective and the required competence and control of work are in place.

1.3 METHODOLOGY

This publication is written using the experience of those managing SOTs, a process that has been greatly aided by the assistance of the members of the Energy Institute Human and Organisational Factors Committee (HOFCOM), as well as the experience of the author as a former UK Health and Safety Executive (HSE) inspector.

2 OVERVIEW OF THE HUMAN FACTOR ELEMENTS OF SHUTDOWNS, OUTAGES AND TURNAROUNDS

This publication is organised around the influence that human factors (HF) has on the success or failure of an SOT programme. This is not a complete list of every activity, but a selected group of issues and activities where HF can make a significant contribution. Figure 1 illustrates the content of this publication, linked to section numbers.

The inclusion of these issues and activities into this publication has been shaped by past incidents, and so there is a strong theme of work control and supervision along with competence, as these are implicated in the majority of incidents that have occurred on major hazard sites, both in normal operation and during SOT. Additionally, a number of other issues have been included that occur less often in the incident and safety literature and that are more specific to SOT: examples include tools, spare parts and consumables. Issues related to these areas tend to receive little attention but they have the potential to cause significant problems if not managed effectively. Because they tend not to apply in normal operations they are often underrepresented in guidance on major hazard safety; however, some very significant incidents have occurred when spare parts, stores or equipment have not been managed carefully.

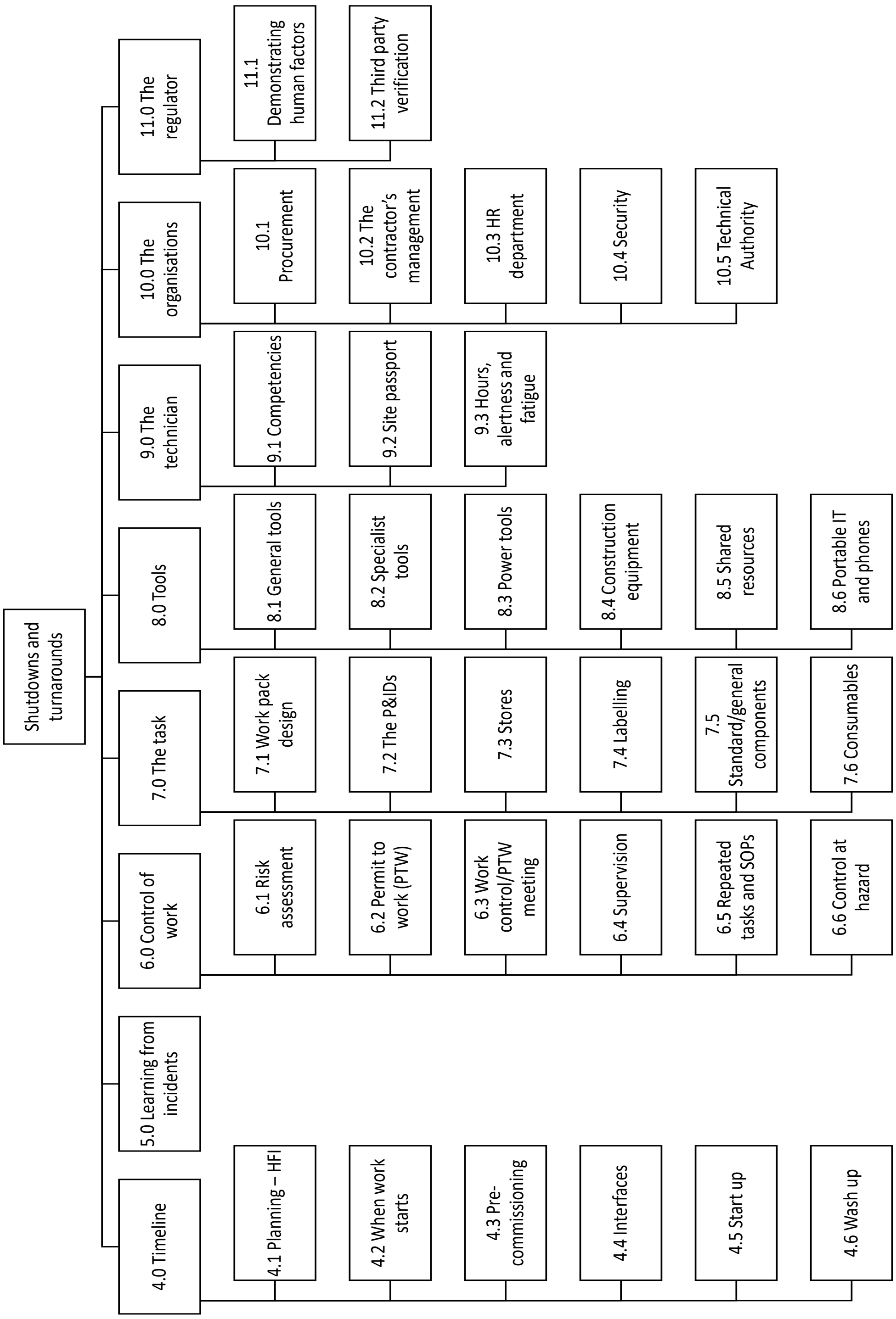

Figure 1: Overview of issues covered in this publication

2.1 HOW TO USE THIS PUBLICATION

The aim of this publication is to provide clear and concise guidance for companies to manage and ensure safe operations when using contractors and suppliers for SOT projects. It should also be relevant to shorter projects lasting from a few days to a few weeks in length.

Where possible, this publication makes use of existing guidance material on managing/ engaging contractors but supplements this with HF guidance best suited to SOTs. The approach taken has been to focus on the HF elements not covered in existing guidance; it is intended that the guidance in this publication should be combined with existing guidance to produce a more complete picture. An implicit assumption is therefore made that users of this publication are experienced in planning and manging SOT programmes and conversant with existing guidance and good practice, but despite this they continue to experience problems related to HF. This publication should therefore be used alongside relevant technical, regulatory and HF guidance as it is intended to support and enhance existing guidance rather than replace it.

– This publication is: a guide to the HF elements that apply to SOTs.
– This publication is not: a how-to for planning an SOT or major project, but it should help with that task.

This publication is intended to be used by anyone who can make good use of the guidance given. Some issues will require a significant degree of HF specialism, others can be addressed by anyone familiar with work on a major hazard site.

This publication contains a section for each of the selected HF issues shown in Figure 1. Each section provides a short discussion of the issues, some things to consider, some guidance on how to overcome the issue (where possible) and a check-list. Relevant case studies are also included.

It is not necessary to read this whole publication cover-to-cover. It is intended to be used like a toolkit. Clearly some issues are linked, for example permit to work (PTW) and supervision, and this has been noted in the text.

2.2 HELPFUL RESOURCES

References to guidance, regulations, research and incidents are included throughout this publication and listed in Annex A. However, there are other resources that should be utilised to help understand and address HF issues in an SOT programme:

– Company incident reports: the conclusions or root causes shouldn't be taken at face value; think about the issues in this publication and see whether some of these were implicated. If so, consider what changes could have prevented the incident.
– Breakdown and maintenance events: look for events that took place shortly after an SOT. These may not have been safety incidents but they could provide information about human error and latent[3] failures. Consider whether any of these breakdowns/

3 'Latent failure' in Reason's Swiss cheese model refers to a failure in the first three of the four domains: organisational, supervision and preconditions but not the fourth – direct acts. Here it is being used both in that way and also to refer to acts that remain hidden or dormant ready to cause an incident at a later time (such as upon start-up). Since these dormant or delayed errors tend to occur when supervision is weak or other pre-conditions are present this distinction may not be important in practice.

outages/trips can be linked back to an error in the maintenance work or how the SOT was managed or organised.

- Site formal safety report (for example any COMAH report, offshore safety case or Seveso Directive compliance report): the formal site operational safety report, safety case or risk control policy defines site work control systems for normal operations, competence requirements and the major hazards. Consider how widely this is available and how is this being factored into the SOT planning and communicated to relevant stakeholders, i.e. contractors.
- Operational risk assessment policy: what does the company SMS require in regard to operational risk assessments for concurrent operations, or operations with degraded (or temporary) safety defences? Some operations prior to the SOT will have been under an operational risk assessment and some operations will continue during the SOT. Be mindful of the SMS requirements that apply.
- Industry safety alerts: are there any that are relevant? Consideration should be given not only to those from similar sites or operations, but also those relevant to activities carried out during the SOT that are not usually carried out in normal operations (an example could be confined space entry).
- Supply chain contracts: what is covered in the normal contract with SOT contractors? In the light of the issues covered in this publication consider whether there are things that are missing that could be added. Does the contract focus on the correct issues?

3 ELEMENTS OF THE HUMAN FACTORS MODEL

The approach used in this publication uses the three factor model of HF (as used in HSG 48 *Reducing error and influencing behaviour*). In this model, HF consists of the following aspects (and often where the aspects overlap or combine) that influence human performance:

1. the individual (e.g. competence, biology, psychology);
2. the organisation (e.g. leadership, policies, culture), and
3. the job (e.g. the task, the work environment).

At the same time, the approach taken here is intentionally compatible with the barrier/defences approach in the Step Change in Safety guide *Human Factors: how to take the first steps*, which focuses on:

1. plant and equipment;
2. processes, and
3. people.

These basic categories have been expanded to cover the necessary detail of what takes place during an SOT programme (Figure 1).

4 TIMELINE

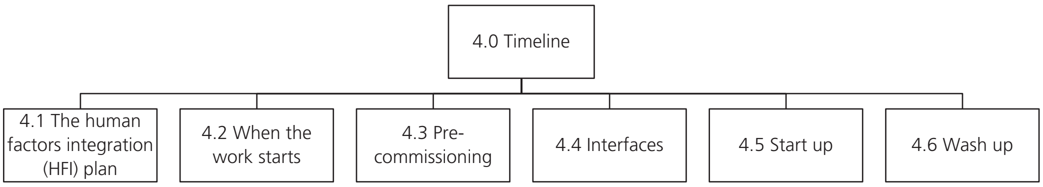

Figure 2: Timeline

The elements of the timeline shown in Figure 2 have been selected because they describe milestones in the progress of the SOT programme where there are specific opportunities to reduce the probability of human error. Error reduction measures are most cost-effective in planning, where small changes to specifications or methods could yield significant efficiency gains. When the project starts, contractors have been appointed and staff are ready to start work, so this is a time to control the 'human element'. When the work is completed and the plant is ready to start there is one final opportunity to capture any errors before they manifest themselves upon and after start-up.

4.1 THE HUMAN FACTORS INTEGRATION (HFI) PLAN

A human factors integration (HFI) plan is essential to fully realise the potential benefits from addressing HF. HFI plans are now commonplace on all new major projects, but the same approach is sometimes lacking for smaller projects. HFI should be part of all projects, with the application of the HFI scaled to be appropriate for the project.

Guidance on the creation and delivery of an HFI plan is contained in:

– HSE Research Report RR001, Human factors integration: Implementation in the onshore and offshore industries, and
– International Association of Oil and Gas Producers (IOGP) report 454, Human factors engineering in major projects.

These two references cover the principal elements of an HFI plan:

– be clear about who is responsible for HFI – the 'HFI Champion';
– follow the available guidance;
– set the policy of HFI early;
– set up measurable performance indicators/markers for successful HFI at the start that are tracked and reported throughout the project, and
– communicate the HFI plan and its requirements to the procurement team and suppliers.

HSE research report RR213 *Human factors guidance for selecting appropriate maintenance strategies for safety in the offshore oil and gas industry* contains a useful set of questions to confirm that the planned approach is likely to be the most effective and to confirm that the preconditions for effectiveness are met. While originally intended for maintenance rather than SOTs, the question set can easily be applied to a defined work programme.

4.2 WHEN THE WORK STARTS

When work starts it should be ensured that contractors and company departments have met their commitments: for departments this is likely to be in providing information and resources; for contractors it is likely to be providing competent teams. To do this, the following should be considered:

- Competence should be verified. Figure 5 and Tables 3 and 6 can be used to check whether additional supervision is required and which contractors' work sites require close monitoring. The pre-qualification requirements and commitments made by suppliers and contractors should also be revisited.
- The HFI plan should be reviewed and used to confirm that the necessary conditions are in place.
- The contractor maturity matrix in Table 6 and the supervision flow chart in Figure 5 should be used to review assumptions made and decisions reached. Are these still valid or is additional oversight required for some tasks or contractors?
- The organisation should be prepared to over-resource supervision for the first few days of the project. This could be done by bringing in retired staff for a few days or temporary transfers from other sites. If this is impractical, one solution adopted by the operator of a large refinery was to provide a dedicated telephone helpline that connected to a senior supervisor who undertook to answer all queries promptly.
- Consider using social media (such as Facebook or YouTube or other social media websites) and the internet to communicate messages to contractors, e.g.:
  - Provide a peer-to-peer area for contractors to support each other.
  - Post online videos made by staff about the values on site, optimised for hand held (i.e. smartphone) display.
  - Post details of site access, safe driving routes and laydown areas. Keep these regularly updated so that they are a dynamic resource. These can be optimised for smartphones so drivers can check before they arrive.
  - Provide a frequently asked questions section that gets updated regularly.

See also 10.4 Security and access.

Checklist 1: When the work starts

- Is the induction training in place?
- Are the site access arrangements for checking identity and competence in place?
- Are the emergency response plans up to date and in place?
- Are contractors arriving being given all the information they need in a format they can use?
- Does the site layout make sense – e.g. for car parking, access, deliveries?

4.3 PRE-COMISSIONING

The systems that have been worked on during the SOT should be tested prior to being brought online. Experience has shown that this is a period when errors can often occur.

Pressure and integrity testing involves the installation of boundary isolations prior to test, their removal after test, and then the reconnection of the tested sections to the rest of the plant. Isolations used for test may not be in the locations normally used for maintenance and so special care should be taken to confirm all are removed and the correct reconnections and pipe/process alignments made.

A number of serious incidents have occurred during isolations for SOT work:

– Pressure has slowly migrated across an isolation so that there is pressure where there should not be. Pressures should be regularly monitored during test.
– Sections have been left pressurised after test and this pressure has been released suddenly when reconnecting the lines.
– Isolations have been left in place on start-up.
– Vents have been left open from pressure test blowdown resulting in an uncontrolled release on start-up.

If inert gas is being used for tests, workers should be alerted to the hazard of asphyxiation by the inert gas when venting.

The breakdown of tasks in the PTWs for test and commissioning should be made very specific. It is very important to keep track of where pressure is and where it is not, especially when tests continue after a shift change. A particularly dangerous situation occurs when a pressure test fails and a job has to be redone to fix the pressure leak. This usually requires a separate PTW within the existing test/pressurise/depressurise sequence. However, it may be safer to suspend the PTWs for the test and plan the job again to re-establish the correct and safe sequence.

While the examples above are related to process pipework, these issues apply equally to electrical isolations where connections may be broken, made for testing, and then broken again prior to being made for start-up. If something requires rework it is all too easy to get out of sequence and break into a live line or open the wrong cabinet.

For each system that has been worked on, including any that were isolated but not worked on, there should be a defined system status for hand-back to the operations team prior to startup. This should cover the condition or settings of all SCEs, alarms and safety devices.

Case study 1: Shutting off protection

A major North Sea incident occurred where a maintenance engineer had shut off part of the control system of a gas turbine generator during routine maintenance. The logic controlling the purging system for the combustion chamber had been bypassed. There was a flame-out problem on restart. A significant explosion occurred due to build-up of fuel within the chamber, damaging the power turbine and exhaust and taking out the waste heat recovery systems. HSE inspectors investigating were surprised that no controls were in place to prevent the maintenance engineer switching off this safety control system.

Source: HSE RR430, *Offshore gas turbines (and major driven equipment) integrity and inspection guidance notes*

Checklist 2: Pre-commissioning

- Are all locked open/locked closed valves in the correct alignment?
- Are all isolations in the correct condition for start-up?
- Are all electrical isolations returned to service?
- Are all safety systems, alarms and relieves functional?
- Are the drains and vents clear?
- Are systems that must communicate (i.e. digital control systems) working effectively?
- Has everything that was brought in for the work now been cleared away?
- If changes have been made are these clearly shown and understood?
- Have physical markings, such as paint or labels, been used to show what has been checked and what has not?

4.4 INTERFACES

Interfaces between organisations will have been important throughout the SOT programme; those interfaces have been primarily addressed by contractual agreements supported by collaboration on the site. However, when the plant is being commissioned and started up, the importance and urgency of good communications and shared understanding increase. If readings and other parameters are not as expected when power and process media are introduced into the plant, it is vital to be clear about staff's roles and what they are doing in real time. The right time to resolve any confusion about 'who is doing what' is not while events are moving very rapidly; instead, this should happen earlier when there is more time.

One effective way to do this is to 'walk through' the possible scenarios with the relevant staff and contractors together and stop whenever there is a point of confusion. It should be agreed what identifies this point, what action is required and who is responsible for taking it. As the walkthrough progresses, these should be captured into a trigger action response plan (TARP)[4].

All parties should agree the TARP and it should then be issued as part of the formal start-up process. Note in Table 1 that the trigger variable (the condition that triggers an action) is **agreed**. This is especially important if the person to observe and the person to take action are not employed by the same organisation and where there may be significant cost implications for action. This is why agreeing the TARP in advance is crucial, as it should prevent revisiting any points of disagreement as events unfold.

Table 1: Example TARP table

Parameter	Person to observe	Agreed trigger variable	When to act/trigger value	What action to take	Person to take action	Expected outcome	Approved

4 TARPs were originally developed by the Australian mining industry: http://www.dmp.wa.gov.au/Safety/Developing-emergency-response-7933.aspx#toc_7952

Checklist 3: Interfaces

- Are the interface agreements in the project plan now in place?
- Have these been agreed by all relevant parties?
- Do they specify who is responsible for the scenarios identified in the hazard and operability studies (HAZOPs)?
- Is it clear who takes action and when?
- Have the interface agreements been tested?
- Have staff received training on how to use the interface agreements and what they mean?

4.5 START-UP

The configuration of plant alarms and displays are typically optimised for steady and safe continuous production. Alarms and trips are set to alert to deviations before they cause harm. In general, these deviations that trigger warnings are related to the failure of safety defences built into the process control. However, during start-up, it will usually be necessary to operate the plant in unstable conditions with a number of defences weakened and alarms and trips locked out. 'Locked open' and 'locked closed' valves may be unlocked and in their abnormal positions. It should be remembered that the locked-open/locked-closed valve register is likely to be an SCE.

Case study 2: One person when there should be two

A very serious (significant material damage and the potential for harm) incident occurred during the start-up of a 1 000 horse power electric motor. The motor had warning lights for cooling fan failure and motor winding overheating. As the windings would overheat on start-up, these were overridden manually as the motor sped up to a steady operating speed. The cooling fan power supply displayed that it was on and the central control room (CCR) operator assumed this meant the fans were running. In reality, the display only showed that power was being sent to the fans, not that they were receiving it. Unknown to the CCR operator the fan power supply had remained isolated after repair at a local panel near to the fans. The CCR operator continued to override the winding temperature alarm expecting it to stabilise. The temperature rose until the motor caught fire and destroyed itself. Once the temperature rose above the start-up range, a series of other alarms triggered leading to an ‘alarm flood’ that confused the CCR operator. The problem of local isolation of the cooling fans was known and the procedure called for start-up under PTW with a local observer to confirm fan rotation. A manager instructed the start-up to go ahead from the CCR alone without also utilising a local observer. The loss cost approximately £5 million. The two immediate causes of this event were:

- starting with no local observer, in breach of procedures, and
- not checking the plant was in the correct state (power to fans) for a start-up.

The poor design of the fan power indicator and the alarm flood were also contributing factors.

Consider using bowtie diagrams

Risk assessments, HAZOPS and safety defence analyses for normal operation may not cover all the situations during start-up. A bowtie diagram can be a useful way to visualise and analyse the start-up. Normal operation relies on safety defences on the left hand side (LHS) of the bowtie that protect against the top event – a loss of process stability or containment. During start-up, many of these LHS defences are locked out or have yet to come online. The plant is intentionally being operated in an unstable manner in a regime with fewer defences on the LHS and is more reliant on defences (mitigation) on the right hand side (RHS) of the bowtie that occur between loss of control and catastrophe.

There is a wealth of material on how to create and apply bowtie diagrams, for example:[5]

– The Civil Aviation Authority (CAA) website: https://www.caa.co.uk/Safety-Initiatives-and-Resources/Working-with-industry/Bowtie/
– CGE Risk website: http://www.cgerisk.com/knowledge-base/risk-assessment/the bowtiemethod

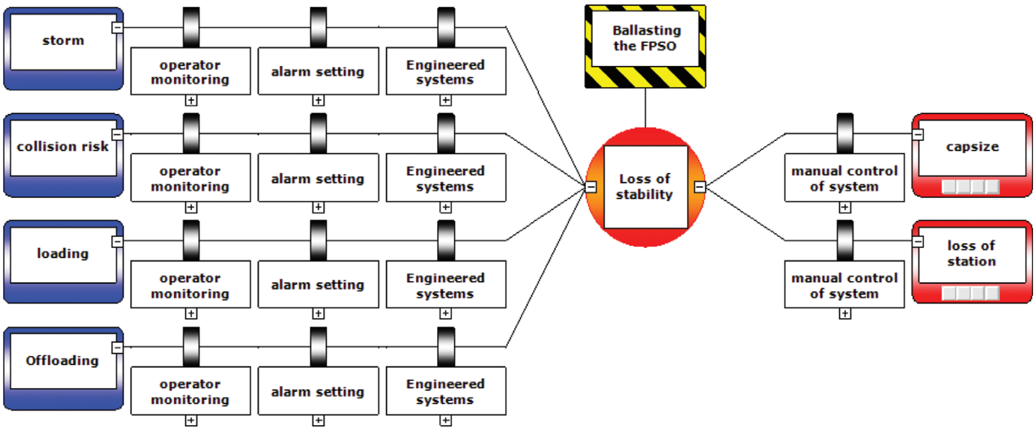

Figure 3: Example bowtie diagram

Visualising start-up in this way may help those involved to think differently about which alarms/systems/barriers will be overridden, for how long and why, and what additional protections may be needed during the periods of unavoidable instability.

Checklist 4: Start-up

– Do we have the staff numbers required?
– Are the relevant specialists (including contractors) available if there are problems or information we need?
– Are we monitoring all the additional variables required at start-up?
– Are we clear about what safety systems, alarms, and trips are bypassed for start-up and what the consequences are?
– Are we clear about when these safety systems will be brought back on line?
– Do we have agreed transient limits for process parameters during start-up that enable everyone to recognise when things are deviating from plan?
– Are we ready to start?

5 At the time of writing the US Centre for Chemical Process Safety (CCPS) and EI are producing guidance on the use of bowtie methods in process safety. This will include a chapter on HF.

4.6 WASH-UP

Project 'wash-up' (review) is the final opportunity to capture lessons learned to prevent making the same mistakes next time, and to build on the successes. During wash-up, the following questions should be asked:

- What would have stopped each problem?
- What could we have done better?
- Who over- or under- delivered?
- Who and what do we need to ensure we are ready/better prepared for next time?
- Did we delegate or contract the work in the right way?

It should be considered how the answers to these questions will be communicated to the team doing the next programme or to another site. Can it be done in an engaging or user friendly way? A detailed written report may be necessary, but other approaches should be considered, such as including a story board or video interviews with staff on the company intranet. Some of this could be done while walking the site and illustrating the costs of mistakes and the benefits of success.

Checklist 5: Wash-up

- Are we confident any problems on this project will not occur on the next?
- Do we have effective improvement measures?
- Have we done enough to ask those involved about issues that occurred and what can be improved?
- Have we captured this and placed it in a suitable location in the management system?
- Do we have a plan to use this information for the next project?

5 LEARNING FROM INCIDENTS

During an SOT, things will inevitably go wrong (deviations, unplanned events, near misses, etc.). The key is to identify the causes of deviations and unplanned events early, before they happen again or result in more serious consequences, and to do so while there is time to make useful changes.

Because of the nature of SOTs, being relatively short-term projects, the nature of learning from incidents (LFI) is somewhat different to regular operations. Because time is limited, the scope for investigation and change is equally limited. However, this does not mean LFI is not highly relevant.

The objective of LFI during SOT should be to flush out problems with systems and planning early on. This necessitates that the workforce be mobilised to report issues quickly. They may overcome issues locally, but to get the benefits of LFI, solutions and lessons should be quickly injected across the whole project. Wash-ups and debriefs work well, but, while some significant cases may require in-depth investigation, there is little benefit for the SOT in conducting long and detailed root cause investigations for lesser events. There is, however, a lot of value to be gained from rapid overview and quick feedback of these lesser incidents to the working teams. While in-depth investigations are relevant for serious events and post project debriefs, during the SOT itself, the primary action after all incidents will be to strengthen supervision and site control. The benefit of rapid LFI is to know exactly where the weak areas are and where to direct limited resources.

Case study 3: Many unrelated incidents

An operator company installing a significant new module of process plant was experiencing an unexpectedly high number of dropped objects. Each event was investigated but no common root causes were found. Some objects were left behind from construction, some incidents involved lifts and others involved tools. While there was no common root cause, there were common solutions based upon strengthening safety defences, one being site visits by supervisors, giving clear messages to look for and be aware of dropped object hazards to reduce the likelihood of more dropped objects during the project.

A key discovery was that supervisor site visits were often too late to capture unsafe conditions, a failure in oversight that would become even more important once hydrocarbons were introduced during plant commissioning. Improving early task supervision would therefore prevent a number of incidents with a variety of underlying causes.

Checklist 6: Learning from incidents

- Can we capture emerging issues early from incident investigations?
- Do we have an effective system to know about incidents?
- Does our investigation process enable us to extract lessons quickly?
- Do we have a process for getting learning points out to where they are needed and in time?

6 CONTROL OF WORK

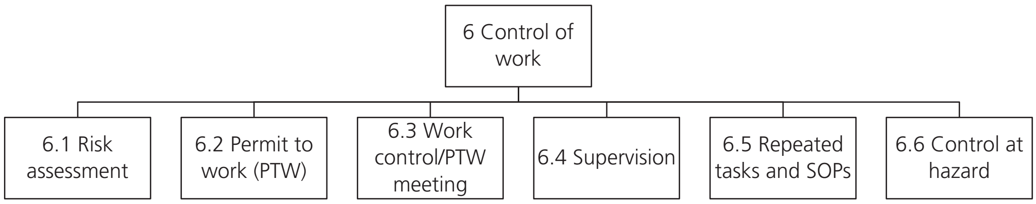

Figure 4: Control of work

In this publication the term 'control of work' is used to denote the whole system that controls the tasks on site to deliver the SOT. This covers the risk assessment prior to work, the PTW that permits it (or the procedures to follow if it is routine), and the supervision that oversees it and confirms that work is carried out as intended. The PTW system is fundamental to all major hazard sites. When site managers are asked 'how do you know work is carried out safely and correctly on this site?' they typically answer 'because we operate a PTW system and because it is supervised'. Tasks can be supervised without a PTW, but a PTW system without effective supervision is unlikely to deliver its aims.

Although the emphasis of this section is on control through supervision and the management process, there is another complementary approach which is 'control at hazard' – meaning controlling the hazard via very visible locking or marking at the place of work. This is described in 6.6. It is common to use compass points to orient on site but in reality 'site north' can be somewhat arbitrary, so, while the core crew will be familiar with where this means, many contractor staff may be confused. Signage and orientation should be considered for those new to the site.

6.1 RISK ASSESSMENT

Risk assessment is a cornerstone of health, safety, environment and business risk management and is always emphasised as a key element in incident prevention. Risk assessment typically follows this pattern:

- Step 1: Identify hazards, i.e. anything that may cause harm.
- Step 2: Decide who (or what) may be harmed, and how.
- Step 3: Assess the risks and take action to identify and implement control measures.
- Step 4: Make a record of the findings.
- Step 5: Review the completeness of the risk assessment and effectiveness of the controls and update.

Following an incident, it is not unusual to find that the hazard that led to the incident is missing from the risk assessment. It is much easier to be harmed by a hazard that has not been identified compared to one that has, because it is hard to take precautions against a hazard that has not been identified. Consider reviewing recent incidents in the organisation and comparing these against the risk assessments – ask whether the hazards that led to an incident had been included in the risk assessment (meaning treated as probable enough to require control measures, not simply listed and ignored).

This early failure of risk assessment is commonplace and therefore to be expected. Often, too much is asked of the staff doing the risk assessments – successfully identifying the hazards in a job requires an in-depth knowledge about what can go wrong for a wide range of tasks, situations, materials and equipment. This is a lot to know and few people have this breadth of knowledge. 'Hazard spotting' training aims to address this but, unfortunately, experience of incidents is the most powerful learning. Relevant incident reports should be made widely available and staff preparing risk assessments should read them and consider their relevance to their own work.

Where the site uses a 'hazard register' for PTW planning, this will typically be heavily biased to normal operations and may omit most SOT-specific hazards. The organisation should prepare a specific SOT hazard register and use this to improve the quality and relevance of risk assessments.

A meaningful risk assessment cannot be completed without knowledge of how a task can go wrong. The organisation should consider creating site-specific hazard prompts or checklists that encourage staff to consider hazards in the following three categories:

– Occupational safety: all competent workers and supervisors should be proficient in identifying workplace occupational hazards. This area is well covered in health and safety training.
– Project hazards: site management and contractor management and specialist contractors should be familiar with how their activities can go wrong. How is their knowledge and experience captured in the risk assessments?
– Major accident hazards (MAHs): these are generally the preserve of the site operator, who knows the processes and hazards, and for most sites these will be in the HAZOPs and formal safety report or safety case. This information is often kept back from the site because it is contained in the formal safety assessments (COMAH report, safety case) that are not widely shared or available during the work planning on site. However, these hazards are real and many major incidents have occurred as a result of errors during an SOT. It should be considered how to include MAHs in the workplace risk assessments and work packs.

There is no hierarchy to the above hazards; each type of hazard can result in death, be it a fall from a scaffold, a failed isolation or an explosion, but a risk-based approach should be taken to determine how much resource is spent on each category. Sometimes too much attention is focused on occupational safety at the expense of identifying MAHs and controls. Different expertise (and different people) may also be required to identify different types of hazards.

Case study 4: Nimrod XV-230

A graphic example of the consequences of not including frontline staff in risk assessment is the loss of Nimrod XV-230. The aircraft and crew were lost as the result of an in-flight engine fire. This risk was not in the operational risk assessment approved for service (Nimrod operations had an operational safety case), yet the aircraft technicians were seeing the results of engine fires and close calls on a regular basis. There was no evidence that those compiling the risk assessment had ever consulted those repairing the aircraft. Haddon-Cave concluded that the safety case was prepared by consultants without any input from the frontline operators. This led to the hazard (engine airbleed/in-flight refuelling leaks and fire) being absent from the safety case but well known to the maintenance staff and flight crews. Even the most cursory review of past incidents with the maintenance team would have identified this hazard and its severity.

Source: Haddon-Cave, *The Nimrod review: an independent review into the broader issues surrounding the loss of the RAF Nimrod MR2 Aircraft XV230 in Afghanistan in 2006*

A common failure of risk assessment is to propose controls or mitigations that will not be effective. The organisation should consider 'stress testing' the hazard controls. The suggested controls in the risk assessments should be proactively challenged by asking staff to 'walk through' the task and check whether the proposed mitigations would work. This is beneficial regardless of the outcome: if the control works then it reinforces its importance; if it does not it emphasises the need for better controls and shows how close the task was to having an incident.

Checklist 7: Risk assessment quality check

Walk the site and randomly sample risk assessments:

1. Do they contain a representative balance of occupational, project and MAHs appropriate for the site?
2. Is one category of hazard overrepresented?
3. Are the people with the required knowledge participating in the risk assessments?
4. Use a walk through: do the proposed controls actually mitigate the hazard?
5. Would some specific hazard awareness training or checklists improve the quality of risk assessments?

6.2 PERMIT TO WORK (PTW)

It should be made very clear which jobs require PTWs and which do not. It is less likely that a job that is compliant with a **well-completed** PTW will result in an incident; well-completed means that the PTW:

1. makes the hazards clear by having a risk assessment that contains all the relevant hazards and does not contain any irrelevant hazards;
2. has effective control measures that are clearly described and achievable;
3. specifies the conditions that must be in place before the job can start, and
4. specifies the conditions in place when the job is complete.

Points 3 and 4 should be observable as these will be verified by supervision.

While it is attractive to require all jobs to have a PTW, in practice this can be difficult to achieve, especially when supervisors are needed to make site visits and confirm PTW conditions are in place. If many jobs proceed without a supervisor's visit to check the PTW conditions are in place then there is a real risk that standards will drop as teams realise they can cut corners without being observed.

Another problem with requiring that all jobs have a PTW is the time needed to prepare and approve all PTWs. This can lead to delays that encourage teams to start work without a PTW and complete the paperwork later – a significant risk.

Instead, it is better to plan up front which types of job will require a PTW and which will not. There should be a clear distinction between jobs requiring a PTW and those not. Where any doubt exists this should be clarified by a senior manager. Many serious incidents have occurred when jobs that should have a PTW have been recategorised to be outside the PTW system to save time.

It is easier to enforce PTW compliance and get contractor buy-in when it is clear that the use of the PTW is restricted to jobs that are hazardous. Targeting the PTW in this way also frees supervisor time to make more site visits to confirm PTW conditions especially when routine tasks are addressed by the use of standard operating procedures (SOPs).

From a HF perceptive the primary function of a PTW is to trap human error before it escalates into an incident. This can be addressed by using a checklist (Table 2) to identify jobs more likely to result in human error. This can be applied to the established PTW categories such as hot work, cold work etc. The objective of the checklist is to identify recognised human error forcing conditions. The issues selected for inclusion are drawn from many incidents and near misses and so they relate to what goes wrong in the real world rather than recognised HF categories. This is intentional: experience from past incidents shows that staff do not make the read across from (e.g.) confirming an isolation is in place to confirming a valve is fitted the correct way around.

Table 2: Checklist for error forcing conditions

No.	Error factor	Description	Measures
1	Back-to-front	Things that can be assembled in a number of ways, only one of which is safe. May function when incorrectly installed but remain unsafe	– Mark the component with correct fitting. For example, an arrow and writing showing which way around* – Add diagram to task instructions and PTW – Add checking step to procedure
2	Look the same but are not	Components that are superficially similar but functionally very different so that substitution is unsafe. Examples are: valves with fire safe and non-fire safe ratings; carbon and stainless steel seal rings	– Mark components clearly – use descriptor terms as well as numbers – Keep similar looking parts separate – Add note to PTW and add checking step to procedure
3	Similar tag numbers	Typically where there are two parallel trains with sequential tag numbers. Parts may be subtly different (i.e. spool lengths) or isolations may be mixed up	– Avoid similar numbers for similar equipment – Where there are multiple lines, add 'risk of confusion' as a hazard to PTW and risk assessment – Add location check step to procedure
4	Right action wrong target	Carrying out the correct task on the wrong item of equipment. This could be pressuring the wrong accumulator, changing the wrong filter, topping up with the wrong fluid or going to the wrong production train. An 'everyday' example is wrong fuelling. It is a very common human error that can have very severe consequences	– Include this hazard in the PTW risk assessments and toolbox talks – Add location check step to procedure – Add pictures to the procedure showing key distinguishing features

Table 2: Checklist for error forcing conditions (continued)

No.	Error factor	Description	Measures
5	Wrong isolation	This is a subset of 'right action wrong target', but the consequence – cutting into a live line – is usually fatal or results in a major incident. Consider whether there are multiple similar process trains	– Include this hazard in PTW risk assessments and toolbox talks – Walk all isolated lines before breaking containment – Add pictures to the procedure showing key distinguishing features
6	Challenging task environment (specific to the task location)	Is the task to be undertaken in conditions that significantly increase the probability of error? E.g.: – poor light; – confined space; – very dirty; – intrusive PPE; – at height, or – cramped access	– Ensure these risk factors are considered in the PTW risk assessment and controls – Discuss each one in the toolbox talk – Evaluate the scope for redesigning the task
7	Performance shaping factors: tiredness	Will the work team be able to deliver the level of attention and alertness required to complete the task safely?	Include human performance (shaping) factors for tiredness in the task risk assessment and monitor these by supervision on site: – hours on duty during previous shift; – not rested from travel; – disturbed sleep, and – excessive overtime over tour
8	Performance shaping factors: physical exhaustion	Will the work team be able to deliver the level of physical work required to complete the task safely?	Include human performance (shaping) factors for physical exhaustion in the task risk assessment and monitor these by supervision on site: – physically demanding work on previous shift; – physically demanding tasks over the whole shift, and – physically demanding tasks scheduled during a period of low arousal (i.e. early morning)

Table 2: Checklist for error forcing conditions (continued)

No.	Error factor	Description	Measures
9	Performance shaping factors: work environment	Will the work conditions require such additional efforts as to prevent the work team completing the task safely?	Include human performance (shaping) factors for work environment in the task risk assessment and monitor these by supervision on site: – noise; – heat and cold; – wind and rain; – PPE; – lighting, and – exposed work location – i.e. over-side, cellar deck, work at height If practical reschedule the work to avoid the worst of the conditions
10	High Potential: pressure differential	Job has both low pressure and high pressure components and/ or interface, including relief and blowdown. Components can be fitted into the wrong line with severe consequences	Split high pressure and low pressure elements and parts in the work packs and use two means of identification, i.e. 'HP/ LP' plus tag/location

*Valves or other components labelled to show flow direction: wherever possible these should be made tamper-proof. This could be by means of a break seal or a tamper-proof sticker. In one case a valve with a flow label was fitted incorrectly and a worker then removed and reversed the label rather than refitting the valve. This was identified during a pre-start-up walk round, but because of the very serious nature of the violation it was impossible to find out who was responsible or what their motivation was. In another case a valve had a reversible plate showing 'open-close'. The worker installing it believed it was fitted incorrectly and reversed it. The worker was mistaken and a serious release occurred as a result. Subsequently the plates were fitted with break seals so that any changes were apparent.

6.2.1 Other PTW issues to consider

Record keeping
The PTWs will be a record of what was done and which jobs have been completed. If problems arise when the plant is being commissioned it may be important to revisit the PTWs to confirm that components have been fitted correctly and tasks completed.

Electronic or paper
While the additional functionality of electronic work control/PTW systems is attractive in normal operations it is worth considering a paper system for SOT. Contractors can learn a paper PTW system quickly. With many transient or temporary staff on site, signatures become very important for identifying who has done what. It may not be practical to set up all the required electronic PTW permissions. Another problem with electronic PTWs during SOT is the need for electrical power and access to the corporate IT network. There may be

times when the power is off for maintenance work and the PTW terminals and printers are offline. When this occurs it is very hard to keep contractors waiting.

Multiple PTW offices
An option sometimes used on decommissioning sites is to set up multiple PTW offices. This greatly increases the capacity of the PTW system and cuts the delays that underlie the temptation to work outside the PTW system. It also allows for the site production PTW system to be kept separate from the SOT work and PTWs. However this separation with multiple PTW offices introduces a significant communication problem that should be addressed: it should be clear where each task should be (or has been) approved and what the interactions are between tasks overseen and approved at one location and those overseen and approved at another. One option is to have overlap of attendees so that one person from each area attends the PTW reviews at the other location. If the PTW system is computerised then the networked IT makes it possible to put up the PTW lists from multiple sites together and check for any conflicts.

6.3 WORK CONTROL/PTW MEETING

The PTWs due for issue should be reviewed in a work control meeting before the start of the shift, ideally at least one shift in advance (opinions vary on this issue, but experience from the offshore industry suggests that requiring PTWs to be prepared at least one shift in advance improves the quality of risk assessments and review discussions).

The objectives for the meeting should be:

1. To check risk assessments have covered the significant risks, including:

- to the work force – occupational health and safety;
- to the plant – MAHs, and
- due to human error – latent failures and MAH.

These are not exact categories; the point is to hold discussions that cover the appropriate range of hazards. When PTWs are sampled on MAH sites they tend to concentrate heavily on occupational hazards and omit MAHs and human error. It is extremely rare to find 'going to the wrong place' as a hazard in a PTW risk assessment yet this has been the cause of a number of very serious incidents.

2. To identify any conflicts between jobs:

This often requires thinking in three dimensions as teams may be working above, below or in adjacent modules (when, for example, radioactive sources are being used). It is also important to know how elements of the plant are interconnected; this does not only mean the process pipework and cabling but also the drains, vents and heating and ventilation systems (HVAC) as these can and do communicate hazardous substances. Case Study 5 is an example of how one job can pose a significant risk to another and why having all the PTWs discussed together is important to identify problems like this.

Case study 5: Unclosed valve

On the day of the incident a maintenance team removed the pressure control valve for repairs. However, due to an inadequate isolation scheme, the valve was not closed, leaving an open end on the flare system. The maintenance team then went for a scheduled break. At the same time, a team of operators was depressurising a vessel through the same flare system to allow retrieval of a pipeline cleaning device known as a pig.

Neither work party was aware of the other's activity on the flare system. As the vessel was depressurised, gas escaped from the open-ended pipework into the turbine module. This triggered the gas detection system and an automatic blowdown of the platform. However, because blowdown of the gas was through the common flare system, more gas entered the system and increased the volume of gas escaping through the open end which resulted in a second uncontrolled major gas release in the turbine hall. In total, 600 kg of gas leaked into the turbine hall.

Had the maintenance team not been on a break, they could have been asphyxiated.

Source: Step Change in Safety

3. To confirm that the control measures are effective:

A number of investigations of incidents involving jobs where PTWs have been issued have found the control measures within the PTW often bear little or no relation to the actual hazards. There have been instances where the workforce have adopted the habit of including as many hazards and controls on the PTW as possible in the belief that this would assure approval, and in some cases the behaviour of management has reinforced this belief.

In one example, the PTW for a job at ground level required a 20-page risk assessment that included a full section on ladders and working at height. PTWs like this undermine the principles of effective risk assessment and work control. A survey found that 40 % of the offshore workforce felt the PTW was an obstacle to getting the job done.

To avoid falling into this trap, it should be ensured that the organisation:

- does not approve PTWs based on their size, and
- does reward (and publicise) clear, concise, specific and accurate risk assessments with no more than the directly relevant controls as good practice.

4. To identify high risk jobs or challenging or unusual controls:

High risk jobs should receive special attention to confirm the PTW conditions are in place before they start.

Those submitting PTWs should be asked to rank order the hazards by severity and the controls by criticality. This forces additional consideration and makes the risk assessments and controls much easier to read and evaluate. Sites that have adopted this approach have found risk assessments get shorter and PTW approval gets faster. Irrelevant hazards and unnecessary controls soon start to drop off the bottom of the lists which helps focus on those that matter most.

As an example, no PTW should ever require the use of standard workwear such as overalls, hard hats or work boots. If there is a problem on site with workers working without workwear or normal personal protective equipment (PPE) then this is not a problem that can be solved by a PTW. Conversely, if this is not a problem then why is it in the PTW?

6.4 SUPERVISION

The supervisor is the primary communication pathway between the work team and the management. They are also the lens through which workers observe management and management observe workers. The supervisors will make or break the safety culture depending on how they convey and demonstrate the safety values to their teams.

For normal operations it may be better to employ the supervisors directly because they function as the delivery for the operating company management system, with its requirements for accurate reporting and direction. However this may not be practical on an SOT project as many more supervisors will typically be required than could be retained between projects and specialist teams may need to be led by supervisors with the requisite specialist knowledge. The key is to ensure that all teams are effectively supervised regardless of whether the supervisor is an employee or a contractor.

An effective way to do this is to use core crew supervisors to oversee contractor supervision early in the project and determine which teams are being effectively supervised, and which are not and therefore require additional assistance.

Case study 6: Failure to check supervision early

A serious incident occurred on an offshore installation during an SOT because a contractor team was set to work for three days before anyone went to see how well they were doing. The team was inexperienced and the supervisor was recently promoted. As the team ran into trouble with the task of cleaning far down inside a column, the supervisor stepped in to help and went down the leg leaving the least experienced team member at the top. The procedure required the supervisor to remain outside the leg maintaining oversight at all times. The inexperienced worker lifted a 15 kg chain block incorrectly and dropped it 30 metres onto the work team including the supervisor. Remarkably it missed everyone. Installation operator procedures (set out in the accepted safety case) required early site visits for new contractors but these were not being done. A site visit would have found the inexperienced contractor supervisor had become entrained into the activity and lost oversight.

Key questions to consider are:

- How are supervisors trained and appointed?
- Are supervisors skilled in both technical skills and leadership?
- Do supervisors have an understanding of major hazards as well as occupational health and safety?

A multi-national survey of contractor supervision in 2008/9 found that a number of contractor companies in the UK appointed supervisors by 'Buggins' turn'[6] so that each team member had a turn at being supervisor (with the additional pay this entailed) (HSE North Sea Offshore Authorities Forum (NSOAF), *Multinational audit: 'Supervision'*). This was a most unsatisfactory arrangement that effectively rendered the supervisor powerless. It should be ensured that this is not the practice used by contractors.

6 A colloquialism meaning that everyone gets a turn.

It should also be considered whether there is a need for additional supervision at a job/task level: does this task require additional supervision? This type of supervision can be by a core crew or contractor supervisor.

The flow chart in Figure 5 provides structure to the decision process to determine how to allocate supervision. Table 3 provides a checklist to help identify jobs that justify closer supervision. This can be used at the planning and PTW review stages.

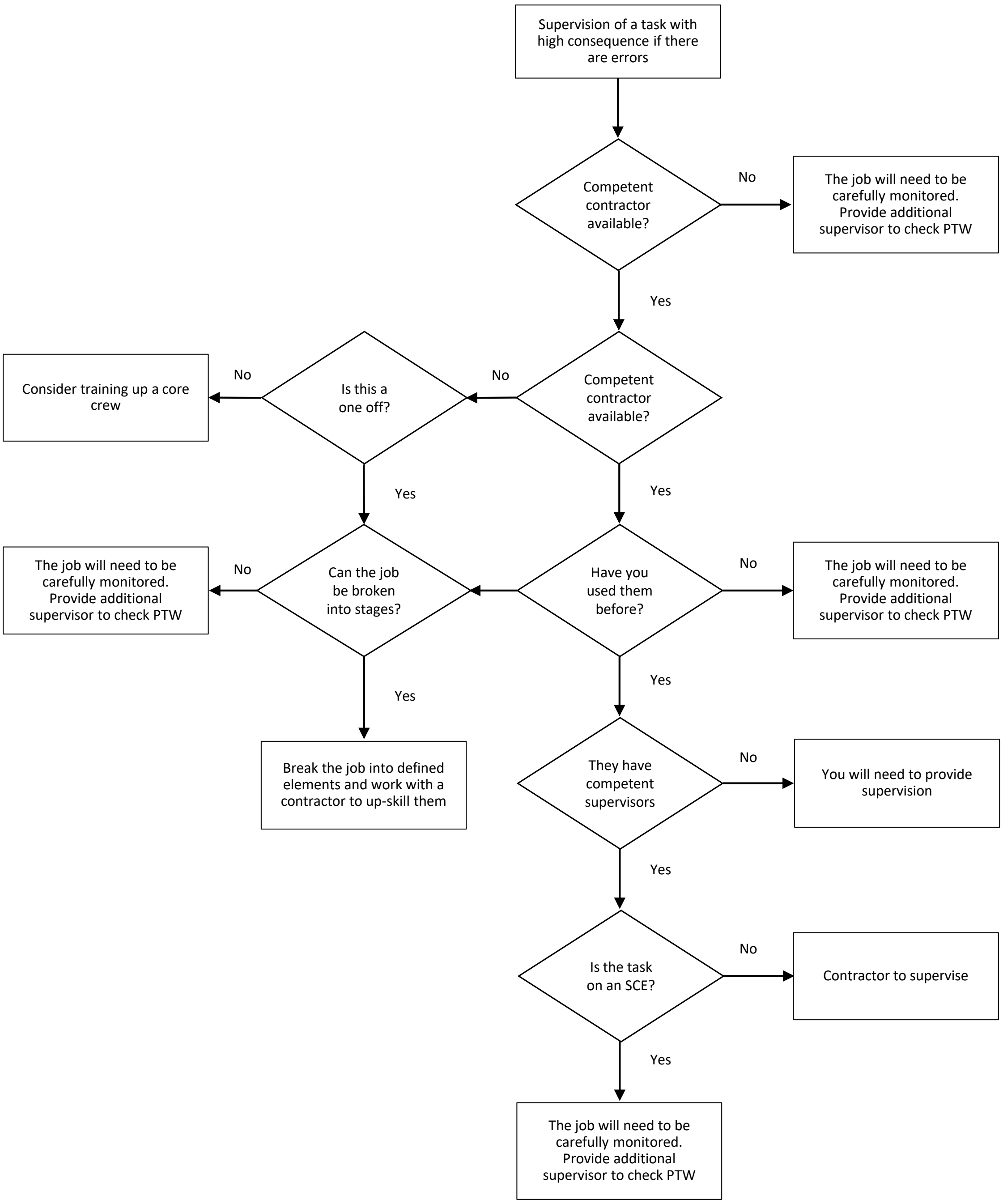

Figure 5: Allocating supervision

Table 3: Identifying jobs that justify closer supervision

No.	Criteria	Description	Supervisor action
1	High human error potential	Identified using the human error potential check list (Table 2)	– Confirm appropriate human error reduction measures are considered in PTW – Confirmed in toolbox talk – Confirmed at supervisor site visit
2	Novel tasks	Tasks rarely or never performed before. Tasks not covered by past experience and training	– Identify novel tasks in PTW risk assessment/review – Ensure additional protection in place – i.e. walkthrough tasks during supervisor site visit
3	Complex procedures	Procedures with a high skill requirement and a number of stages	– Flag up complex tasks at PTW and risk assessment – Reinforce during toolbox talk
4	Unproven contractors	Contractors that are new to the site and where no past experience of their capabilities exists	– Flag up in PTW – Schedule an early supervisor site visit to ensure contractor is working to PTW conditions
5	Job includes handover	Job extends across shift or crew change	– Flag up at PTW and risk assessment – Use written handover sheet – Reconfirm PTW conditions as part of handover
6	Job crosses locations	Elements of the job (e.g. isolations) are on more than one installation	– Flag up additional hazard at PTW and risk assessment – Check communications at toolbox talk
7	A combined/ simultaneous operations (COMOPS/ SIMOPS) task	A task that would have to stop and be made safe if the concurrent activity runs into difficulty	– Refer the PTW and risk assessment to the TARP (See 4.4, Table 1) – Ensure the work team are notified in sufficient time
8	Significant performance shaping factor hazard identified in task screening	The task or team assessment has flagged up a significant negative performance shaping factor	– Reschedule work to reduce risk – Break job into smaller tasks – Assign more crew – Evaluate alternatives

6.5 REPEATED TASKS AND STANDARD OPERATING PROCEDURES (SOPS)

Another way to reduce pressure on the PTW system is to proceduralise jobs that are repeated. This could be the whole job or a task within a job that may or may not require a PTW.

Risk assessments tend not to get better with repetition (if anything, they get worse) and so there is no particular benefit in repeatedly risk assessing the same task on different days or at different locations – these differences are important, but they can be addressed in the toolbox talk. It is more efficient to have a written SOP that includes the hazards and mitigations within the procedure. The best possible risk assessment should have been done, and the controls that would otherwise appear in the PTW are instead captured in the SOP. It should be ensured that the standard of the risk assessment and SOP is very high. Compliance with the SOP now effectively delivers the risk assessment, risk controls and the work instruction together. Where locations or other features vary, a checklist can be used for discussion at the planning meeting and again at the toolbox talk to confirm that the SOP remains appropriate. An example of where an SOP may require additional controls to be identified at the toolbox talk could be when the weather deteriorates and there is poor visibility or high wind.

Because there is still a need to address the requirement within the PTW system of knowing what jobs are going on and where, all jobs with an SOP can still be taken to the PTW review meeting and can be given a simplified PTW, but the process will be much faster and questions to ask at the review more straightforward, i.e.:

- Is this an SOP job?
- Is the SOP valid in this situation?
- Are any special conditions required?
- Can these be covered by the toolbox talk?

There is no need to review the risk assessment conditions in detail but the job should be logged into the day's work plan. A PTW can be issued but it is likely no risk assessment is required and the only conditions of starting work are likely to be:

- comply with the SOP, and
- cover local variations in the toolbox talk.

Examples of tasks suitable for controlling via SOPs include:

- bolted flange make up;
- transducer fitting and calibration, and
- cleaning and corrosion removal.

A sensible objective would be to shift 50 % or more of tasks to SOP-based PTWs with the remaining, highest risk, tasks requiring risk assessment. This should be combined with a focus on procedure use and adherence (PU&A) monitoring by supervision and supported by periodic audits. As a final note, it is not the intent that moving jobs from being controlled by PTWs to SOPs means that the job has or needs less oversight and control. PTWs add value for complex tasks but become undervalued for repeated tasks.

6.6 CONTROL AT HAZARD

Locked out tags and padlocks are common on MAH sites but they are part of the PTW and work control system. Here, 'control at hazard' refers to the flags, tags, streamers and gates attached or removed by the work team. This may (but not necessarily) be done within the PTW system. This approach is commonly used in aviation where there is widespread use of large streamers with 'Remove before flight' written on them. These are used to lock flight controls for maintenance and are designed to be visible from a distance and without needing to know where to look.

Figure 6: Example streamers on an aircraft

Examples include the following:

- Large flags and streamers attached to lock pins.
- Large tags with clips to fix to controls stating 'Do not operate'. These should include a section for the person who fixed the label to write who fixed it and why.
- Stout bags stating 'Do not operate' that can be put over a control marked with a tag showing who has attached it and why.
- Portable gates and bars that fit across the access to a confined space stating 'Do not enter' and showing who has attached it and why.

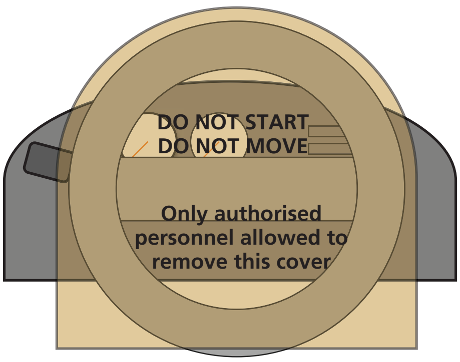

Figure 7: Illustration of a stout bag covering a steering wheel

Case study 7: A lesson from bus operations

In the UK, bus maintenance depots are classed as industrial workplaces and come under HSE inspection and regulation. For many years inspection had focused on the hazards of open vehicle inspection pits, machine tools and portable equipment. Yet, when a fatality occurred in a bus depot, it was actually when a technician stopped to change a rear light and crouched at the rear of the bus out of view. A driver got in to move the bus, unaware of the person out of view at the rear, and went to move the bus forward. Unfortunately the bus jolted back and fatally injured the technician. As a result of this accident it is now common practice to use marked bags on steering wheels. One of the many tragedies of this incident is that the focus on safety in the workshop area had diverted attention away from the hazards due to vehicle movement. The solution came from the aviation sector, where movement is a widely recognised hazard.

The standard practice during aircraft overhauls is to tie a label to the control column in the cockpit when a component is removed. The label describes what was removed and who by, and it is the responsibility of the person removing the label to confirm that the component is refitted and ready for service. This must be by physical examination and test, not by reference to documentation alone.

A significant problem occurs with confined space entry as many of those killed in confined spaces appear to have been unaware of the risks of entry. Physically marking and barring entry points provides a final level of warning and protection against unapproved entry. These may not physically prevent a person entering a confined space, but they may make them stop, think, then check with supervisors.

Figure 8: Example barring of confined space entry (reproduced with permission of CableSafe)

Other relevant products include the following:

- Valve covers.
- Flange tags: flange tags provide a local means of tracking the status of flanges. These are similar in design to the widely used 'scafftags' for scaffolding but with the additional elements required to track work on a flange joint.
- Marking tapes stating 'Do not cross': these are widely used but there are other tapes available and some can be made to order. Consider if this is an option for other commonly occurring hazards.

Figure 9: Isolated valve with tag

Figure 10: Marking tape

One feature shared by all these local solutions is that they recognise that protection is required because sometimes the paperwork is wrong. The unfortunate fact is that many incidents have occurred when documentation about the status of a plant or component was incorrect, misleading or missing and there was no tag, label or cover to alert the operator to recheck and confirm before going ahead. If staff or management believe that 'these types of protection are not required because the documentation is always correct' then this suggests complacency and that these types of protection are urgently needed.

7 THE TASK

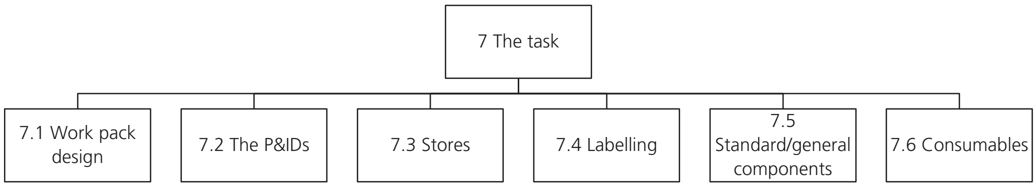

Figure 11: The task

A poorly designed task will set the worker up to fail by building in human error forcing conditions. The objective of those designing the task is to 'set the operator up to succeed' by designing out error forcing conditions wherever possible. Involvement of those doing the tasks always helps as they know what goes wrong. Similarly, reviewing incident and near-miss data can identify error-inducing tasks, although it is worth noting that many investigations are superficial and may not contain the required detail.

7.1 WORK PACK DESIGN

The quality and layout of the work packs sent to site play an important role in reducing the scope for human error. Some very serious incidents have resulted from poorly designed work packs or procedures contained in the work pack. What seems clear in the engineering or work planning office may not be so clear on site.

Table 4 provides a checklist for producing good standard work packs. It lists the following:

- Error forcing conditions: these are the things to avoid. These should be checked for in work packs and procedures before they go to site.
- Error: this is how the error forcing condition creates a hazard.
- Consequence: this is what is likely to result if the error forcing condition is present in the work pack.
- Control measures: good practices that will reduce the probability of the error.

Note that all the error forcing conditions, errors and consequences have been drawn from real incidents and a number have resulted in very serious harm. Most examples are from aviation because these investigation reports contain the greatest detail; however, many are also from the petrochemical industry. Some incidents have occurred due to multiple errors in the work packs so it is hard to be specific about linking errors to the resulting consequences; however, the 12 error forcing conditions have resulted in a number of individual fatalities in the petrochemical industry, one or more air crashes and at least one major incident offshore with a significant hydrocarbon release.

Table 4: Checklist for producing work packs

Error forcing condition	Error	Consequence	Control measures
Unnumbered tasks	Two tasks are confused so that some elements of one task are carried out on another task. Some may be done twice on one task and not at all on another	**Latent failure** Some stages of a task will be omitted or a task will be omitted. Others may be done twice but recorded as two separate tasks **Accident** Task is completed out of sequence	Number all tasks and number all steps uniquely Use task and step numbering when checking jobs Use task and step numbering for any hand-overs
Job cards with multiple similar tasks	Two tasks are confused so that some elements of one task are carried out on another task. Some may be done twice on one task and not at all on another	**Latent failure** Some stages of a task will be omitted or a task will be omitted. Others may be done twice but recorded as two separate tasks **Accident** Incorrect task is undertaken	Unique task numbering is carried through to job cards Enhanced descriptors are used for components and tasks to aid differentiation
Unnumbered steps	Loss of place in list, a step is missed	**Latent failure** Missing action (i.e. torqueing bolt, fitting seal) may not show on initial test **Accident** Task is undertaken before job is made safe	Number all tasks and number all steps uniquely Use task and step numbering when checking jobs Use task and step numbering for any hand-overs
Tasks with too many steps	Loss of place in list, a step is missed	**Latent failure** Missing action (i.e. torqueing bolt, fitting seal) may not show on initial test **Accident** Any one or more of the conditions above	Break long tasks into numbered sub-tasks (stage 1 of n, stage 2 of n, etc.) with 8–10 steps maximum for each stage

Table 4: Checklist for producing work packs (continued)

Error forcing condition	Error	Consequence	Control measures
Task list split over page break	Loss of place in list, a step is missed All steps on second page are missed	**Latent failure** Missing action (i.e. torqueing bolt, fitting seal) may not show on initial test **Accident** Any one or more of the conditions above	Break long tasks into numbered sub-tasks (stage 1 of n, etc.) with 8–10 steps maximum for each stage Do not split stages over a page break. Make sure the job is 'safe' at any break point
Confusing or non-specific term used within a task	Belief that term has been complied with when it has not because it is not specific enough for definitive judgement	**Latent failure** Relevant task is signed off as completed when it is not in a safe or correct condition	Remove any unspecified descriptors and replace with specific verifiable values. Avoid terms such as 'tight', 'hot', etc. – provide a value
Confusing or non-specific term used for equipment	Belief that the correct equipment is being used when it is not	**Accident** Equipment fails during operation	Describe correct equipment in detail and provide type number or reference number that can be checked on site
Similar parts on same task	Parts are confused and fitted or 'made up' incorrectly	**Latent failure** Flange torques or seals may be incorrect. Valves may be in wrong location	Use enhanced marking up of similar parts and link these to related parts. This could be colour coding or descriptors (i.e. 'HP/LP')
Elements that can be fitted in multiple orientations	Valves that fit both ways around but have a correct flow direction	**Latent failure** Part may function for a short while then fail in service	Use enhanced marking of parts (i.e. 'top') and mark flow direction Add pictures or additional descriptors Check line flow direction from known datum point
Parts that look alike but are not, i.e. different threads, standards or suppliers	The incorrect part is fitted. This is a high risk for small bore fittings and a known cause of hydrocarbon releases	**Latent failure** Part may function for a short while then fail in service	Wherever possible use only one supplier for similar parts and a single numbering coding system Segregate parts that are not compatible, do not wrack or store close to each other

Table 4: Checklist for producing work packs (continued)

Error forcing condition	Error	Consequence	Control measures
Generic items that are not interchangeable	Examples are sealants, greases and cleaning agents that will be widely available on site but may not be interchangeable (i.e. one sealant for another)	**Latent failure** Use of incorrect chemical resulting in material degradation over time	Control the material freely available on site and where possible keep to a single supplier. Use product codes and descriptions on task procedures and carry these over to the PTW
Confusing or ambiguous orientation information	The use of terms such as 'platform North' or 'upper level' without being specific to modules and visible landmarks	**Latent failure or accident** Components are incorrectly installed, i.e. facing the wrong way. Latent failure or failure on test. Delays in locating components and work locations. Non-specific PTWs	Where possible use pictures or digital images to show the orientation. Mark the worksite clearly using terminology consistently used e.g. 'Platform North'

7.2 PROCESS AND INSTRUMENTATION DIAGRAMS (P&IDs) AND OTHER INFORMATION

It is established practice to use the P&IDs to plan work packs and isolations. This generally works for new plant for which the P&IDs are an accurate representation of the plant. However, for mature assets, over time there can be a significant divergence between the P&IDs held in the engineering or headquarters (HQ) offices and the plant itself. In effect, there are two plants: the one HQ believe exists and the one that actually does.

This divergence can be a significant hazard and has resulted in serious incidents and, more commonly, a lot of risky site rework and unplanned modification. One of the most significant hazards occurs when isolations are planned and marked up on P&IDs. In one case, a job required over 100 isolations over the course of several days, but one was missed as a pipe connection was missing from the P&ID supplied. This particular plant had been designed in the 1980s with a design philosophy of minimising potential leak sites by removal of flanges. This had the unintended consequence of making it extremely difficult to isolate small sections of plant.

If the accuracy of the P&IDs used for planning cannot be verified then there are really only two options to mitigate this:

1. update the P&IDs before the SOT is planned, or
2. plan to allow time for site surveys to correct the P&IDs when isolations are required.

Neither of the options is better than the other. Option 1 takes time up-front and the P&IDs require regular updating. Option 2 takes up time on site and the marked-up P&IDs should be be filed at HQ.

It may be useful to include 'confidence in the P&ID' (or other plans) as a risk in the work planning and risk assessments. If the confidence is low then this should be reflected in the hazards and risk assessment along with suitable controls such as a site survey or continuous checking.

Information technology offers some possibilities for resolving this issue. Digitised drawings and computer aided design (CAD) drawings can be shared with contractors subject to ownership agreements and the necessary software. Head- or body- mounted cameras (headcams) are now robust and widely used by the emergency services, cyclists and extreme sportspeople, and can provide recorded or real time information about plant arrangement that can be viewed in the engineering or project office. 3D CAD mock-ups could be ported to augmented reality to enable piping and plant layouts to be visualised on site. This technology is widely accepted in the tourist industry to overlay information about antiquities and reconstruct the past, and there is no obvious obstacle to using it to construct the project objectives.

Case study 8: A large construction project

The 2015 UK Reading Station remodelling project used augmented reality running on hand-held tablets to overlay construction onto the site in real time as the user walked about the site. Those involved reported significant time savings from seeing where loads would be needed and placing material and equipment close to the point of use. Previously loads had been put on flat areas and often moved several times when they were found to be in the way.

Source: Wilcox et al (2012), *Augmented reality: Bringing BIM to life*, in Journal of Building Information Modelling, Fall 2012

7.3 STORES AND COMPONENTS

The focus of the storeperson tends to be on controlling what equipment goes out, usually with a strong control over PPE – gloves, eye and hearing protection and boots. The same control is seldom extended to safety-critical components and equally seldom to what parts come in. The fitment of incorrect parts represents a significant latent failure risk for a major incident and it is worth mobilising the stores to be part of the preventative measures. This is especially important (also see 7.5) for items that can be confused or where a failure leads to a major event, as for example with process seals. It should be considered how parts are placed in the stores, ordered and labelled and what, if any, checks are made when they are withdrawn to be installed.

7.4 LABELLING AND IDENTIFICATION

During an SOT project, a lot of materials will be arriving on site from suppliers and contractors. Where possible, suppliers and contractors should be worked with to set up a clear project identification system. Case study 9 provides an example that should be considered for use on site.

Case study 9: Use of labels

A pilot project by the UK HSE showed that printing safe handling and storage messages directly onto loads had a significant positive contribution to reducing handling, lifting and crane accidents. The labels used simple graphics (the organisation should be prepared to create and print its own labels) printed onto self-adhesive labels and fixed to material at the supplier before being loaded for shipment to site. The use of graphics was important in the context of construction where many users knew English only as a second language.

Source: HSE research report RR505, *Trojan horse health and safety messaging: An assessment of the long-term and behavioural impact on construction site operatives*

Another major success was printing the site arrival and safe route instructions onto the reverse of the bill of shipping. A study of deliveries in the timber industry found that lorry drivers tended to lose paperwork but never lost the shipping bill, as without this they could not unload at their destination. If it is not practical to print the site map and safe site transit instructions on the shipping bill then the organisation should consider printing it on a brightly coloured envelope into which the shipping bill is placed at their point of departure.

Human factors good practice should be applied to numbering systems and labelling:

- Distinguish numbers and letters clearly – not just zero and O but also 1, L, l, i, I and any others prone to confusion.
- Clearly distinguish part-, consignment- and serial- numbers.
- Break long numbers into sections so that they are easier to read and check, but use a box to outline the number to show that this is one number, not several.
- Do not use a lot of unnecessary numbers (for example four or five noughts in front of each part number).
- Make sure suppliers use labels that will stay attached on site.
- Where parts have labels showing the direction of flow these should be made tamper-proof.

7.5 STANDARD OR GENERAL USE COMPONENTS AND SPARES

On a large SOT project there will be many components that are used in quantities of hundreds or even thousands. Some examples include:

- O rings;
- nuts, bolts and washers;
- pipe/flange seal rings;
- small bore pipe fittings, and
- electrical connectors.

For all these small service items there will be approved grades, materials or other features that will be well-known to the core crew. However, during SOT projects many contractors are on site who are unfamiliar with the approved and non-approved specifications. Many contractors will bring small parts onto the site in their toolboxes and vehicles and there is a significant risk of unsuitable or non-approved parts coming on to the site and becoming mixed in with the correct parts.

The risk is significantly increased when the correct and incorrect components look very similar. Unfortunately this is often the case. Examples include the following:

O rings
O rings come in a number of materials and the difference can be extremely significant. Although small, these can have big consequences.

Case study 10: Wrong O rings

In 2015 the Cidade de São Mateus floating production storage and offloading (FPSO) unit suffered an explosion killing nine workers and resulting in an estimated $75 million unrecoverable costs. The incident was caused by the failure of neoprene O rings where Viton O rings should have been used. In this case the fluid composition was changed without consideration; however, the incident serves as an example of the consequences of error in such a mundane component.

Flange seal rings
There is no industry standard colour coding, so a green ring means 'stainless steel: for sour service' in one supplier's code and 'carbon steel: not for sour service' in another's.

Case study 11: Costly rings failure

A carbon steel seal ring was brought onto an offshore installation during an SOT by a contractor. It is probable that one or more of the carbon steel seals were left behind in the stores. Sometime later one or more were fitted into the process plant that required all to be stainless steel seal rings. Alter a period of years in service the incorrect ring failed resulting in a significant release and full shutdown. The largest cost incurred was shutting the plant while surveying hundreds of joints to identify how many more incorrect seals had been fitted. This was made harder because many PTW records were poorly completed.

Nuts, bolts and washers
Bolts and studs used in the construction of process plant are typically high tensile, but dimensionally identical fasteners are also available in lower grades of steel with unsuitable properties. Engineering departments and core crew will be well aware of this hazard and familiar with the markings on the correct fixings, but contractors may bring their own materials onto site that are not of a suitable quality and they might be less familiar with the hazards.

A second very significant hazard is the mixing up of threads on older plant. Metric threads have been the UK standard since the 1970s but prior to this unified fine threads (UNF) were the standard from the 1950s. Before that most threads in the UK were British standard fine (BSF), Whitworth (BSW) and British Association (BA). UNF continues to be the standard in the USA. Any plant dating from the 1940s up to the 1980s will have a range of threads. Most personnel younger than 50 will have had very little contact with these earlier thread systems. Even on modern installations the USA practice of using UNF can create confusion. A modern FPSO unit is currently operating in the North Sea with three compressors – two with metric threads and one with UNF. The metric units were procured in Asia and the other in the USA. They have very clear signs alerting maintenance crews of the hazard.

Case study 12: The flight of BAC111: G-BJRT

In 1990 British Airways Flight 5390 came close to disaster when one of the cockpit windscreens detached at over 17 000 ft altitude. Metric fixings had been used in an imperial thread. The fixings had held the required torque giving the impression that they were correct but in reality they could not hold the load. A subsequent Air Accident Investigation Board (AAIB) report found the correct and incorrect fixings to be nearly identical in appearance and racked close to each other in the stores. Note also that one of the recommendations was to ensure that those involved in such tasks must wear their glasses (if prescribed), because of the similarity in fixings.

Small bore pipe fittings

These are especially dangerous. Not only are there metric and imperial systems, but fittings are not interchangeable between manufacturers. Small bore fittings have been the cause of many serious incidents and at one stage were the largest cause of leaks on UK offshore installations. Many of these leaks resulted from poor installation and mismatch of components. There are extensive reports on this issue, for example HSE website *Analysis of investigated offshore hydrocarbon releases*, http://www.hse.gov.uk/offshore/statistics/hsr2002/section4.htm#immediate (See 4.2.3 of reference).

Guidance for addressing potential issues with all similar appearance items is as follows:

– Try to keep to a single supplier source.
– Mark items clearly.
– Retain small items in packaging; do not allow loose items without labels onto the site.
– Train staff in the hazards.
– When multiple similar items must be used (for example on the FPSO with metric and imperial fittings described in Case Study 12) label the equipment very clearly and segregate the parts in the stores, preferably under lock and key with access only by PTW.
– Consider the role of site security. Security are generally concerned with preventing unauthorised removal of material from site; however, the bringing onto site of unapproved material is a potential MAH. Security can be trained to recognise potentially hazardous components such as boxes of loose pipe fittings and fixings and remove these to a quarantine area for checking by the relevant technical authority before being allowed onto site.

7.6 CONSUMABLES

Examples of consumables relevant to SOT include:

– specialist cleaners and solvents;
– adhesives;
– lubricants;
– inhibitors and corrosion protection, and
– short life PPE – i.e. gloves, breathing protection and ear plugs.

Those planning the SOT and work packs will typically specify consumables in their method statements and procedures. There will be consumables already on site and in common use and contractors will bring their own preferred types with them. Some may be a suitable substitute for those specified by the engineering team, others may not. Equipment suppliers will also often specify consumables, often of their own manufacture, that are unique to a single item of equipment.

Each consumable should require a material safety data sheet (MSDS) and many will require chemical hazard safety assessment (for example Control of Substances Hazardous to Health (COSHH), EU Chemical Agents Directive) and PPE. The greater the number of consumables on site the greater the potential for an error and the more effort required to prevent one.

Case study 13: A bottom up approach

Encouraged by a company programme for staff to identify savings, a cleaner employed by a UK nuclear power station undertook a detailed review of the consumables used on the site. As a result of his detailed work they were able to change from over 110 to under 20 cleaning and related consumables with an annual saving of over £100 000. Many of the remaining consumables were significantly safer and therefore required less PPE and no risk assessment, a significant contribution to the savings.

Early in the planning stage, the organisation should work with contractors and suppliers to establish a master list of approved consumables and update this as the project develops. Where MSDS and/or COSHH (or EU Chemical Agents Directive) requires PPE consider including in an SOP that can be used in the PTW and toolbox talk. Each demand to introduce another lubricant, cleaning product or adhesive should be challenged once the master list is complete. While this takes time the first time it is done, once the outcomes are recorded for use on subsequent projects the risk reduction and savings will accumulate.

8 TOOLS

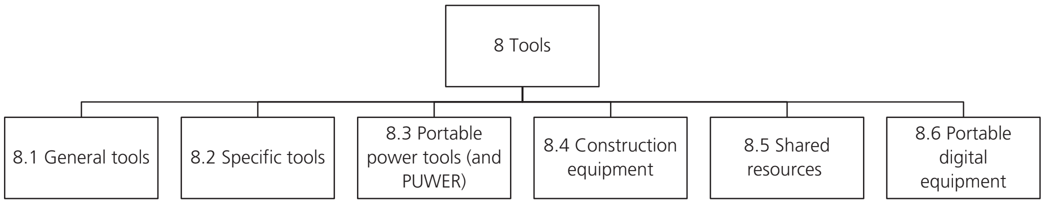

Figure 12: Tools

There is scant mention of tools in the literature on MAH and SOT programmes, yet they feature heavily in worker conversations. Tools are often the cause of ongoing complaints and irritations. Problems can therefore impact negatively upon concentration and increase the potential for error. Programme success often depends on good working relationships between core crew and contractors, as well as amongst contractors. Problems with tools can become a significant irritant that has the capacity to undermine working relationships.

8.1 GENERAL TOOLS

Examples of general tools include all the tools found in any technician's toolbox, e.g.:

- spanners;
- sockets;
- screwdrivers;
- pliers, and
- hammers, etc.

Case study 14 illustrates why tools are a source of potential problems on an SOT project. In short, there can be a real reluctance to share tools and spare parts, which can be a large issue if it means the right tool or component is not available to the contractor.

Case study 14: Reluctance to share

During the 1990s there was a UK offshore cross-industry initiative to move from existing practice of using core crew to undertake ongoing maintenance, to a programme of campaign maintenance in which specifically trained crews would be brought in to carry out lots of maintenance in a short period. The predicted benefits were realised for some categories of maintenance where the tasks were very similar from location to location, e.g. rotating machinery, but where each job varied there were few if any benefits. One lesson that emerged was the importance of tools.

Core crew owned their own tools or had a stock of shared tools on the installation. They would not share these with the campaign crew for fear of losing them. The campaign crews therefore had to bring all their tools with them, which is no small challenge offshore. It proved almost impossible to predict all the tools that would be needed and so there were always requests to borrow tools, causing friction between the campaign and core crews. The alternative was to use the wrong tool.

These issues do not only apply to tools; a similar situation occurred with spare parts. The core crew would build up a store of spares they knew were needed to keep the plant running and they were reluctant to share these with the campaign crew as they feared being left with no spares once the maintenance was complete. If this occurred they knew the breakdown would be on 'their watch' and they would be blamed if the spares were not available. The result was that the campaign teams had to bring all their tools **and** spares.

Part of the problem is the very significant price disparity between quality and cheap tools. A set of six high quality (professional) spanners costs around £190 in the UK, whereas a cheap set from a local discount store costs £1–£2. The high quality tools will not break and cause injury, the cheap ones probably will do, but many of those planning the jobs will be unaware of the difference and the importance of this to a skilled technician.

Checklist 8: General tools

1. Do we have a policy on small tools?
2. Are we clear what is:
   – provided from the site stores?
   – brought onto site by contractors?
   – personal to the core crew?
3. Have we consulted the core crew on their preferences?
4. How will problems be identified and resolved?

8.2 SPECIFIC TOOLS

Examples of specialist tools include:

– torque wrenches;
– hydra-torque units (hydraulic nut tighteners);
– pressure test and charging equipment;
– electrical test equipment, and
– explosive or high energy fastening equipment ('Hilti guns').

As with power tools (see 8.3) some specialist tools will be part of the site equipment and others will arrive on site with contractors. It is helpful to know what is on site and who is responsible for it. For specialist tools there are two factors to consider:

1. The risks to the user – does the tool contain stored energy such as pressure or does it enable the user to access energy, for example electrical or pressure?
2. The risks to the plant – could misuse or poor condition or calibration lead to a latent failure so that the plant condition is not as expected on start-up?

For the most part the risks to the user are covered in the UK by the Provision and Use of Work Equipment Regulations 1998 (PUWER); however, some tools are especially hazardous, including:

– tools where a lot of force is developed so that parts can be ejected;
– equipment accessing pressure, such as pressure test and accumulator charging equipment, and
– high voltage electrical test equipment.

In general, hydraulic pressure is contained as the hydraulic fluid is non-compressible; however, the same is not true of gas pressure testing and accumulator/gas charging equipment and therefor access to this equipment should be carefully controlled.

The primary way for tools to introduce latent failures is when tools are out of calibration. Bolts may not receive the correct torque leading to leaks later in service (under-torque) or early failure (over-torque), and pressures may be set wrong on transducers or pressure relief valves leading to early or late operation and potential MAH risk. Ensure that equipment that requires calibration is identified and link this to the PUWER register.

Test equipment

Test equipment commonly requires regular calibration, and for test results to be valid the calibration must be 'in-date'. This means that test results and calibration certificates should be kept in a central register or other filing system that allows tracking and recovery of test results and calibration details during the programme and once the plant is returned to service. Test and calibration details can be important evidence in an incident investigation.

Check list 9: Test equipment

1. Do we know what high hazard tools are on site?
2. What are the means to control access?
3. Is use restricted to competent users?
4. Is there a risk assessment before use?
5. Do we know what tools require calibration?
6. Is calibration checked at the appropriate intervals (in some cases before each use)?
7. Who has responsibility?

Case study 15: Accumulator charging

An operator on an offshore installation went to charge a high pressure accumulator using a nitrogen bottle. Unfortunately the operator accidentally connected the bottle to the low pressure accumulator. The high pressure charging set being used could not prevent the overpressure of the accumulator. The injured party was in the 'line of fire'. The low pressure accumulator failed catastrophically due to overpressure and the injured party lost one arm and suffered significant facial injuries.

Case study 16: Crane maintenance

A crane driver was carrying out scheduled maintenance on a crane and noticed that the hydraulic accumulator needed charging. The crane driver connected a nearby cylinder and began charging, when the accumulator exploded. Fortunately the operator was at a safe distance. The investigation found the crane driver did not have permission to charge the unit, and had accidentally connected a nearby oxygen cylinder instead of nitrogen. The oxygen cylinder was left over from previous turnaround work, and it was believed to have been removed from the site, but there were still oxygen bottles in the stores adjacent to nitrogen bottles. An earlier audit had identified an issue with segregating oxygen and nitrogen gas bottles but it was believed that all oxygen had since been removed.

8.3 PORTABLE POWER TOOLS (AND PUWER)

Portable power tools will be in much greater use during an SOT programme than in normal operations. Some will be tools that are part of the site resources, others will have been brought onto site by contractors. Some may have been hired in by the operator for specific tasks. These tools are likely to be:

- battery rechargeable;
- 110 Volt (yellow round plug 16A, powered from a step down transformer), or
- 240 volt (UK standard – square pin 13A three pin plug or blue round plug 16A).

Regardless of type and use all will be subject to health and safety regulations and good practice. The principal relevant UK regulations are:

- PUWER: this covers the specification of the correct equipment, competence to use it, mitigation of risk in use and maintenance in a safe condition.
- Control of Vibration at Work Regulations 2005: this covers the health hazard from vibration, principally hand-arm vibration (HAV), the need for monitoring and exposure control.
- Personal Protective Equipment at Work Regulations 1992: this covers the need for appropriate, effective and well-fitting PPE.

There are other regulations, for example, Noise at Work 2005 and regulations covering specific hazards (lead, for example); however, PUWER, HAV and PPE regulations overlap to cover most duties.

These regulations are written to cover a wide variety of sites that include those in manufacturing with significant potential exposure to HAV and also sites with harsh conditions where tools will quickly degrade. As a MAH site the majority of hazards envisaged by the regulations will either be absent or will already be controlled by existing site management processes. However, this should not be taken for granted and it is important to demonstrate that site management is effective in ensuring PUWER, HAV and PPE compliance and controlling the risks.

PUWER

A register of all power tools on site should be kept, which records when each tool was last inspected and confirms whether it is fit for use. In the majority of cases this can be a visual inspection on a weekly basis or prior to use. If a tool is unfit it should be taken out of service for repair. If a large number of tools are on site consider implementing a 'power tool amnesty' in which all tools can be taken to the (for example) mechanical workshop and visually inspected (with no consequences for the individuals involved). Those fit for use can then be marked (tag or paint) as OK and entered onto a site register. Any unfit tools can be quarantined.

Toolbox talks should be used to confirm that the team are competent to use the power tool and have identified and mitigated the hazards, including confirming whether correct PPE is available and is going to be used.

Where power tools present specific hazards – for example the potential for extended vibration exposure – the task should be entered into the PTW system to ensure a risk assessment is undertaken and exposure is monitored.

Contractors
Contractors should be required to be PUWER-, HAV- and PPE- compliant prior to arrival on site and should be able to demonstrate this in practice by having a register of tools and demonstrate that these tools are fit for service.

PUWER requires the site operator and contractor to agree PUWER duties, however in practice the site operator will find it hard to know what tools a contractor brings to site, how hard they work them and what condition they are in. Therefore it is more effective to agree with contractors that they are responsible for PUWER (and HAV). This does not remove overall responsibility from the operator for ensuring compliance. To achieve this, periodic visits to contractor work sites and their onsite containers should be made; it should be verified that tools are fit for use and that exposure is being recorded and is within HAV limits for the tool in question.

HAV
The HSE has a simple to use and clear guide to HAV monitoring. This is a paper-based risk matrix that enables judgements to be made about likely exposure. This system should be more than adequate for a typical SOT project. Contractors should be alerted some time prior to the start of work that they will be required to comply with the HSE guidance and must be ready for site inspection (HSE website, *Hand-arm vibration exposure calculator*, http://www.hse.gov.uk/vibration/hav/vibrationcalc.htm).

PPE
Contractors should be responsible for specialist PPE relevant to their activity; however, general purpose PPE such as ear plugs, work gloves and eye protection should be made freely available; the potential downside of having degraded PPE in use on the site is significantly greater than the cost of this provision.

Regulatory/compliance demonstration
It can be helpful to prepare a 'compliance matrix' for PUWER and HAV. The purpose of this is to show which work control practices contribute to delivering compliance with which regulations. The matrix lists the principal elements of the regulations on the vertical axis and the site work control elements across the top axis, e.g.: toolbox talk, work plan, PTW risk assessment, supervision, site audit, etc.

This is helpful for a number of reasons:

- it makes demonstrating and verifying compliance much easier;
- it links control measures to regulations which helps compliance, and
- it identifies overlaps and gaps so that resources can be better allocated to ensure all regulations are covered.

Checklist 10: Power tools

1. Is responsibility clear for:
    a. PUWER?
    b. HAV?
    c. PPE?
2. Is this agreed within the contracts in a manner that can be verified on site?
3. Is some role or named person responsible for checking compliance?
4. Are the key elements of PUWER, HAV and PPE covered in the PTW risk assessments and PTW conditions where these apply?
5. Are there toolbox talk prompts ready to use for PUWER, HAV and PPE?
6. Is there a site policy on power supply (battery rechargeable vs 110 V vs 240 V)? (Note that this is not a requirement, but it can help to provide contractors with some guidance.)

8.4 CONSTRUCTION EQUIPMENT

Construction equipment includes any powered mobile equipment not usually on site but brought in as part of the SOT programme. Examples include:

– telehandlers;
– mobile cranes;
– larger forklifts;
– diggers;
– mobile elevating work platforms, and
– dumper trucks.

Extensive safety guidance is available on this type of equipment for example on the HSE website, *Mobile plant and vehicles*, http://www.hse.gov.uk/construction/safetytopics/mobileplant.htm.

The key issues for SOTs are:

– This equipment is not a usual feature of the site, and so many staff may be unfamiliar with how it moves, what particular hazards it creates and how restricted the visibility can be for drivers and operators.
– The organisation should have a clear policy on exclusion zones to maintain separation between people and equipment, and policies on lines of sight, banksmen and agreed communication and hand signals should be enforced, linking these to the site's 'golden rules', 'life saving rules', etc. where necessary.
– There should be a clear policy on who is competent and allowed to operate machinery, and access to plant and equipment should be kept under management control. Where appropriate, the PTW system should be used to oversee access and use of equipment and to ensure that risk assessments are undertaken and control measures are in place.
– New technologies are entering service that can interlock plant equipment controls with workplace passports and 'smart keys' to restrict access to those with approval. There are now also new technologies that alert workers that they are entering a preprogramed exclusion zone around moving or live equipment by means of a personal alarm (for example built into their hard hat). These developments have the potential to reduce risk but are not 'silver bullets'.

Case study 17: Telehandler fatality

A roof mechanic was using a telehandler to lift a pallet of tiles to a fourth storey roof. He was operating the telehandler with the boom fully raised but not extended. Raising the boom reduced the overall length of the vehicle; however, it ultimately caused it to overbalance as it was being turned and manoeuvred. He tried to flee the telehandler as it began to topple, but he was unable to move away in time and it landed on top of him, causing fatal crush injuries.

His death was investigated by the HSE, which found the safety of the vehicle was compromised by limited space and other obstructions in the area where he was required to work. HSE inspectors established that the mechanic had no option but to operate the vehicle in this way. The space between the buildings where he worked was almost the same length of the telehandler with the boom lowered, and meant he would have had no turning circle.

Source: Fleet news website, *Costain sentenced for Parkway telehandler death*, http://www.fleetnews.co.uk/news/2014/7/25/costain-sentenced-for-parkway-telehandler-death/53090/

Check list 11: Construction vehicles

1. Are we confident we can maintain separation between moving equipment and persons on site?
2. How is this separation effective for persons **unconnected** with the activity?
3. How are we ensuring access is restricted to competent users?
4. How are we ensuring that the use of equipment is properly planned and safe?

8.5 SHARED RESOURCES

Shared resources refers to things that contractors need to get the job done but for which availability is limited. Typically this is large equipment but there are exceptions such as radios. Resources include:

- site or overhead crane;
- large site welding set (possibly with site-coded welder);
- specialist machine tools;
- construction equipment;
- temporary or portable electrical supplies;
- the test or calibration engineer;
- the PTW terminal and/or printer, and
- portable two-way radios.

The problem with shared resources occurs when a number of contractors require the same resource (often the crane or forklift) at the same time. Someone has to get priority and others have to wait. In some cases the wait can be many hours or even days and the contractors in the queue may be faced with missed deadlines and significant penalty payments and damage to their reputation, increasing pressure to cut corners.

The situation can become very pressurised and tense. Disputes over shared equipment were found to be one of the very few issues that had led to reported work place violence as fights had broken out between contractors. The lesson here is not to underestimate the potential for problems if the allocation of shared resources does not work effectively.

Case study 18: Waiting for PTWs

An offshore installation had only a handful of computer terminals at which PTWs could be processed for the start of the shift. While the number was fine for normal operations it was completely inadequate for an SOT programme. Contractors were waiting hours at the start of each shift to get access to the terminals to print their PTWs. Unable to start work without a valid PTW and faced with not meeting deadlines they hit upon the idea of putting many jobs on the same PTW. Within a few shifts the jobs on the plant bore little relation to the PTWs. A section of process pipe was put back into service without having been properly tightened. A significant leak occurred leading to a major incident and formal investigation, at which point the inadequate provision of PTW terminal access came to light.

Case study 19: Waiting for the crane

A large fabrication yard had a 250 tonne crawler crane to cover the whole site. The site was over one mile in size from one end to the other. A dispute broke out between two contractors at opposite ends of the site over who was to get the crane. A decision was made to move the crane from one end of the yard to the other and then back again. The crane could only move 100 m before the tracks had to be greased, which is a task that took approximately one hour. Faced with watching the crane take all day to traverse the site someone ordered the crane driver to skip greasing the tracks. Later that day, and while still in transit, a track seized sheering one of the four 30 cm drive shafts clean in two and taking the crane out of service for nearly one week.

Check list 12: Shared equipment

1. How are 'pinch points' and 'bottle necks' for shared resources and equipment identified?
2. Are all those who need to be involved included in the allocation of shared resources?
3. Is there a process to resolve disputes over allocation?

8.6 PORTABLE DIGITAL EQUIPMENT: SMART PHONES, TABLETS, LAPTOPS, CAMERAS

If mobile phone use on site (and the fire/explosion risk involved) is a concern, then the organisation should find out why phone calls have to be made or received. Often there are a lot of calls made by technicians for technical support and a lot of contractors are keeping in touch with their office to plan their next job. If this is the case it can be effective to provide a porta-cabin or office with free landlines, desks and note pads close to security. There should be lockers and security should check that mobile phones are surrendered and placed in a locker. Many workers do not want to carry their own, expensive, phones on site but have little option. Once an option is provided that meets their needs most are happy to use it. This facility should also be able to handle in-coming calls via a central number and public address system or communications to team leaders.

Portable digital equipment, for example smart phones, tablets and laptop PCs, are both a benefit and a threat to the site. The majority of devices have the capability to take and upload photographs directly to the internet. As a positive, technicians now routinely use this facility to e-mail photographs of the job to their head office for technical support saving a great deal of time in the process. As a negative, this may mean that images of plant are being sent to a competitor.

It is also worth being aware that this may mean emergency response will be recorded during a serious incident. Perhaps the most well-known example is the loss of the cruise ship Costa Concordia; many passengers recorded video of the crew giving emergency directions (directions that were wrong). These recordings, and those taken covertly by crew members on the bridge, became important evidence against the organisation. Recording of the company response to an incident is not in itself a threat, but it does highlight the need to get emergency response right.

It is important to have a clear policy on the taking of photographs:

– Sending images to an office involved in the contract for technical support should be considered acceptable.
– Sending images for technical advice to an organisation not involved should require approval and a justification.
– Uploading images to social media should not be allowed. If details of the work on site are to be placed on social media this should be done with management approval. Where the site is well run people may feel proud and want to share that, but this should still be subject to some form of oversight. Reasonable requests are likely to be approved.
– Where individuals are being filmed, wherever possible, their permission should be sought and an explanation given before any images are captured. Individual- and cultural- sensitivities can be very strong on this and there are legal duties to protect individual rights.

There are risks from portable devices:

– They can be distracting.
– Flashes can trigger fire detection and deluge.
– Chargers can catch fire, especially cheap aftermarket replacements.
– Software viruses can be brought onto the site and uploaded to control systems.
– They are not intrinsically safe electrical equipment.

For these reasons it may be helpful to have a policy that all portable digital equipment, including smart phones, are logged onto site so that there is some register of what is on site. This may be a one-time per item check done by security. This can also protect users, as theft of these items can also be a problem. Note that the technology exists to track Wi-Fi devices across a site. This is being applied in the UK on large construction sites as a personnel tracking system: workers are instructed to leave their phones on; the system alarms when a device goes into an exclusion zone, for example under a heavy crane lift. These systems do not identify individuals as the phones are not logged into the system. As each device has a unique identifier these can be tracked without assigning to a person.

The organisation should not allow portable PCs to be connected the central IT system until they have been checked. This has a management of change (MoC) element too: control software brought onto site by a contractor or vendor/supplier and uploaded is no different to a design modification. The organisation should be aware of what the software is, what it does and what the consequences are.

Case study 20: Unapproved (and unrecorded) software changes

A gas turbine generator oversped to destruction after the vendor uploaded a software update. Unknown to both the operator and the vendor, at some time in the past the mechanical over-speed trip had failed and been bypassed by the addition of lines of code in the control system to create a software over-speed trip. The lines of code had been inserted by someone with expertise, probably as a temporary fix while the hardware trip was fixed. This was not in the records and as this was in breach of the company requirement for all over-speed trips to be hardware, there was no check prior to the upgrade. Because the unit was running satisfactorily it was assumed the hardware trip was functional. The upgrade overwrote the software trip allowing the machine to over-speed catastrophically.

9 THE TECHNICIAN

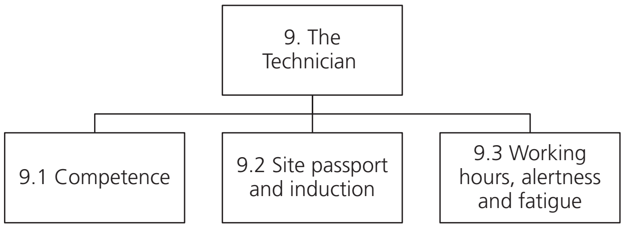

Figure 13: The technician

The technician carrying out the task is the person who delivers the job on time and on spec – or who makes an error and leaves the plant (unknowingly) with a latent failure. They are also the most likely to be injured if a task goes wrong. Risks that are hypothetical for those in the planning office are real for the technicians on the site. The focus should always be on enabling the technician to be an effective part of the programme (and not on thinking of the technician as the cause of problems). This is best illustrated by the management of working hours, where the focus should be on maintaining alertness not encouraging overtime.

9.1 COMPETENCE

There will typically be different competence issues for core crew and contractors on site. Core crew (permanent operator staff) will be familiar with the plant, its layout and operation (including start-up), but they may not be familiar with the tools and techniques required to strip, repair and reinstate it. Contractor staff should be skilled in their own specialisms but may not be familiar with the plant layout, the hazards in operation or the MAHs on site.

It is normal practice on SOT projects to manage competence for contractors by specifying this in the contract. This effectively makes competence a purchasing function. Addressing competence by procurement can be effective in setting out the competence at the project start when the contractor teams arrive, but it is not configured to assure competence once the work is underway. This ongoing assurance requires periodic checking and/or audit against the initial competence requirements. For this to be effective the competence requirements should be set out in sufficient detail and format for checks to be made. Purchasing and contracts departments may not have the required knowledge to do this and so there is a role for operations staff, human resources (HR) and purchasing to collaborate on setting relevant, realistic and verifiable competence criteria.

It is widely accepted that major projects suffer from skill loss. Once work has begun there is a temptation for companies to move their best teams onto the next project. This can become a serious issue if the project overruns and margins for the contractors are squeezed. The site operators' supervisors are vital in observing work sites and identifying any workers who lack the necessary competence. It should be considered how a worker without the necessary competence would be identified, what action should be taken and how? The objective is to identify a person lacking the necessary competence before they cause or experience an incident. Should such an event occur, the job should be stopped while a solution is found. There are positive options, such as to apply close supervision, buddy them to a more experienced worker or put them through additional training. However, the organisation should also be prepared to reject incompetent workers from the site and send them back to their employer. It is worth noting that, if lack of competence has been exposed by an incident then this not only illustrates the worker's lack of competence but also that they were able to work on the site in a manner that enabled them to have the incident.

In general, co-workers know who is competent and who is not, but they may not be willing to speak up. Having the team supervisors under direct line management therefore gives much greater control in identifying competence and should enable the organisation to identify a problem before it escalates into an incident.

Case study 21: A competence failure

An operating company contracted a specialist supplier to provide teams of maintenance technicians along with team supervisors. The operator's maintenance superintendent was made aware of concerns regarding the competence of one of the contract technicians. After observing the person working and interviewing them the superintendent concluded that the technician was not competent so they called in their team supervisor to discuss options. The team supervisor (who worked for the contractor company) pointed to the contract and said that the company was contracted to supply competent technicians and that is what they have done, and if the superintendent feels otherwise then he would need to speak to their legal department. The operating company cancelled the contract to supply supervisors and took direct control of competence on site.

As with risk assessment and the hazards on site, competence should address three issues:

1. the skill required to do the job;
2. the specific nature of the plant and anything unique to it, and
3. the major hazards, and the SCEs and safety-critical tasks that control them.

A contractor can and should be very well able to deliver category 1 competence, the skill to do the job. Depending on their past engagement with the site they may or may not be able to deliver category 2 competence, the required understanding of the features unique to this site, plant and equipment. If contracts are awarded by tender with little thought to knowledge retention then it is unlikely a contractor could deliver this competence. SOT contracting companies do make significant efforts to retain knowledge between contracts by maintaining a cohort of experienced staff; however, this is only effective if the same organisation is used for successive SOTs.

Case study 22: No continuity

An operator was required to undertake three-yearly non-destructive testing (NDT) inspections of a major structural element. This work was difficult with poor access, low light and required considerable skill. Each inspection was put out to tender and awarded on price. There was no standard way to record anomalies and no fixed datum for the measurements so each contractor created their own; no two were the same and so it was impossible to trend the data from one survey to the next. Changing NDT contractors effectively negated any trend data, potentially the best early warning of an issue available.

Only operators' technical staff can reasonably be expected to be competent in the major hazards, HAZOPs, SCEs and safety-critical tasks, etc. as set out in the SMS and operational formal safety (e.g. COMAH) report. It should be considered how this MAH control understanding will be delivered to jobs with a significant MAH potential. Also bear in mind that during an SOT most MAH hazard is in the form of latent failure. Pre-commissioning tests are intended to capture latent failures; however, this is not an 'exact science' and there is no guarantee of identifying these.

It is also worth considering the role of the accepted formal safety report (e.g. safety case) during the SOT. While many of the hazardous processes are suspended and hazardous pressures and inventories much reduced, the plant may still be bound by permissioning regime conditions, and commitments to only use competent staff still apply.

For design, engineering and research posts, it is normal practice for clients to approve designated persons and require a change request if the contractor proposes to substitute another employee. This approach should be considered for technicians in critical roles.

Verification of competence (see also 10.3)
The verification of competence, and supporting certificates and qualifications, is important. In some sectors forgery has become a serious issue and steps should be taken to prevent it. Certificates should be checked, and additional action can be taken to contact sources, check databases and trace original certificates. This takes time and should not be left to site managers once the SOT is underway. Competence verification should be scheduled in as a purchasing and HR activity.

The Institution of Civil Engineers (ICE) provides excellent guidance on fraudulent qualifications, *Fraudulent qualification guidance.* While this is targeted at civil engineers many of the principles can be applied elsewhere. There is little or no public domain data on the extent of fraudulent qualifications in the energy sector, however the experience in the marine sector would indicate there is likely to be a problem.

Checklist 13: Competence

1. Where appropriate do we consider skill retention and previous experience of our site when allocating work?
2. Do we have competence criteria for everyone on the site, core crew and contractors?
3. Do we have indicators or markers for competence that can be assessed on contract placement and checked periodically thereafter?
4. Do we have a procedure for dealing with a worker on site who lacks the necessary competence to work safely?
5. Do we involve colleagues in HR and purchasing to mobilise all our expertise on competence?
6. Do we have measures to identify fraudulent competence claims?

9.2 SITE PASSPORT AND INDUCTION

Staff numbers increase significantly during an SOT programme. Decommissioning projects are the extreme case with reports of a 10-fold increase in staff onsite compared to normal operations. Experience from these projects has highlighted the importance of access control and the challenge of maintaining an effective safety culture with such an influx of new personnel.

The following are some examples of good practice that may be beneficial:

– Consider creating site passports for the SOT project duration. This does not have to be a 'smart card'; it can be printed but should preferably have a barcode and link to a database with ID, next of kin, emergency contact, employer's contact, key competencies and any relevant permissions (i.e. fork lift, digger etc.).

- Have the basic safety induction training delivered outside the site security so that only those who have passed are allowed onto the site.
- Form a group of experienced core crew and contractors and resource them to make a short video about:
  a. arrival for new staff;
  b. site values and culture;
  c. expected standards of behaviour;
  d. site golden rules/life saving rules;
  e. site alarms and emergency evacuation, and
  f. links to on-line training – i.e. PTW.

This should be optimised for viewing on a smart phone or tablet and the link sent out to all workers before they arrive, e.g. via their employers.

- Make key safety training available freely online for contractors to watch before they arrive. This can be combined with a short assessment so that those who have invested time learning at home can be rewarded by being processed through induction more quickly.
- Follow offshore practice of using coloured hard hats to denote those who are new to the site. The offshore practice is to use green hard hats for those new to an installation for the first three trips. Recently a new designation of 'green hand' has been introduced for those new to the industry. Green hands wear a bright cover on their hard hat for the first trip. The objective of these initiatives is to enable experienced staff to look out for inexperienced staff and alert them to danger. This can be part of a 'buddy' or 'mentor' arrangement. It also helps avoid the danger of assuming a green hand is aware of the danger they are in. The offshore system may be too complex for an SOT programme; however, the principles are sound and some elements could be borrowed. See Offshore Petroleum Industry Training Organization (OPITO) standard 9016 Green hand training standard.
- The cost of 'smart' or 'intelligent' systems is falling and it may be economically viable to use radio frequency identification cards (RFID) to identify and track workers on site. RFID cards can now be interlocked to restrict access to equipment and combined with an electronic PTW system to verify location in the PTW work control system in an integrated safe system of work (ISSOW). Bar codes can be used in the same way with scanners linked to the PTW/ISSOW to link worker ID, competence and location.
- Finally, challenge the site induction: it is surprising how many inductions contain basic errors such as giving the wrong site emergency telephone number.

Check list 14: Passports and inductions

1. Is there an effective means to track numbers on site?
2. Does the site safety induction adequately cover what a new arrival needs to know?
3. What processes ensure that only those with site induction and site minimum safety training get access to site?
4. How are those new to the site integrated into the safety culture?
5. Is everything being done to utilise the time before first arrival at site (i.e. using social media)?
6. Is there further scope to interlink site IT and work control systems?

9.3 WORKING HOURS, ALERTNESS AND FATIGUE

The nature of an SOT programme, with its pressure to get the plant on stream, creates an environment that encourages working long hours. When work is behind schedule the obvious, but often wrong, solution is to turn to overtime to increase the hours being worked, which can result in both tiredness (sleepiness and lapses of attention) and fatigue (exhaustion and insufficient capacity to maintain attention). Overtime has and will continue to be used to address short-term increases in work load; however, it comes with significant risks that should not be overlooked:

- Tiredness and fatigue are a significant cause of human error and accidents.
- Accidents due to tiredness and fatigue are more likely and more severe when operating moving machinery.
- Human errors may lie undetected as latent failures. The costs of the additional checking and rework required after error has been uncovered may far outweigh the gains (e.g. to schedules) from working longer hours during the SOT programme (see case study 24).
- Research into accidents in vehicle production have found overtime on the previous shift to be the best predictor of an accident on the next (Proctor et al (1996), Effect of overtime work on cognitive function in automotive workers).
- Overtime typically involves paying a worker the highest hourly rate (1 ½ to 2 times normal) when their performance is at its lowest over the shift.
- Alertness and performance decline after 8 hours and decline sharply after 12 (this is explained in detail in HSE RR446, The development of a fatigue/risk index for shiftworkers). This effect is significantly amplified by consecutive long shifts. Where workers have long days they pace themselves to maintain alertness by working at a lower rate or taking breaks. This is why overtime seldom delivers the expected gains in productivity.
- Alertness is fundamental to the ability of an employee to deliver their competence by recall, decision making or action, and a lack of alertness undermines competence as well as performance.

The organisation should have a clear policy on overtime on the site that applies equally to all workers. This should be set out in the conditions for contractors, and linked to the site safety policy for human error and employee health. It should be made clear that alertness is a necessary condition for safe work. Working hours and overtime payments should be monitored, as these may not align.

Case study 23: Two log books

The Maritime and Coastguard Agency (MCA, the UK regulator for shipping) found it necessary to check both hours-worked logs and overtime claim records as ship logs tended to show hours were within legal limits when significant overtime was being signed off by ships' officers. These payment records were found to be significantly more accurate than the record of hours alone.

Case study 24: Clapham rail disaster

The Clapham rail disaster claimed 35 lives after three trains collided on 12 December, 1988. The collision was caused by a signal failure due to a wiring fault. New wiring had been installed, but the old wiring had been left connected at one end, and loose and uninsulated at the other. An independent inquiry, chaired by Anthony Hidden, QC, found that the signalling technician responsible had not been told his working practices were wrong and his work had not been inspected by an independent person. He had also worked a seven-day week for the previous 13 weeks. The British Rail Board admitted liability for the accident, which was attributed to careless work by signal engineers. As the board was responsible under the 'vicarious liability' principle, it paid compensation reaching £1 million in some cases, though no-one was prosecuted for manslaughter. British Rail was fined £250 000 for violations of health and safety law in connection with the accident.

Check list 15: Working hours, alertness and fatigue

1. Is there a clear site-wide policy on working hours?
2. Is there a fatigue risk management system (FRMS) or any other management process for ensuring employee alertness at work?
3. What indicators are there that employee long hours, tiredness and fatigue are about to become a hazard?
4. How would a dangerously impaired (by long hours) employee be identified before they cause an incident?

10 THE ORGANISATIONS

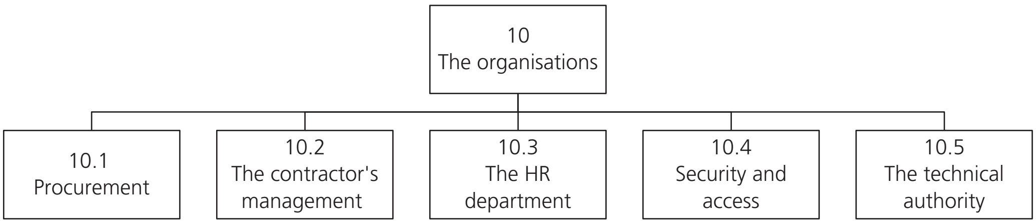

Figure 14: The organisations

A number of organisations come together to deliver a successful SOT programme. Many failures will occur at the boundaries and interfaces between these organisations. The number of interfaces and boundaries should be reduced wherever possible; those that are necessary should be treated as potential 'threats' to the project (in a risk management-sense) to be managed.

10.1 PROCUREMENT

One recognised weakness with pre-qualification of contractors is the sub-contracting of key elements of the work. The organisation should check for this and require the same pre-qualification standard, level of oversight from sub-contractors as it does from contractors (for example, the contractor should audit its supply chain in the same manner as they are audited by the operator).

It can be very helpful to position contractors on a capability maturity matrix (Table 5). This can be used to determine the level of oversight and autonomy for each contractor in which the level of monitoring is proportional to the contractor capability. Project managers may already do this informally based on their own experience, but this approach formalises this and allows the variation in oversight and monitoring to be explained to the regulator and linked to duty holder risk-based management. The appropriate level of oversight should be completed by the duty holder with reference to their own accepted safety/COMAH case. They should ask: what are the SMS and MAH processes and commitments that relate to contractor assessment?

IOGP has produced a comprehensive guide for working together in a contract environment: Report 423, *HSE management – guidelines for working together in a contract environment*.

Table 5: Contractor maturity matrix

Maturity score	Work control	Management capability	MAH understanding	Appropriate oversight for safety/COMAH case
Level 5	Conducts own SMS review and improvement, plus below levels	Take over responsibility for delivery and completion	Are fully conversant with the safety case and major accident prevention through safety defences and SCEs	
Level 4	Own SMS, plus below levels	Risk assess and plan the work as well as carry it out	Understand safety defences, SCEs and MAHs	
Level 3	Own PTW, plus below levels	Have own supervision, team and procedures	Understand SCEs and MAH	
Level 2	Skilled supervisors, plus below level	Have own procedures	Are aware of MAH in risk assessments and act accordingly	
Level 1	Skilled staff	Work to client's task procedures	Rely on client to identify and manage MAH	

Where the selection of a contractor is based upon conditions, for example commitments or assurances provided by the contractor that relate to their performance in a manner that has significant safety implications, it is useful to communicate these conditions to the operations team. This enables them to carry these conditions over into their SMS audit and oversight.

The procurement department has another significant role in an SOT programme: the ordering of many spare parts. It is common for the procurement/buying department to purchase the cheapest components that meet the specification. This is the task they are given and they set out to do it well; it would be hard for any buyer to do other than pick the lowest priced supplier that met the specification. However, underlying this is an assumption that the specification covers all the important variables and therefore that two items that meet the same specification are both identical and interchangeable. Specifications tend to be based on standards and where this is the case there is an assumption that the standard covers all the functional requirements and that any variation not in the standard has no impact on performance – paint colour of a valve for example.

These assumptions are not supported in practice. There are many examples of standards that omit important functional variables and specifications that can be met equally by suitable and unsuitable components in a specific application. The problem is that these important distinctions may only come to light with experience that exposes where the omissions are. Case studies 25 and 26 illustrate how this can go wrong.

Case study 25: Assuming one element ensures another

A rail company wished to purchase a large number of 1/3 pint drinking glasses. The height was determined by storage, and purchasing therefore calculated the diameter to give the required 1/3 pint volume. One glass manufacturer won the order on cost and many thousands of glasses were made and delivered. Unfortunately the specification omitted the volume. The manufacturer had in good faith saved glass (and costs) by supplying waisted glasses that held a smaller volume. They were useless for the intended purpose.

Case study 26: Assuming that 'identical' components perform the same

A large UK refinery had many hundreds of 4 inch ball valves in service. The number alone meant that failures and replacement were common. The valves were all covered by a recognised standard and the purchasing department bought valves on price and delivery from a range of (as they saw it) interchangeable sources. They also assumed that the valves from the various sources were the same as they all met the same standard. The valves procured came from the UK, Southern Europe or the Far East. The UK manufactured ones were quickest to source and most expensive, the Far East slowest but cheapest, with the Southern European ones in between on both counts. The valves were drawn from stores randomly and no distinction was made; however, the maintenance technicians much preferred the UK valves, accepted the Southern European ones and avoided those from the Far East. If they opened a box to find the latter they would often 'lose'/hide it or return it to the stores until they got a UK or European one. What the purchasing department did not know (because no one had ever told them), was:

- The standard covered the bore, pressure and flanges, but it did not cover the hand-wheel or 'bonnet', which varied across the type purchased. As the hand-wheel often corroded and had to be replaced this meant carrying three hand-wheels or three bonnets on a long walk across the site because there was no way of knowing which one would fit until you got there.
- Secondly the service life was very different. The technicians often went back to change relatively new failed valves manufactured in the Far East. They believed (correctly) that a lot of money was being wasted, but they never told purchasing because they had no means to raise the issue.

This issue had gone on for some years when it came to light by chance at a safety awareness day when the purchasing manager arrived early to give a talk on avoiding bribes and heard all about the valve failures. He abandoned his planned talk and led a workshop with the technicians to identify where purchasing could help. They identified significant savings and the two departments now work closely together.

Check list 16: Questions for the procurement department to ask

1. What feedback do we get from technicians?
2. Is there relevant experience we are not accessing when we specify or make purchasing decisions?
3. How does procurement establish the necessary conditions for contractor pre-qualification?
4. Is there any linking between incidents and issues experienced on previous SOT programmes and the pre-qualification checks?
5. How does procurement verify claims made by contractors:
   a. during pre-qualification?
   b. at commencement of work?
   c. during the work programme?
6. What post-project information is collected and used to update pre-qualification requirements for the next project?
7. Is there any assessment or weight given to the contractor's safety culture?

10.2 THE CONTRACTOR'S MANAGEMENT

The safety culture of contractor staff coming onto the site will have been shaped by the work and management culture in that contracting company. The site operator will be aiming for a positive safety culture across the site just as they would in normal operations. Many contractors, of course, have excellent safety cultures[7], but the culture will often be different (for better or worse) compared to the operator's culture.

The organisation should try to understand the influence of the contractor's senior management and how they are positively or negatively influencing behaviour on site. Senior management can have a significant influence on site behaviour, including:

- raising of safety concerns;
- reporting of incidents and near misses;
- participation in investigations;
- working hours and time pressure, and
- compliance with procedures and corner cutting.

Case study 27: Sending the wrong message

The operator of a refinery site introduced a behavioural safety programme based upon open no-blame reporting of unsafe behaviours and conditions. Soon after, a contractor on site made a report. As agreed the shift-end report was sent to the contractor management for information. The contractor management then set about identifying the individual and by the next day had suspended him from work. This action had the immediate effect of destroying all faith in the new reporting scheme and wasting many weeks of training and roll-out on the site. Site workers reported the suspension to the safety regulators and the contractor was then forced to re-employ the suspended staff member under a 'no-victimisation' clause. The whole event soured the relations between the operator and the contractor and left lasting damage to the site safety culture.

7 This is best illustrated by this example from a meeting between an oil major and a large UK services company: after hearing from the operator about the operator's excellent safety culture the services company manager replied 'As over 80 % of the staff are supplied by us it's not your safety culture, it's ours'.

The contractor maturity matrix in Table 5 is intended to measure the readiness of a contractor for the tasks, but there is another dimension that can be measured: their values and culture. The nuclear sector commonly use the Schein model of organisational culture whereby the artifacts of culture (what the contractor does) arise from, and reinforce, its values and assumptions (Figure 15).

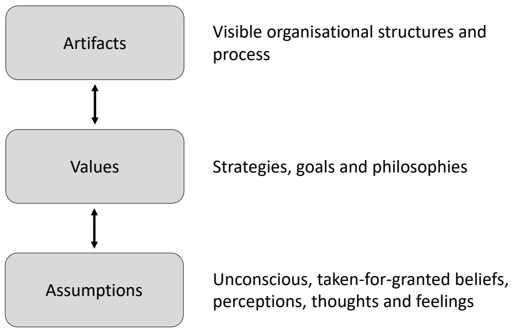

Figure 15: The Schein model of organisational culture

Assessments of a potential contractor’s SMS and capability will tend to measure 'artefacts', but 'values' are equally important. These measurements will come from observations of the past behaviour of the contractor and in conversations with their employees and senior managers. This is important because it is much easier to work with those who share the organisation's values. In the context of an SOT programme, these could be values around safety and risk, long-term business relationships and staff:

– Risk: how is safety valued when a decision about a task running late is required?
– Business relationships: are they investing to get the organisation’s business again in future, or going for maximum profit now?
– Staff: are they seeking to retain experience or hire cheaply?

Typically, organisations involved in petrochemical and hazardous industries share many common values; however, it can be a dangerous assumption to make if a contractor (or client) is moving into the sector from one that is very different. In the rail sector there are examples of companies from other sectors bringing in their culture. This was a positive influence when aviation operators took on rail franchises; however, there are some high profile failures when companies with a background in construction took on rail operations and maintenance (e.g. Jarvis plc. which was found partly responsible for the 2002 Potters Bar rail disaster).

10.3 THE HR DEPARTMENT

The training, development and qualifications for professional HR staff have a significant overlap with human factors. This is most true for competence but also behaviour, communication and eliciting information. Historically, HR departments have tended not to be involved in risk controls, safety management or competence of contractors. This may be because they are not asked or because they believe they have little to offer in safety and risk reduction;

however, they should be asked and they do have something to contribute.

If HR is not already involved the following are some examples of issues where the HR department can make a valuable contribution:

- creating or reviewing competence criteria for contractors;
- verifying competence certificates and supporting evidence (i.e. log books);
- checking contractor staff history for misrepresentation on qualifications;
- supporting a 'no-blame' or 'just culture' policy;
- conflict resolution;
- assisting in investigations – e.g. interviewing, and
- contractor audits.

10.4 SECURITY AND ACCESS

Many people and things enter and leave the site; most are welcome, some are not, and some pose a significant hazard. Security are very well placed to help with these problems. With the appropriate training and procedures the majority of security staff are capable of making a much more significant contribution to site safety, and experience has shown that they both meet, and welcome, the challenge.

Case study 28: Unsafe loads

The saw mills were experiencing a lot of serious incidents due to unsafe loads arriving on their sites. Trucks were heavily overloaded and not in compliance with industry safe load guidance. Repeated campaigns targeted at the timber transport operators had failed to improve loading behaviour as most drivers were self-employed and stood to make more profit if they overloaded their truck. The saw mills worked with the regulator to implement a national policy that any unsafe loads would be turned away. This task was given to site security, who were trained and provided with photo guides of safe and unsafe loads. Safe loads were to be allowed in, unsafe turned away, with no exceptions. Security relished their new responsibility and drivers soon realised that arriving with an unsafe load meant a long and expensive wasted journey. A follow-up study found very high compliance with safe loading.

Here are some examples of issues where site security often do or could have a role:

- turning away unsafe loads;
- ensuring compliance with site maps, safe driving routes and lay down areas;
- controlling what equipment is arriving on site and what certification is coming with it;
- quarantining unmarked spare parts;
- portable power tools – logging onto site for PUWER;
- IT equipment – laptops that can be connected to site equipment – logging and virus checking;
- logging mobile phones and tablets if this is site policy;
- confirming induction training and site safety;
- site passport access control, and

– checking breath for alcohol (this is done at UK heliports – staff are trained to engage in conversation and lean forward, which has proven to be very effective).

However, caution should be taken to ensure that security do not misinterpret instructions and create new unintended consequences (see case study 29).

Case study 29: Obsession with small things

The operators of a COMAH site that had concurrent construction had a site seatbelt policy: anyone not wearing a seatbelt was to be removed from the site. Security took this very seriously and several contractors were removed from site for not wearing seatbelts while parking their cars. This had a huge impact on behaviour and seatbelt wearing became an obsession. People fell into a mind-set that 'seatbelt wearing equals a safe site'.

There was a feed from CCTV cameras for confined space and crane safety in the security cabin, but these were left unmonitored for long periods while security checked for seatbelt violations. Blatant violations of other safety procedures, including confined space entry, were common and the site had a fatal accident. Senior management had failed to properly engage with security and explain what their role was and what safety behaviours were really important to monitor.

Checklist 17: Security

1. Am I making the best use of the security team?
2. Are there other safety issues and possibly major hazard issues where they could have a greater involvement?
3. Have I explained the issues to them and asked for their suggestions?
4. Are my messages to security consistent with my objectives?

10.5 THE TECHNICAL AUTHORITY

There are various competence and regulatory requirements for employing specifically competent persons. Some examples include:

– the technical authority;
– Lifting Operations and Lifting Equipment Regulations (LOLER) competent person, and
– third party inspection/verification.

Problems can arise when the required specialist is not available and work is being held up. Many specialists based offsite will be on a standard day shift whereas the site may be on 24-hour working. This is a particular issue with LOLER, where lifts may be scheduled for night shifts for safety reasons as there are less people on site. If the lift is one that requires approval by the LOLER competent person (i.e. it is considered complex) then, rather than pressing ahead, arrangements should be put in place for this over the 24-hour work period. (As an aside, the same temptation to press ahead can occur when components have to be tested that will become inaccessible in the next phase of work. This latter situation can lead to a temptation to press on quickly and conceal any errors).

11 THE REGULATOR

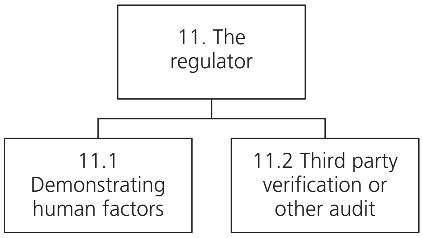

Figure 16: The regulator

In the UK and Europe, the majority of sites undertaking SOT programmes will be MAH sites operating under the COMAH- or related Seveso-based MAH regulations. This means there will be a formal safety report or safety case, and permission to operate is conditional upon compliance with the approval conditions and company SMS. While some or all of the site is shut down, these MAH regulations and compliance conditions still apply. In many cases there will be concurrent production on other parts of the site.

The site safety report should therefore form part of the SOT planning process with an assessment to show how safety report (i.e. COMAH) compliance is maintained throughout the SOT programme. This can be linked to the HFI plan so that there is read-across from one to the other. In the UK the inspection and assessment guides are publicly available and these provide an excellent framework for setting out how risks are controlled. For example the UK COMAH Competent Authority has a comprehensive operational guide: HSE, *Inspecting human factors at COMAH establishments*.

11.1 DEMONSTRATING HUMAN FACTORS MANAGEMENT

It should be remembered that under COMAH and Seveso regulations, the regulator requires that risks are **demonstrated** to be properly controlled. This is not done by having a list of activities or equipment, but by having a report of the control measures produced in a manner that can be verified by site inspection. This demonstration should be in an accessible (i.e. readable, logical) format and risk-based – often it is better to be concise. A matrix with the SCEs on the vertical axis, with columns for the SOT impact and control measures is one way to demonstrate this clearly (Table 6).

Table 6: Human factors demonstration matrix

SCE	Operations hazard	SOT threat	SOT control measure	Return to service gate
1				
2				
3				

If the organisation has either technical of regulatory concerns about specific issues then it should engage with the regulator early and ask for their guidance.

11.2 THIRD PARTY VERIFICATION OR OTHER AUDIT

For some sites there will be a third party inspection and verification scheme; for others there will be some form of audit regime. It should be ensured that there is effective collation of information, record keeping and action tracking. Unfortunately, investigations after major incidents often find one or more of the following:

- tests were not carried out;
- test results were ambiguous or marginal but this was not followed up;
- concerns were noted at the time and logged for action but this was not followed up, and
- results or records of acceptance tests could not be found when required for a subsequent investigation.

Many of the test results will be in the form of signed hard copies and so document control is important. These should be collected and filed on site in a manner that is recoverable.

During inspections and audits, the sequence of measurements in inspections and NDT testing require standardised location numbering and datum. However, an issue that has arisen on a number of major projects is that process plants often bear marks from many previous overhauls that show no consensus on where to measure from and what measure to use. This has several consequences:

- numbering from a previous job may be confused with the current job;
- numbering may be wrong, and
- trending of readings from one survey to the next may be impossible.

This latter point can have significant implications for safety in the long term as it will mask any slowly developing faults (see case study 22: No continuity).

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ANNEX B
ABBREVIATIONS AND ACRONYMS

AAIB	Air Accident Investigation Board
API	American Petroleum Institution
BA	British Association
BSF	British standard fine
BSW	British standard Whitworth
CAA	Civil Aviation Authority
CAD	computer aided design
CCPS	Centre for Chemical Process Safety
CCR	central control room
COMAH	Control of Major Accident Hazards Regulation 2015
COMOPS	combined operations
COSHH	*Control of Substances Hazardous to Health Regulation 2002*
EI	Energy Institute
FPSO	floating production storage and offloading
FRMS	fatigue risk management system
HAV	hand arm vibration
HAZOP	hazard and operability study
HF	human factors
HOFCOM	(EI) Human and Organisational Factors Committee
HP	high pressure
HQ	headquarters
HR	human resources
HSE	Health and Safety Executive
ICE	Institution of Civil Engineers
IOGP	International Association of Oil and Gas Producers
ISSOW	integrated safe system of work
IT	information technology
LFI	learning from incidents
LHS	left hand side
LOLER	Lifting Operations and Lifting Equipment Regulations
LP	low pressure
MAH	major accident hazard
MCA	Maritime and Coastguard Agency
MoC	management of change
MSDS	material safety data sheet
NDT	non-destructive testing

OPITO	Offshore Petroleum Industry Training Organization
PC	personal computer
PPE	personal protective equipment
PTW	permit to work
PU&A	procedure use and adherence
PUWER	Provision and Use of Work Equipment Regulations 1998
RFID	radio frequency identification
RHS	right hand side
SCE	safety critical element
SIMOPS	simultaneous operations
SMS	safety management system
SOP	standard operating procedure
SOT	shutdown, outage and turnaround
TARP	trigger action response plan
UNF	unified fine threads

This publication has been produced as a result of work carried out within the Technical Team of the Energy Institute (EI), funded by the EI's Technical Partners and other stakeholders. The EI's Technical Work Programme provides industry with cost effective, value adding knowledge on key current and future issues affecting those operating in the energy industry.

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9780852938744

ISBN 978 0 85293 874 4
Registered Charity Number: 1097899