Safe plant reinstatement following intrusive work; new Energy Institute guidance

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Companies operating major hazard process facilities must plan for the non-routine modes under which the plant will operate during its life. Reinstatement following intrusive work, or breaking of containment, is one such mode. The Health & Safety Executive (HSE) previously expressed concern over the number of hydrocarbon releases which have been reported by UK offshore oil and gas operators, associated with poor control of reinstatement (Hynds and Templeton 2020). Similar issues have been reported for onshore major hazard facilities in other industry sectors. The HSE identified the need for industry consensus and a document which describes what constitutes good practice. The Energy Institute (EI) will shortly publish guidance which seeks to meet this need. The document sets safe reinstatement within the context of a process for intrusive work.

Safe reinstatement can be achieved by systematically ensuring that risks are sufficiently managed, including managing disturbed joints throughout the work activity, leak testing and line walking to check readiness for start-up. The document provides principles and good practice for carrying out these activities. Since the activities are performed by people, it provides human factors guidance on how to identify and manage relevant risks arising from human vulnerabilities. The importance of leadership in managing major accident hazards has garnered increasing attention in recent years and the document provides guidance and a framework for effective leadership of reinstatement activities.

The intended scope of application of the document is major hazard facilities, onshore and offshore. The project to produce the EI guidance was carried out by a working group of industry and regulator participants under the supervision of the EI's Process Safety Committee. Drafting was carried out by a technical author who is the author of this paper. The paper shares some experiences on the process of using a working group effectively in a way which optimises their input.

The paper will provide an overview of the risks which exist in reinstatement and the good practices which can be applied to manage them. It will illustrate what can go wrong with examples of incidents.

Introduction

A live test was being carried out on the topsides blow down system of an offshore oil and gas production facility when a 97 kg hydrocarbon gas release occurred. If it had ignited, it could have caused serious injury and equipment damage.

The release occurred from a bleed valve in the flare line downstream of a pressure safety valve (PSV) on a gas scrubber. The bleed valve was open and although it was fitted with a blank flange, the blank was not fully tightened. The PSV had previously been removed for testing and the bleed valve had been used to prove the isolation prior to breaking the flanges on the PSV.

Several management system processes had failed or were absent allowing the gas release to occur. The permit to work and associated work pack prepared for the task of removing, and later replacing, the PSV for testing did not identify the bleed valve and blind flange. While the work on the PSV flanges had been recorded in the flange register, the work on the bleed valve blank flange had not. The broken flange was not leak tested before being brought back into service, because it was on the flare side. No alternative arrangements, for example witnessed assembly, were in place to ensure the integrity of the broken blank flange. The company had no documented procedure regarding alternatives to leak testing for circumstances where leak testing was not possible (HSE 2019).

A runaway chemical reaction occurred inside a 17 m^3 pressure vessel known as a residue treater, causing the vessel to explode violently in the methomyl unit at an agro chemicals manufacturing facility. Highly flammable solvent sprayed from the vessel and immediately ignited, causing an intense fire that burned for more than four hours. Two people were killed and eight were injured. The incident occurred during the restart of the methomyl unit after an extended outage to upgrade the control system and replace the original residue treater vessel.

The residue treater was intended to decompose trace quantities of pesticide intermediate methomyl in a stream which contained methyl isobutyl ketone (MIBK), so that the MIBK could be burned as a fuel. Methomyl decomposition is exothermic and the reaction hazards were well known to the operators.

Myriad problems during the start-up resulted in the methomyl concentration in the residue treater being twice the normal level and the operators being unaware. When they applied heat to commence methomyl decomposition, the reaction ran away. They tried to apply cooling, but the controller had been wrongly connected and they were unable to prevent the temperature and pressure rising and the vessel failing.

The operating team had made the decision to start up, even though the shut-down work was incomplete. Hardware and instrumentation were incomplete, functional testing had not been completed and operating procedures had not been updated. They had not carried out a line walk or any other systematic review to define the status of the plant and to manage any deferments (Chemical Safety Board 2011).

These incidents occurred in different industries, offshore oil and gas and chemicals manufacturing, but share similarities in that they both occurred while reinstating major hazard plant after maintenance or project work. The UK offshore hydrocarbon release (HCR) database contains detailed information on unintentional hydrocarbon releases reported to the Health and Safety Executive. For the period 1st October 1992 to 31st December 2020, 5187 HCRs were reported, of which 811 (15.6%) had reinstatement or start-up as the secondary or primary mode at the time of the release. For the period 1st January 2016 to 31st December 2020, 531 HCRs were reported, of which 38 (7.2%) had reinstatement or start-up as the primary or secondary mode at the time of the release. The situation might be improving, but nevertheless, given that reinstatement and start-up represent a small proportion of the time within an installation's overall lifecycle, the data indicate that these operating modes are particularly high risk activities. These data and anecdotal accounts support the view that reinstatement activities in major hazard facilities are worthy of rigorous operational excellence.

To reduce the number of incidents, the Health and Safety Executive are of the view that there is a need for industry consensus in the form of a guidance document, describing what represents good reinstatement practice. The Energy Institute agreed to take on the task of writing and publishing the document. They appointed a project manager, engaged a technical author (the author of this paper), and formed a working group of industry practitioners under the direction of their Process Safety Committee.

Reinstatement within a Process for Managing Intrusive Work

HSE guidance *The Safe Isolation of Plant and Equipment,* HSG253 (HSE 2006) proposes an eight step process for managing intrusive work, comprising:

1. Hazard identification
2. Risk assessment and selection of isolation scheme
3. Planning and preparation of equipment
4. Installation of isolation
5. Draining, venting, purging and flushing
6. Testing and monitoring effectiveness of the isolation
7. Carrying out the intrusive activity
8. Reinstatement of the plant

HSG253 however, provides little guidance on the last step, *reinstatement*, or what suitable risk controls should be anticipated earlier in the intrusive work process required to be ready for a safe reinstatement.

The focus of attention at the *hazard identification* step in managing intrusive work, is often those hazards which could affect the intrusive work itself. But the same and additional hazards could become relevant during reinstatement.

For example, pressure from the live plant is a hazard both to the intrusive work and to reinstatement. A suitable isolation scheme will control the risk that the pressurised process fluid might escape while the work is going on. But pressure from the live plant could also be a relevant hazard during reinstatement if rapid re-pressurisation could cause equipment damage or if there is a failure to adequately contain the fluid during isolation removal or re-introduction of hazardous fluids (e.g. due to passing valves, leaking flanges, open drain/vents etc). If that is the case, it will be necessary to select process isolations so that interfaces between high pressure and low pressure systems can be effectively managed during reinstatement.

HSG253 advises that you should only carry out intrusive work on live plant if there is no reasonably practicable alternative. Live plant represents a risk not only to the intrusive work but, because of the required isolation scheme, can also make it more difficult to achieve a leak tight plant during reinstatement. Depending on the outcome of the risk assessment, isolation schemes involving live plant often require *positive isolation,* as defined in HSG253, by for example removing a spool piece. The joints on either end of the reinstalled spool piece cannot be leak tested in the normal way. So while positive isolation gives higher integrity separation of hazards while the intrusive work is taking place, it presents additional challenges for preventing leaks during reinstatement. Furthermore, reinstating positive isolations is itself intrusive work, with the possibility of elevated risk.

During the *planning and preparation* phase of the intrusive work, the opportunity should be taken to look ahead to the reinstatement activities and plan for them. Depending on the scope of the work, the output from this step should include work packages for the following activities:

> *Managing disturbed joints* - Disturbed joint registers should be developed at this stage. Disturbed joints, including small bore fittings, can be managed in different ways, for example a certification pack or broken flange register. How the joints will be tracked should be agreed up front of the outage to avoid duplication or omissions.
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> *Leak testing* - Create a leak test plan, including a risk assessment of the leak testing activities and subsequent depressurisation to a safe location. The risk assessment should address risks to the equipment arising from the pressurised test medium as well as risks to the people carrying out the test, for example work at height or asphyxiation. This work package will also include a procedure which describes how the test will be done, supported by relevant documentation such as P&IDs and isometrics.
>
> *Line walking* - Create a plan and procedure for line walking, both for line walks before and after leak testing. It might be appropriate for this procedure to be integrated into a broader one which covers reinstatement or the entirety of the intrusive work.

A system should be in place to manage which *drains and vents* have been opened or plugs and caps removed, for example marking up a P&ID, to facilitate a rigorous approach to ensuring that they have been closed again prior to reinstatement.

Reinstatement Process

As described above, anticipating the required reinstatement risk controls during the earlier steps of the intrusive work activity will help to ensure the reinstatement can be completed safety.

The process for managing the reinstatement itself, comprises several risk control activities with a focus on the activities which take place from mechanical completion up to readiness for start-up (Hynds and Templeton 2020). Activities which precede and are subsequent to the core reinstatement processes need also to be considered. For example, safe plant reinstatement relies on having a system to manage broken joints during preceding mechanical work. Joints which were not leak tested during reinstatement should be subject to post start-up checks. Figure 1 shows core elements of the process. Operating companies may group or order the elements differently, taking account of company practices, reflecting grouping of the steps, recycles in the process, overlaps or different sequencing. For example, steps 1 and 2 in the diagram might be considered as part of the same activity; step 4, leak test, might be done after removing the isolations at step 5, where the removal of positive isolations has led to a requirement for additional leak testing of disturbed joints.

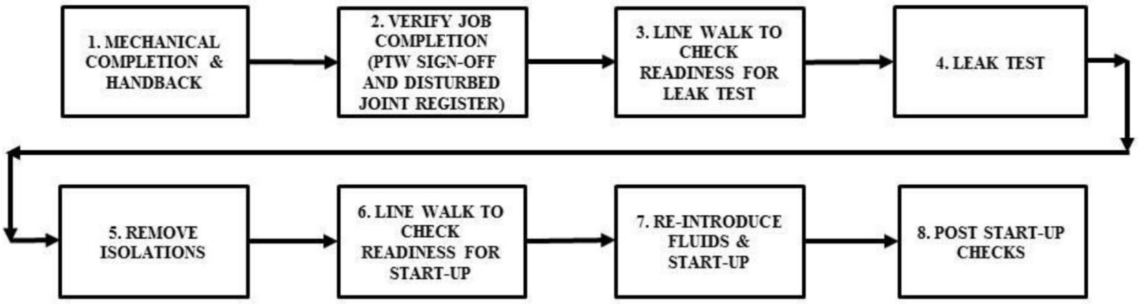

Figure 1; Key elements of the reinstatement process (Hynds and Templeton 2020)

1. Mechanical Completion and Hand Back

The operating company's work permit process must provide a formal hand back process, so that the performing authority certifies the work has been completed, and the issuing authority certifies agreement that the work has been completed and that the plant is ready for testing and recommissioning (Energy Institute 2016b and HSE 2005). The issuing authority also acknowledges taking back control of the plant or equipment which has been worked on. At this stage, the work is closed out in the maintenance management system.

2. Verify job completion (Permit to Work sign off and disturbed joint register)

Operations technicians (issuing authority) verify that the work has been completed. This confirmation is recorded on the work permit; the extent of what they should check should be defined in the work permit procedure. It should always include a visit to the work site. For more complex work additional sign-off by a technical authority (or similar) may be required as defined in company procedures. For less complex work with a small number of permits, this sign off by the issuing authority is sufficient to allow the process to proceed to the next step. For a turnaround or extended shut down with multiple work permits this is an ongoing process and in this case operations technicians should additionally review and confirm that all permits have been handed back and that all work is complete. This additional review should be recorded or managed in the permit to work or maintenance management system.

The operations technician should check that the status of all disturbed joints has been correctly entered in the disturbed joints register (Energy Institute 2007). Managing the disturbed joints should include a tagging scheme and at this step, the operations technician should check that all tags have been correctly signed off and returned. Tags with tear off sections are recommended, with the final section remaining at the joint to help identification during leak testing.

3. Line walk to check readiness for leak test

A key purpose of this line walk is to ensure that the leak test can be performed safely and without risk of equipment damage or personal injury arising from introduction of a pressurised fluid. Relevant hazards could include:

- over-pressure of the equipment being leak tested;
- over-pressure of adjacent equipment due to failure of isolation between systems;
- asphyxiation due to release of the leak test medium, e.g. nitrogen;
- structural weight limitations if the leak testing medium is a liquid, e.g. water;
- missiles being ejected by the pressurised fluid, e.g. gaskets, bolts, blind flanges or fragile pipework (GRP, PVC).

It is common practice for line walking prior to leak testing to have a different and possibly reduced scope from the line walking prior to reintroducing process fluids and start-up. Nevertheless, it should be carried out applying a defined procedure, with a leak test pack containing the necessary documentation, which reflects the scope of the leak test and the associated hazards.

4. Leak Test

The objective of leak testing is to confirm a desired level of leak tightness of process equipment and pipework that has been re-assembled after inspection, maintenance, repairs, modifications or replacement, prior to it being returned to operation. Potential leak points such as flanges, fittings, valves and seals should be tested. Joints which have not been broken but may have been disturbed in other ways, for example subject to unusual external loads, should also be considered.

Leak testing is not a substitute for correct joint assembly but is part of the disturbed joint assurance process. If a leak is revealed during testing, it can be tempting to just increase the bolt load. But if the joint was already assembled correctly, increasing the bolt load could hide a problem which will manifest itself later on in service as a loss of containment of hazardous materials. Leaks revealed during testing should be investigated and the cause identified and rectified.

A distinction is drawn between strength pressure testing, which is not in the scope of the guidance, and leak testing.

Five types of leak test are defined:

> *Gross Leak Test* - A test carried out at a positive pressure, approximately 10% of the maximum operating pressure up to 10 barg, for gross leak identification. It can be used as the first step in a Reinstatement Leak Test, or in specific situations as an alternative to a full Reinstatement Leak Test.
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> *Reinstatement Leak Test* – is a test using an inert medium carried out typically at 90 – 95% of the relief valve set pressure. If nitrogen is used as the inert medium, a proprietary leak detection soap solution (e.g. Snoop) is applied to potential leak points; leaks are revealed by a continuous stream of bubbles. Flanges can be taped and the tape pierced with a small hole to increase the sensitivity of the test. This type of leak test can detect leak rates as low as 8.5 Nm^3/year.
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> *Sensitive Leak Test* – is a type of reinstatement leak test which uses specialised technology to detect smaller leaks, for example using a nitrogen/helium mixture and sensing instruments to monitor for leakage from potential leak points (flanges, seals etc.). Flanges are taped and pierced with a small hole. This type of leak test can detect leaks as low as 0.14 Nm^3/yr.
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> *Service Leak Test* – A leak test carried out during start-up, using the service fluid under its normal, or if practicable, maximum operating conditions and a systematic leak search carried out.
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> *Reverse Integrity Testing* – Reverse integrity testing (RIT) employs gaskets which are designed to allow leak testing to be carried out on individual gasketed connections. They can be employed to determine if tightness has been achieved before introducing internal pressure and also to monitor the joint after it has been put into service. Regarding leak testing during reinstatement, RIT has the disadvantage that the joint does not experience the full range of stresses and forces which a full pressure leak test provide and therefore might leak in service despite having passed the leak test.

In general, leak testing consists of pressurising a system with a test medium and inspecting individual components to check for leaks. *Pressure or vacuum hold tests* however do not include individual component inspection. The system is held at a predetermined pressure or vacuum and the pressure monitored for a predetermined time, to detect respectively a drop or rise in pressure.

Operating companies should record their requirements for leak testing in a procedure which defines what type of leak test is required, in which situation and how the leak test should be carried out. The decision about which type of leak test to use should be based on the hazardous properties of the process fluid and the potential consequences if a leak were to occur. The procedure should specify the pass criteria.

Consideration should be given to the possibility that a leak test might fail due to a passing boundary valve, and test medium detected in an adjacent system.

A *leak test work pack* should be created when the intrusive work is being planned (Step 3 in the HSG253 scheme). This should help ensure that all joints are identified, and that any equipment, procedures or additional approvals necessary for the test can be identified and obtained in good time. It also reduces incentives to take shortcuts or make compromises.

Things do not always go to plan. Operating companies should have in place defined processes to deal with situations where it is desired to deviate from their standard leak testing procedures or where the leak test fails to meet the required criteria and there is a desire to nevertheless proceed to introduce process fluids.

There are significant hazards associated with leak testing which must be managed. In systems where the risks of leaks are assessed as low, a case can be made that the risks from the leak testing itself are not justified and this step can therefore be omitted or replaced by service testing using process fluids during start-up. This would not normally be the case however for hazardous materials e.g. toxic, flammable, asphyxiant, odorous etc. Leak testing introduces hazards from the test medium as well as the testing activity, which for example might include work at height. A risk assessment should be carried out on the leak test procedure, suitable risk controls defined and systems put in place to ensure implementation of the risk control measures.

Small bore tubing assemblies should not be overlooked for leak testing. Their small size as well as the nature of the connections they use, makes them vulnerable to leaks due to mis-assembly or damage. Leak testing of these assemblies is therefore an important part of the reinstatement process.

5. Remove Isolations

During the planning phase for the intrusive work, a plan should have been made for the order in which the isolations will be removed. Where intrusive work has taken place under multiple permits, separate work activities might rely on the same isolations, including instrumentation isolations. Removal of an isolation which was installed for one work activity might therefore jeopardise another one. A cross referencing scheme should be in place to ensure that such interactions are documented on work permits and taken into account when the isolations are being removed. Additionally, isolations should be controlled by an isolation certificate which lists all of the work permits which are relying on that isolation.

6. Line walk to check readiness for start-up

Taking equipment off line to carry out intrusive work necessitates putting it into a configuration which is different from the normal operational one. Valves which would normally be locked open might have been locked closed as part of an isolation scheme, isolation valves immediately upstream or downstream of safety valves might have been closed to allow the safety valve to be removed, emergency shut down systems might have been disabled and trips and interlocks might have been placed in bypass. All of the processes associated with the intrusive work and subsequent reinstatement activities should have included arrangements to ensure that the plant was restored to its normal operational configuration:

- the hand back from maintenance;
- the leak test work pack;
- removing the isolations.

These processes should be carefully designed and rigorously implemented to achieve that objective and should not assume that line walking will take care of anything which has been overlooked. Nevertheless, in case things have been missed, line walking is a final check that the plant is indeed in a safe operating configuration before introducing process fluids.

Operating companies should have in place a procedure which defines in what circumstances line walking should take place, how it should be done, the responsibilities of the people involved, the documentation required to carry out and manage the activities and how actions will be followed up. The procedure could be part of a larger integrated procedure which covers additional reinstatement activities, e.g. safe isolation and leak testing.

It is good practice for line walking to take place following any maintenance work which has involved breaking containment, regardless of the scale of the work.

The procedure should specify what needs to be in place before line walking can commence. For maintenance work, all work should have been completed and work permits handed back. New or modified plant should be mechanically complete with the pre start-up safety review (PSSR) completed. Isolations should have been removed except for boundaries between live plant and the plant being reinstated.

The line walking should be managed with a work pack which includes assignment of responsibilities, marked up P&IDs, isometrics, layout drawings, list of instrument tag numbers to be checked and checklists.

For less complex work being carried out under a single permit, it might be sufficient for the line walk to be carried out by an operations technician with minimal documentation. More complex systems might require different functional teams.

The line walking procedure should define how items reported in the line walk will be managed. This should include a process for defining which items need to be rectified prior to introducing process fluids and which can be deferred until after start-up. Items which will be deferred can be managed using a “punch list” or within a computerised maintenance management system. If an item will be deferred, the rationale behind the deferment should be recorded as well as any risk mitigation arrangements which are required to be in place until the item has been actioned. Each deferred action on the punch list should be authorised by an identified individual. The level of authorisation should be commensurate with the risk related to the deferment.

7. Reintroduce fluids and start-up

Companies should have a defined procedure, which specifies authority levels for approval and sign off prior to the reinstatement progressing to reintroducing process fluids. The procedure should account for the full range of types of intrusive work activities. For less complex activities, for example repair of a pump, the authority could be delegated to defined roles in the operations shift team. For more complex activities, for example a unit maintenance turnaround, it would be appropriate for operations management to be required to give their approval. It should also specify what the approving authority is required to verify before they give their approval.

Disturbed joints which could not be leak tested, for example flare connections and leak testing connections, should be service tested, i.e. checked for leaks when process fluids are reintroduced.

8. Post start-up checks

The reinstatement process should include a defined approach for checking for leaks during and after start-up and what to do if leaks are found. The extent and scope of the checks should be related to the criticality of the potential leak points. For example, infra-red camera techniques can be used to detect hydrocarbon leaks upon reintroduction of process fluids or a specified period of time, e.g. 72 hours after plant started or once the plant is warm (whichever is the sooner).

Managing the integrity of disturbed joints

Losses of primary containment (LOPCs) following intrusive work can occur from a number of possible sources. The HSE Offshore Hydrocarbon Releases database (HSE 2021) reported that between 1992 and 2015, out of the total 773 releases during reinstatement or start-up, 97 were from flanges. This probably understates the number of disturbed joint releases, since flanges are a sub-set of disturbed joints. Norwegian Oil & Gas (2013) found that, of 56 LOPCs greater than 0.1 kg/s, which occurred on the Norwegian Continental Shelf between 2008 and 2011, 13 or 23%, were from disturbed joints.

Energy Institute (2007) recommends a management system for bolted joints. The management system applies to the joints during construction and commissioning phases and through their operational life. Having a bolted joint management system in place will help reinstatement to be carried out safely and efficiently. Even in the absence of a full management system, elements of it can be regarded as good practice which can be selectively applied.

A disturbed joint register is one such management system element. Maintaining a disturbed joint register throughout the intrusive work and subsequent reinstatement is fundamental to safe reinstatement. If the joints are being managed in a management system, they will be uniquely and clearly identified with a permanent tag in the field, and a database established to record information about each joint. Temporary tags can then be applied to the joint to indicate and control its status as the intrusive work and reinstatement progresses. It is good practice to apply the temporary tags prior to breaking containment and subsequently operate a “No tag, no touch” policy. A common method is to use tear off multipart tags where the status is indicated by the colour of the portions remaining on the tag.

Common status conditions are:

- Joint to be broken out/Joint broken out.
- Joint to be assembled/ Joint assembled.
- Joint to be controlled tightened/Joint tightened.
- Joint to be tested/Joint tested.
- Post start-up check.

Human Factors

The process of isolating and reinstating plant has the potential for human factors to introduce threats, as well as placing high reliance on human performance, to plan and manage the avoidance of threats, and to manage errors. The eight key elements of the reinstatement process set out in Figure 1, are all activities carried out by people and as such are vulnerable to human failure.

The guidance highlights some of the relevant human failure vulnerabilities, appropriate risk control strategies, and outlines the principles of a systematic approach to analysing safety critical reinstatement tasks. The objective should be to design reinstatement processes which are robust to human errors. This should be done in two ways: by following what has been established as good practice, for example conducting shift handovers face to face; and by assessing your own reinstatement processes using a systematic methodology which is based on a model of human behaviour.

Shift Handover

Reinstatement activities will often extend over more than one shift and shift handover is key in this process. They can also be started on one shift, interrupted and resumed some shifts later. For work to be carried on safely, incoming shift workers must understand the status of the plant and the potential consequences of actions taken on previous shifts. Effective shift handover communication will allow them to establish an accurate mental model of the status of the plant. HSE (1996) and The Keil Centre (2016) provide recommendations on how handovers should be conducted.

Competence

Many of the tasks carried out during reinstatement are safety critical. Training is the means by which a basic level of competence is enabled but is not sufficient for developing competence. The competence requirements for people engaged in safety critical reinstatement tasks should be managed through a competence management system which includes selection criteria, training needs analysis, on-the-job development, refresher training, coaching and mentoring. Step Change (2017) gives guidance on how to develop such a framework.

Checking and Verification

Having a second person check or verify that another person has performed a task correctly, is a human performance tool which can be a useful risk reduction measure during safety critical reinstatement activities. Given that this may be the final check before an operator takes an action which may have high potential consequences, it is imperative that these checks and verifications are performed effectively to maintain that safety barrier. There are two types of practice which are of interest, peer checking and independent verification (Department of Energy 2009).

Peer checking is a series of actions by two individuals working together at the same time and place, before and during a specific action, to prevent an error by the performer. A peer is a second individual with appropriate knowledge and experience.

An example where peer checking could be useful during reinstatement activities would be line breaking to reinstate a positive isolation (as defined in HSG253), where breaking into the wrong line could lead to a loss of containment. When a line is to be broken by a maintenance technician, it is common practice for an operator to be the peer checker and be present prior to line breaking to confirm that the correct joint is being broken, that there is no pressure in the line and to initiate emergency actions in case there is a loss of containment.

Joints which cannot be leak tested, for example flare connections, may instead be witness assembled. Witness assembly involves the joint being assembled by a competent technician while being observed by a specialist. The specialist witness is peer checking the assembly operation.

Independent verification confirms the condition of equipment or accuracy of documents or calculations required for safe operation. It is a process by which a verifier, separated by time and distance from the action by the performer who changed the component's state or produced the document, confirms the condition of the component or document. Independent verification is used when an improper component, state or document could subsequently cause adverse consequences if the improper condition remains undetected.

Examples where independent verification would be useful during reinstatement activities are, verification that the correct P&IDs have been printed off for the leak testing or line walking work packs, or verification that critical items have not been overlooked in a line walk.

Care should be taken not to rely too heavily on peer checking and independent verification. Research into the double checking of medicines in health care (Armitage 2007) found, similar to Department of Energy (2009), that they are vulnerable to:

- deference to authority, if the checker or verifier is junior to the performer;
- reduction of responsibility, if one party assumes the other has done the task correctly;
- automatic processing, resulting in mindlessness and reduced attentiveness; and
- lack of time.

It has even been suggested that these factors can result in peer checking and independent verification increasing the risk of error. This paradoxical outcome can be countered by:

- increasing the error wisdom of those carrying out the practices, by sharing examples of reinstatement incidents and awareness about the consequences of reinstatement error scenarios;
- establishing a culture where people welcome and even seek out their actions being checked or verified;
- establishing a leadership vision of the team collectively working towards safe reinstatement.

Human Machine Interface

In its investigation report into the 2005 BP Texas City Isomerization Plant incident, the Chemical Safety Board (2007) described how the control room board operator had overfilled the raffinate splitter. For some time prior to the release, the flow into the splitter had exceeded the flow out, but the board operator had not noticed it. These flows were displayed on different screens. The board operator's task of monitoring and controlling the flows and the level would have been made easier and less vulnerable to failure, if there had been a start-up screen which showed all the paraments which were important for safely starting up the unit. Screens or graphics designed specifically for reinstatement activities can reduce vulnerability to human error.

Safety Critical Task Analysis (SCTA)

Reinstatement activities comprise safety critical tasks which operating companies should analyse using SCTA. SCTA is a methodology which should be facilitated by a trained and competent facilitator.

Task Analysis is the study of what a person is required to do, in terms of actions and mental processes to achieve a goal (Energy Institute 2020). A Safety Critical Task (SCT) is one where human factors could cause, or contribute to, a major accident, or fail to reduce the effect of one, including during:

- operational tasks;
- prevention and detection;
- control and mitigation; and
- emergency response.

For example, failure of a disturbed joint during leak testing might have been identified as a hazardous consequence. The task of incrementally increasing the pressure in steps of 25% of the final leak test pressure is a safety critical one which is intended to limit the consequences in case the joint fails. The task is vulnerable to being violated, i.e. skipping one or more increments, especially if there is time pressure. This vulnerability might have been revealed by considering performance influencing factors *work pressures* or *production vs. safety*). A suitable risk reduction measure might be to require that the incremental pressure steps are recorded and signed for.

Maintenance turnarounds of large process plant can put an abnormally high workload on operations and maintenance personnel. Even when the turnaround has gone according to plan, after several weeks of turnaround activities, personnel can be significantly fatigued. Especially if there have been delays and the turnaround is behind schedule, there can also be pressures to get the plant back into operation. The reinstatement phase is not the time to try and recover delays which occurred earlier in a turnaround. Leaders have a part to play in protecting the organisation from such pressures, but nevertheless people's performance can be affected by feelings of personal accountability for the schedule. The performance influencing factors *fatigue*, *work overload* and *peer pressure* can be relevant. Taking these factors into account, reinstatement and start-up activities should be suitably planned and managed to ensure that sufficient crew levels are in place and that the crew have sufficient time, knowledge, understanding and competency. Where possible, start-up timing should be selected to avoid critical activities being carried out at shift or crew change.

Safe Plant Reinstatement Process within a Management System

Companies for whom this guidance is intended, already have in place health, safety and environmental management systems (HSEMSs). Such systems are intended to enable the organisation to provide a safe and healthy workplace, prevent work-related injury and ill health, avoid environmental impact and continually improve performance. They are all based around the plan, do, check act (PDCA) cycle.

Organisations which operate major hazard facilities, integrate process safety management within their HSEMS. This helps them ensure that the associated practices are implemented effectively and are sustained. The same is true for the recommended reinstatement good practices which an organisation has determined are relevant for its situation. The guidance outlines how a systems approach can help to ensure safe plant reinstatement, with reference to the headings of ISO 45001 (ISO 2018).

For example, under *Organisational Roles, Responsibilities and Authorities*, top management should ensure that the responsibilities and authorities for relevant roles within the reinstatement processes in the HSEMS are assigned and communicated at all levels within the organisation and maintained as documented information. This should include:

- authority to issue permits to work and to take equipment back at handover;
- appropriate authority to sign equipment off as mechanically complete;
- authority levels to progress through the stages of reinstatement, including for approval and sign off prior to the reinstatement progressing to reintroducing process fluids;
- authority to deviate from documented reinstatement procedures;
- authority to sign off management of change documentation.

Under *Hazard Identification and Risk Assessment*, the hazards which might be present during reinstatement activities and their associated risks should be assessed. This includes:

- systematically identifying which hazards should be considered;
- using risk assessment to select the isolation scheme;
- ensuring that positive isolations (as defined in HSG253) can be safely removed when the work has been completed;
- assessing the criticality of bolted joints and using the result to support decisions regarding leak testing;
- risk assessing the leak testing plan;
- using risk assessment to determine whether it is safe to reintroduce process fluids if equipment which affects the operation of the plant is not available;
- making a decision on how to deal with a passing boundary valve during leak testing
- evaluating alternative arrangements when it is necessary to deviate from the intended plan.

Risk assessments should take account of human factors.

Leadership

Good leadership is essential for an organisation to achieve its process safety goals. Findings by the HSE of systematic failings during reinstatement off-shore and in other major hazard facilities, and the serious process safety risks they present, suggest that these often require more than a few tweaks to management systems to resolve (Hynds and Templeton 2020); the necessary organisational and cultural changes require strong leadership.

Regulatory bodies have published leadership expectations (COMAH Competent Authority 2019a and 2019b), and guidance has been published by professional associations and trade bodies (Center for Chemical Process Safety 2019, Health & Safety Executive 2009, and Oil & Gas UK 2019). These provide a starting point for building a leadership strategy for safe plant reinstatement. Implementing a leadership strategy requires developing a plan, executing it, monitoring performance, learning from experience and adjusting it. The new guidance provides a framework for achieving this.

A distinction is drawn between management and leadership. In its report of its investigation into the 2014 release of sulphuric acid at the Tesoro Martinez Refinery, the Chemical Safety Board (2016) told how the refinery's procedures required leak testing of instrument small bore tubing but not of small bore tubing in process applications like sample systems. Had the sample system been tested before it was reinstated, the acid leak and injury to two personnel could have been prevented. Correcting this management system failure was a task for the refinery leadership team, but would not on its own have required much in the way of leadership skills.

However, the Chemical Safety Board identified process safety culture weaknesses at Tesoro, evidenced by previous sulphuric acid incidents, worker statements, gaps in safety standards, deviations from established procedures and practices, and past efforts to assess and strengthen site safety culture.

Leaders from the board room down need a sufficient understanding of process safety management and how the various elements of a process safety management system come into play in safe reinstatement. But addressing findings like those of the CSB at Tesoro, takes more than an understanding of process safety management. It requires leadership skills to engage the workforce in the need for change, create an attractive vision of where the refinery needs to get to, and bring people along on the journey to that better place.

Successful process safety leadership is a dynamic system of behaviours and interactions between leaders and followers, which is adjusted depending on the context, Figure 14. Studies have shown that people are more likely to follow a leader who is honest, has integrity, is forward looking and competent. But rather than being a result simply of the traits and behaviours of a leader, leadership emerges from the dynamic relationship between the leader, the followers and their shared context.

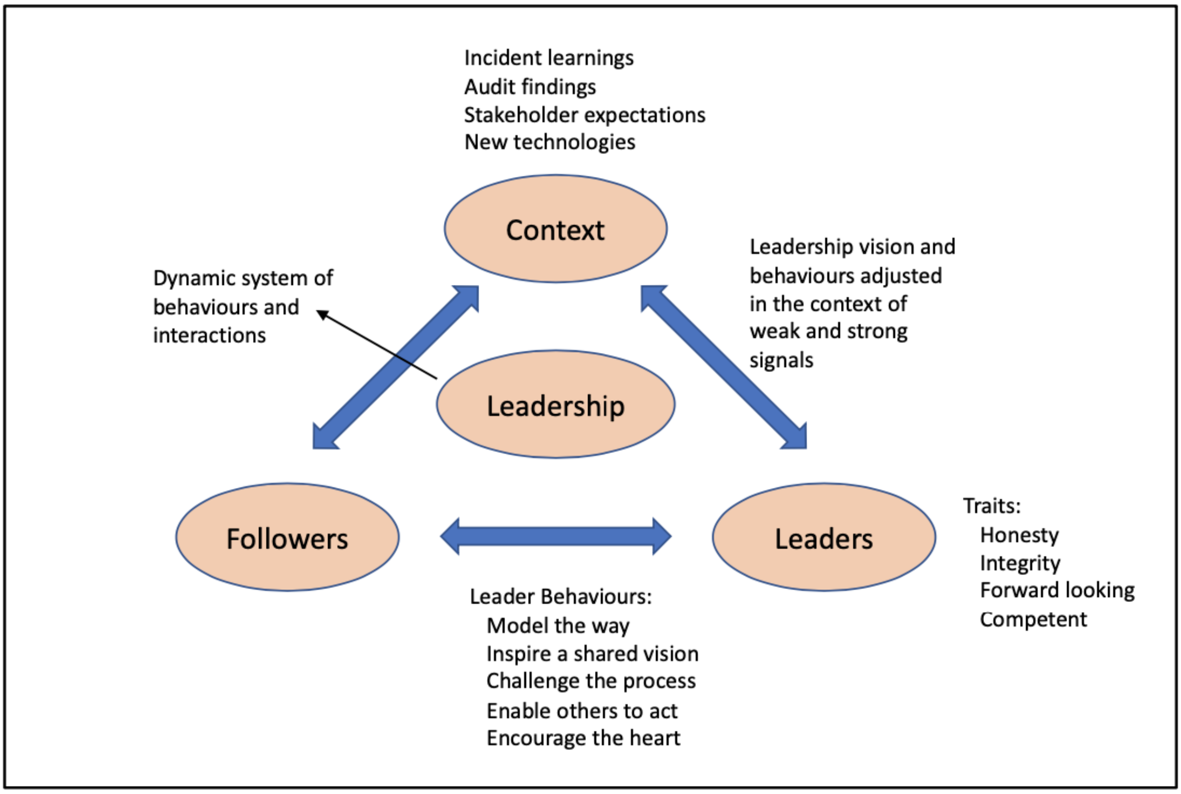

Figure 2; Process Safety Leadership Model, a dynamic system of behaviours and interactions (Webb 2020)

Organising the Successful Drafting of a Guidance Document using a Working Group

The Energy Institute creates and publishes guidance documents on technical and management topics relating to the energy industries. It exists for the benefit of its members and is organised in a way which draws on its membership. As is normally the case, this guidance was written under the supervision of a technical committee, in this case the Process Safety Committee (PSC) which comprises EI staff and industry and regulator representatives. The PSC created a working group (WG) which comprised a chairman, who was a PSC member and worked for a member company, an EI staff member as project manager, an independent technical author (the author of this paper) and WG members drawn from member and non-member companies.

The "conventional" process for producing a new EI document typically entails a technical author producing a complete first draft prior to the working group reviewing the document. The process for developing this guidance was that a table of contents for the document was first agreed. The technical author then drafted the document a section at a time. Once complete, each draft section was sent to the WG members as pre-read for a 1 ½ hour meeting on that section. The chairman would step through the new draft at a pace which allowed for the possibility that the WG members had not had time to read the pre-read. The technical author noted any comments. The meetings were also opportunities for WG members to offer to share company information. The technical author would redraft that section based on comments received at the meeting and it would be sent out as pre-read for the next meeting where it would be approved or further comments taken. Each meeting thus comprised reviewing the redrafted section which had been discussed at the last meeting followed by reviewing the new section draft. Working this way had a number of advantages:

- dealing with the drafts a section at a time made it less burdensome for the WG members to read and comment;
- it made it easier for the technical author to draw on the knowledge and experience of the WG members.
- for this first edition guidance, the development process offered better member engagement over the conventional process.

As soon as the working group was satisfied with the document, several industry bodies and external experts were invited to review the working group draft and pass comment on its content. Approximately 180 comments in total were received during Q1 2022 and were resolved during Q2 2022. The next stage is to ballot the PSC on its approval to publish and publication of the guidance is anticipated in Q4 2022.

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