Leak testing when reinstating plant – it's more complicated than you think

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'Service testing' using the process fluid during plant reinstatement after maintenance has been common practice for many years in the oil and gas industry. This practice has largely been criticised by the Competent Authority and industry bodies in favour of full reinstatement testing at up to 110% of the maximum allowable working pressure of a process system using an inert fluid, which, on the face of it, seems to be the safest option.

The first observation is that use of inert fluid (typically nitrogen) may be unacceptably hazardous to both the people carrying out the test and around the plant. A potential asphyxiant, supplied at high pressures, nitrogen testing usually involves use of temporary equipment including flexible hoses and depending on complexity, specialist contractors. These complexities immediately requires the personal safety and process safety risks to be balanced.

The hazards of pneumatic testing due to the stored energy of gas at high pressure are well known. The potential for missiles and shock waves due to test equipment or pressure system failure presents significant risk to personnel. Hydrostatic testing therefore, presents an immediate risk reduction but introduces its own issues including availability/space for storage of a suitable test liquid, the compatibility of plant materials with the test liquid, low point and deadleg corrosion, introduction of microbes and a requirement to dispose of potentially contaminated test liquid. For systems designed to handle hydrocarbon gas the introduction of liquid for leak testing is rarely considered to be practical.

To better understand the potential risks of leak testing, a safety critical task analysis (SCTA) for reinstatement of a fuel gas system on an offshore production platform was carried out. This analysis highlighted several complicating factors that were not immediately obvious.

Isolation of the fuel gas system included isolation of both duty/standby pressure safety valves (PSVs) from the vent system. A 'sanction to test' (or equivalent) would be required to remove this isolation before testing the envelope, adding complexity that does not arise with service testing where the whole isolation can be removed.

The choice of location for the inert gas (nitrogen) inlet created a dilemma. Using a bleed point from the double block and bleed isolation applied when preparing the system for maintenance has the advantage that a blank flange had been removed already but the associated inboard isolation block valve would have to be opened so that the inert gas could flow to the system. This could be added to the sanction to test but could make any corrective work more challenging since the integrity of the initial isolation will have been compromised.

Similar issues can arise for the vent point required to carry out the leak test. A fixed vent connection may be available in some cases, but again is likely to be part of the isolation put in place for the maintenance activities.

Non-return valves (NRV) create a risk of overpressure downstream of an NRV if the relief point within the test boundary is upstream, and if intrusive work is subsequently required to rectify a leak the trapped pressure is a hazard to personnel.

High pressure – low pressure (HP/LP) interfaces within the isolation boundary proved to be a particularly complicated aspect of leak testing. Testing the upstream, high pressure side of the interface, introduces the risk of over pressurising the downstream, low pressure side.

This work highlights the benefits of SCTA for assessing critical, complex tasks such as leak testing. Also, that leak testing can be more complicated than you think. Whilst an inert fluid is inherently safer than a flammable or toxic process fluid, it is not always the case that leak testing with an inert will always be the lowest risk option.

Key words: Human Factors, Safety Critical Task Analysis, SCTA, leak testing, pressure testing, plant reinstatement, isolation, return to service, loss of containment

Introduction

Maintenance, inspection and testing is critical for making sure plant and equipment continues to satisfy its design intent. It often requires breaking the pressure envelope that is critical for keeping hazardous substances under control. The immediate potential for loss of containment prior to breaking containment is controlled by suitable isolation, draining, venting, flushing and/or purging when preparing plant for maintenance. The objective being to make the plant safe for intrusive work to take place.

After maintenance is complete the pressure envelope of the plant must be reinstated. Failures at this stage can result in loss of containment when the plant is restarted and returned to service. Data shows that major accidents are disproportionately more likely during plant start-up [IChemE 2009].

Guidance document HSG 253 from the UK Health and Safety Executive [HSE 2006] has been useful at defining acceptable standards for preparing plant for maintenance since its first publication in 1997. Whilst this document also highlights potential issues with reinstatement of plant, details about what constitutes good practice are quite vague and the document has not been reissued with any updated guidance since 2006.

Detailed procedures for Safe Isolation and Reinstatement of Plant (SIRP) have become fairly standardised in some sectors, including the UK's North sea oil and gas industry. However, a significant gap for what constitutes good practice when reinstating plant has existed, and was discussed at Hazards 30 [Hynds and Templeton, 2020]. It has been recently addressed in part by guidance published in 2023 by the Energy Institute [EI, 2023].

These recent developments have shown that past and current practices for leak testing during reinstatement fall short of what may be considered good practice. However, there are pros and cons for all approaches and judgement is required to ensure that the chosen solution is actually the lower risk. This paper illustrates how Safety Critical Task Analysis (SCTA) can help to understand how leak testing is carried out and uses a case study to illustrate some potential complexities.

Leak testing overview

The need to avoid leaks when plant is returned to service after maintenance has been recognised for many years and methods have emerged to reduce their likelihood. Line walks and visual inspections make sure the plant is in the required state. Documentation checks make sure all work is complete, permits to work signed off etc. and is usually independently checked and verified. Administrative controls such as Pre-Start-up Safety Review (PSSR) or similar formalised operational checks provide a final hold point before process fluids are introduced. Leak testing uses first hand physical evidence to provide assurance that the likelihood of loss of containment during normal or abnormal operations from potential leak points has been reduced to As Low as Reasonably Practicable (ALARP), thereby protecting people, plant and the environment.

Purpose of leak testing during reinstatement

The focus of leak testing is flanged, screwed and clamped joints on pipework and pressure vessels, small bore tubing (SBT) fittings and any other equipment that may have been disturbed as part of the maintenance activities.

Joint and SBT integrity management systems have been developed that cover the full lifecycle of joints. They typically require all joints disturbed during maintenance to be recorded and procedures followed that ensure all are broken and then remade using the correct methods and materials. Multi-part tags are often used to provide clear identification, status and traceability from the point when the joint is disturbed through to final confirmation that it has been remade with proven integrity.

Leak testing is part of the final verification stage to prove that the systems in place to ensure plant is ready for return to service are working as intended.

Leak test methods

Leak testing typically involves pressurising the plant in stages, pausing and checking for leaks. Standard methods include:

- Service test – Pressurise the plant with process fluid until it reaches full operating pressure;
- Gross leak test – A check for gross leaks at a relatively low pressure using an inert fluid (e.g. nitrogen, water or air) to pressurise plant. May be carried out as part of plant purge, and followed by service testing;
- Pneumatic full reinstatement leak test - An inert fluid is used to pressurise the plant in stages to a high pressure, determined by the plant's design or Maximum Allowable Working Pressure (MAWP);
- Hydraulic leak test - Plant is filled with a low hazard liquid (e.g. water) and then pressurised using a hydraulic hand-operated Tangye, air driven pump or in some cases, an inert gas, known as a 'squeeze'. It can be conducted as a gross or full pressure reinstatement leak test.

For each method leaks can be detected through visual inspection of joints, the use of leak detection fluid and/or pressure decay tests.

Other leak test methods are available including a sensitive leak test, which uses a specialised fluid of nitrogen typically with a 1% helium tracer and specialised equipment to detect smaller leaks than may be possible with the standard methods above.

Reverse Integrity Testing (RIT) is another method of integrity testing which uses a special gasket that creates an inner and outer seal. The space in the cavity can be pressurised externally and monitored to confirm there is an effective seal. RIT is a useful tool for providing assurance on joints which due to system design cannot undergo a full reinstatement test such as a flare or vent system.

Selecting the appropriate leak test method

Whilst we often talk about risk based decision making where safety is concerned, there is usually a default option that provides a short-cut when selecting how to proceed. Recent developments suggest that industry is moving towards an expectation that full reinstatement leak testing becomes the default.

If we consider the risk of plant reinstatement the hazardous properties of the process fluid and the potential consequences of a leak are likely to be the dominant factors. The number of disturbed joints may be a consideration (i.e. a small number may be viewed as a lower risk), as well as the size of the line(s)/system among many other considerations

However, service testing has been used widely across industry, including for hazardous processes. Pneumatic gross leak testing is also used if there is a convenient supply of inert gas (i.e. the site has a compressed air or nitrogen distribution network at sufficient pressure). Other forms of leak test have often been viewed as more specialist and used less widely.

It could be concluded that in the past the leak test method was often selected for convenience rather than risk based. More stringent leak test methods have always been used where a need was identified, but judgements made historically may not be consistent with current expectations. The recently published guidance has widely been interpreted and reinforced by the Competent Authority to mean full reinstatement leak testing should be the default option. However, this method has its own risks that need to be considered when deciding which method is the correct one to use for each specific circumstance.

Hazards of leak testing

There are very few things we do in the process industry that do not involve some hazard.

Process fluids

The main concern with service testing is that process fluid is introduced to an unproven system. If the fluid is hazardous any leaks that occur could result in fire or explosion, and/or expose personnel to harmful substances. This is why other forms of leak testing before introducing process fluids may be preferred. Benefits of service testing may include that it does not require any temporary arrangements, reduces plant down time, specialist competencies are not required, and personnel are not exposed to high test pressures.

Inert gases

Nitrogen is the most widely used inert leak test gas; with a helium tracer added in some cases for specialist applications. Carbon dioxide is another commonly available gas that may be used. The benefit is that these gases are not flammable or toxic, but they are asphyxiants and have the potential to kill. A further challenge with inert gases is that they usually have no odour, so people cannot detect them by smell.

The source of the inert gas can introduce additional hazards. If the site has a permanent distribution network (most common for nitrogen) the generation and/or storage facility is likely to be remote from the leak test location and not an immediate asphyxiant concern. However, temporary supplies of inert gas typically involve pressurised storage with let down and/or vaporisation plant. These introduce hazards of high pressure gas and low temperatures due to the Joule Thomson effect. On small sites, the location of temporary equipment can also create hazards if emergency routes are blocked or people have to adopt harmful postures because access is compromised.

These inert gases may be less hazardous than many process fluids but using them for leak testing cannot be considered as inherently safe.

High pressures

Gross leak testing is carried out at relatively low pressures, which are inherently safer than the potentially high pressures used for full reinstatement testing. However, the source of the test fluid (i.e. gas cylinders) may be very high, 200-300 bar, and even low pressure supplies from a permanent network may still exceed the design pressure of plant being tested. The hazards of over pressurising plant are fairly evident. Ruptures and high energy missiles, and the associated loss of containment are the main concerns. Even a release of an inert gas could harm people in an area with inadequate ventilation to disperse the gas, such as a gas compressor house or slug catcher bund. Structural damage may occur that does not cause an immediate hazard but could contribute to premature failure of plant when in service.

Leak testing using an externally supplied fluid will involve temporary connections, typically including flexible pipework (hoses) and fittings. Whilst all components should be appropriately designed for use, they are generally viewed as less reliable than fixed solid pipework, especially when human errors during connection and disconnection are taken into account. Hose and fitting failures at high pressure create a significant whipping hazard that can cause serious injuries. There can be manual handling involved in routing and connecting hoses. Also, having supplies of temporary pipework and hoses at a facility can lead to general misuse. The depressurisation route, if not via a hard piped vent on the process plant, also poses a threat to people if the temporary vent point is not suitably located or sized.

Liquid test fluid

The main concern with pneumatic testing is the stored energy of gas at high pressure. Hydrostatic testing reduces this risk by filling the plant with a low hazard liquid before applying pressure. The likelihood of plant failure due to over pressurisation remains the same but the consequences from rupture are greatly reduced. Also, if the test liquid is not harmful to humans the consequences of the loss of containment that occurs is reduced. However, fluid injection into the body must still be taken into consideration. Fluid at pressure of just 100psi (7 barg) can penetrate the skin causing fatal injuries.

An immediate concern with using liquid as test fluid is its weight. Plant designed for gas service or for partial liquid inventory only (e.g. distillation column) may not be designed to withstand the forces created by being filled with liquid.

Disposal of the liquid after testing can be a concern that may not have safety implications but makes hydrostatic testing impractical. If the liquid is compatible with the process and does not create quality issues the plant can be started up with it remaining in place. If this is not acceptable, it will need to be drained and disposed of, which may have environmental implications, particularly on an offshore installation where discharges to sea are closely controlled. Contaminated liquids often need to be shipped back to shore for treatment prior to disposal. Containers for provision of the test liquid and recovery of the post-test contaminated liquid also need consideration with respect to offshore storage space. During shutdown periods where the entire process is offline, available loading/unloading and storage space is often at a premium and large volumes of liquid may be required for process vessels.

Water is the most commonly liquid used for hydrostatic testing. However, it is unsuitable for many types of process. For example, plant handling natural gas can be sensitive to water content, with relatively small quantities causing hydrate formation. There have been cases where hydrates have blocked impulse tubing to instrumentation used by Safety Instrumented System (SIS), resulting in multiple layers of protection being made inoperable (common cause failure). Cryogenic systems are another example where water is totally unsuitable. Water can be treated with chemicals (e.g. glycol) to reduce the likelihood of these problems, but then it becomes a potential environmental issue. Other issues may be concerns about corrosion or microbial growth. Again, chemical treatment is possible, but with the same environmental concerns. Water is also not suitable for testing oil based hydraulic control systems or where the introduction of water could cause a violent chemical reaction, such as in the processing of acids and alkalis.

Case study

Safety Critical Task Analysis (SCTA) was used to look at leak testing as part of a wider scope of human factors work at an offshore gas platform. The operations team were asked to select a suitable representative case to assess. They chose the platform's fuel gas system because it was considered to be one of the more complex examples that would be undertaken by the core crew. A procedure had been produced for a full reinstatement leak test of the system.

System description

Figure 1 shows a simplified representation of the fuel gas system. High pressure gas enters the system and passes through a heater before its pressure is reduced by flowing through an orifice plate. A pipework specification change occurs after this, creating a High Pressure – Low Pressure (HP-LP) interface. The lower pressure gas passes through a knock-out drum where liquid is collected at the bottom of the vessel. Gas leaves the drum via a non-return valve and feeds into the fuel gas network. Liquid from the vessel is drained under level control to an open hazardous drains system that operates at atmospheric pressure. Another HP-LP interface occurs in this drain line.

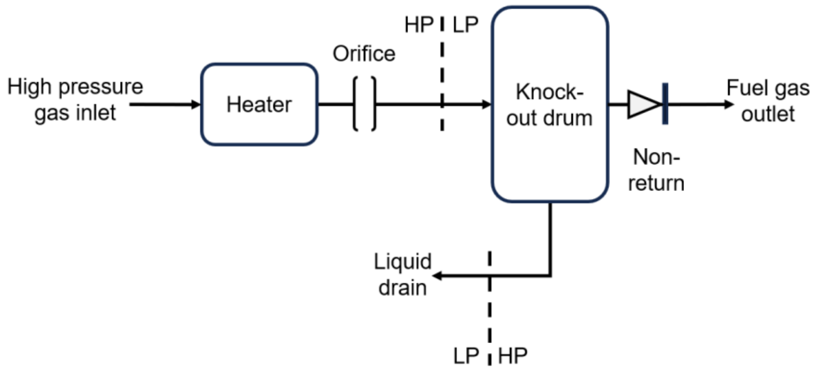

Figure 1 - Simplified diagram of the fuel gas system

Plant status for maintenance

Figure 2 shows the plant status when maintenance is taking place. Valves showed as filled-in dark grey are closed as part of the isolation and valves shown as clear are open. The overall isolation philosophy is double block and bleed at the system inlet and outlet, with bleeds also closed but available to be opened for periodic integrity checks of the isolation. Pressure safety valves (PSV) are isolated at their inlet and outlet; and the level control in the drain line and the valve that forms part of the low level Safety Instrumented System (SIS) are closed. Manual valves either side of the orifice are open to allow the whole system to be isolated as a single item. A local vent from the knock-out drum is open to prove the integrity of the isolation. Depending on the maintenance work taking place, positive isolation in the form of removable spools and slip plates will be used inside the defined boundary, which result in joints being disturbed.

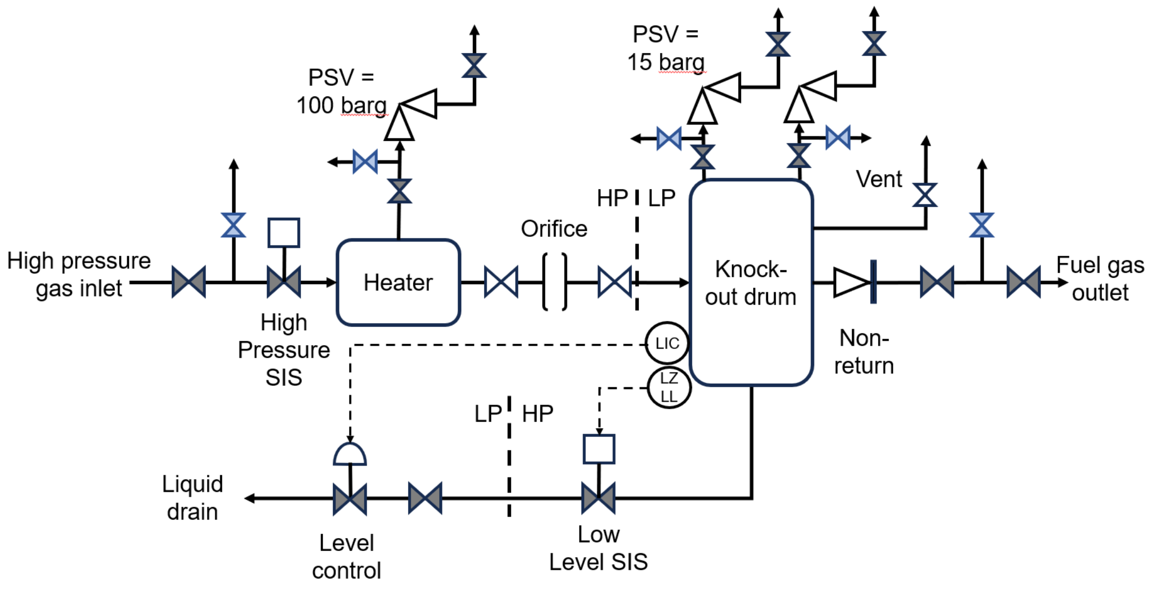

Figure 2 - More detailed view of the plant showing valve isolation status for maintenance

Leak test options

Carrying out a service test of the system from its isolated state would be simple. Gas can be introduced via its normal route to pressurise the system, before establishing normal flow through the system. The obvious flaw with this approach is that any leaks that do occur will be process gas and potentially hazardous.

The next simplest option would be to carry out a pneumatic gross leak check. The vent valve on the knock-out drum could be used to introduce the test gas (assuming it was accessible). This would be effective at checking for leaks inside of the isolation boundary but would be at pressure below normal operations. It could be followed by a service test, as above.

Procedure for pneumatic full reinstatement test

A procedure and fully marked up Piping and Instrument Diagram (P&ID) had been developed by platform personnel for carrying out a full reinstatement test using high pressure nitrogen as the test fluid. It appeared to describe a very reasonable and practical method of performing the task, but on closer examination it became clear that there were complicating factors that needed some detailed analysis. This immediately validated the plan to carry out a SCTA.

Applying safety critical task analysis to leak testing

SCTA is a tried and tested method of qualitatively evaluating human factors risks associated with tasks that have a clearly defined start and end, and consist of clearly defined actions or steps. It involves:

- Describing the task method in a structured and systematic way so that anomalies, ambiguities and inconsistencies can be identified and resolved;
- Analysing each task step to identify potential human errors and consequences;
- Evaluating Performance Influencing Factors (PIF) that may make the likelihood of error greater than it should be;
- Considering the risk controls in place and determining if they are sufficient to reduce risks of the task to As Low As Reasonably Practicable (ALARP).

Leak testing is amenable to this approach.

Task method

Hierarchical task analysis was used to map out the method for leak testing the fuel gas system. Figure 3 shows the high level sub-tasks that were identified. Although developed for the fuel gas system these should be largely generic.

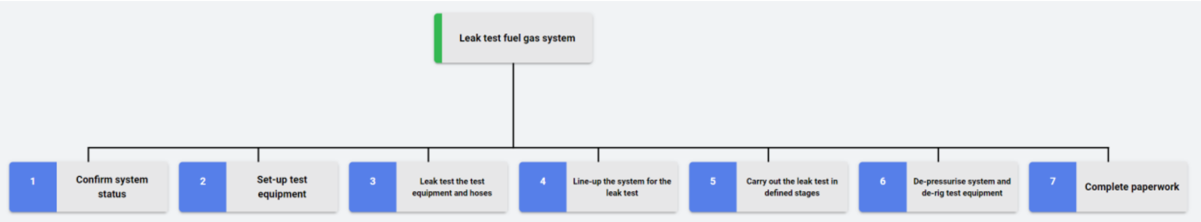

Figure 3 - High level overview of the task

At this level the task method appeared to be very straightforward. As is usually the case, the devil is very much in the detail, which is described in the next level in the hierarchy. As an example, Figure 4 shows this for sub-task 4, which was lining up the system for the leak test.

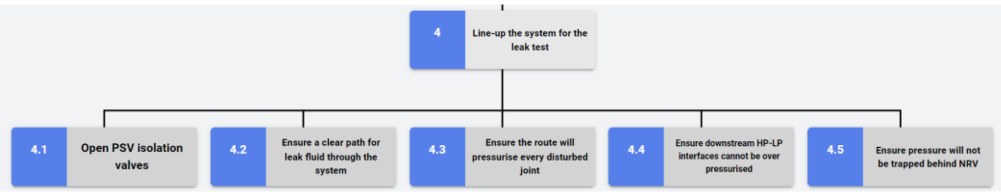

Figure 4 - Steps performed under the sub-task for lining up the system for the leak test

By mapping out the task at this level of detail it became apparent that there were several potentially complicating factors that need to be considered when evaluating the risk.

De-isolating PSVs

If PSVs discharge to a common vent system they have to be isolated for maintenance work to prevent potential gas flow from the vent system to the plant being maintained. Full reinstatement testing uses high pressures and the source of the pressure (e.g. gas cylinders) can be very high (up to 300 bar). Although it is possible to control the pressure (typically using a regulator installed on a test manifold), it cannot be considered 100% reliable and so the PSVs should be available to protect the plant whilst the leak test takes place.

The complicating factor with de-isolating the PSVs for the leak test is that the remainder of the isolation should remain intact until the test is complete. A Sanction To Test (STT) can be used to remove part of the isolation, but clearly this is additional work requiring detailed planning and modifications to the isolation certificate, introducing further complexity.

It is worth noting that PSVs have to be de-isolated as part of plant reinstatement. During service testing this will occur as part of the overall de-isolation. During gross leak testing it may be possible to leave the PSVs isolated during the test if pressures will be significantly lower than plant design specifications, or if a suitably sized PSV is installed on the temporary equipment set at a relief pressure below that of the system PSV.

Identifying where to connect the leak test gas supply

The leak test gas (nitrogen in this case) was to be supplied from cylinders via a flexible hose. For a gross leak test the vent on the knock out drum could be used but this was not suitable for the full reinstatement test because it would not allow the high pressure part of the system to be pressurised to its test pressure.

The bleed point on the fuel gas system inlet isolation was identified as the most suitable place to connect the nitrogen hose. However, this would require the inlet inboard isolation valve to be opened, which was secured closed as part of the overall isolation. Also, valves isolated in the open state around the HP-LP interface would have to be de-isolated and closed. A STT can be used to allow this, as described above for PSV, but each item add complexity and potential risk.

Another complicating factor was identified. If the leak test was unsuccessful (i.e. a leak was discovered) the system may have to be re-isolated to allow remedial work to take place. The normal method of proving its integrity would not be possible because the outboard isolation valve would be closed and so no pressure would be present to perform a suitable test. Alternative methods could be used (e.g. injecting nitrogen between the isolation valve), but again this is additional work.

There may be other connection points available that could be used instead of the inlet isolation bleed valve. However, if they had not been used as part of the original isolation or the maintenance work they would be blanked or plugged closed. The positive isolation can be removed, but it creates additional work, including requirements for recording and tagging for joint integrity management. It would then not be possible to complete a full reinstatement test on that additional joint and it would need to undergo a service test, thus increasing the number of potential leak points.

Non return valves

An alternative connection point for the nitrogen inlet was the bleed point on the system outlet isolation. In this case it was not viable because it would not allow the high pressure side of the plant to be pressurised to its test pressure. However, it highlights potential issues with NRV.

Trying to pressurise against an NRV will not be successful because the test gas will not be able to flow to the remainder of the plant. If it were to be attempted in error it could mean that a leak test may be accepted as a pass when in fact leaks were present that had not been detected. The requirement to confirm NRVs have been re-installed with flow in the correct direction cannot be understated and this check should form part of the leak test line walk and checklist. However, a more immediate problem is that the downstream side of the NRV may not be protected against overpressure because PSVs are the 'wrong' side of the NRV. This could result in a rupture of pipework. Another potential issue is if a leak is discovered and remedial work has to be carried out there could be trapped pressure in the system on the 'wrong' side of the NRV that could cause harm to people doing the work. On a P&ID, the distance from an NRV to a downstream block valve can be very misleading and may be a large inventory of gas. Even on a successful leak test, this inventory can still present further hazards post reinstatement for fired equipment if not purged to vent. This highlights how essential it is to complete a detailed line walk of the leak test envelope to ensure the entire inventory can be depressurised safely.

HP / LP interfaces

Arguably the most complicated issue to consider was how to satisfy the requirements of a full reinstatement test for high pressure parts of the system without over-pressurising the low pressure parts. There are solutions but they require additional actions to be taken, that are vulnerable to technical and human failures.

For the gas line between heater and knock-out drum the solution would be to pressure the whole system to satisfy the low pressure test requirement. Isolation valves can then be closed (in this case either side of the restriction orifice) and the high pressure test can take place. This is vulnerable to failures of the valves or human error (failing to close the valves). PSVs on the knock-out drum should provide protection, but can never be 100% reliable and are vulnerable to human error if their isolation valves have been left closed. It is also worth noting that if any joints had been disturbed in this pipework (e.g. a valve or the orifice plate had been removed) it may be necessary to conduct the leak test of the joint at high pressure with only a single valve isolation protecting the low pressure part of the system.

The second HP/ LP interface is in the drain line. The LP side is normally protected by a liquid level in the knock-out drum, with level control and independent SIS to prevent gas blow-by with overpressure protection further downstream. The SIS valve and downstream block valve in the drain line were closed as part of the isolation scheme for the fuel gas system to protect against reverse flow from the drains system. However, that creates a hazard during pressure testing if the low level SIS valve is passing or has been opened in error because the downstream low pressure pipework would be over pressurised and could rupture. Fortunately in this case, the pipework was an equivalent rating to the upstream system, however the joints in the LP drains system would not previously have been subject to a pressure equivalent to the test pressure and so present potential leak points.

Avoiding overpressure of the downstream pipework during leak testing requires an open leak path to be created. In this case, due to the location of the HP/LP interface, the block valve downstream of the SIS valve needs to be open and the fail closed LCV held open (STT required). Again, this introduces additional complexity.

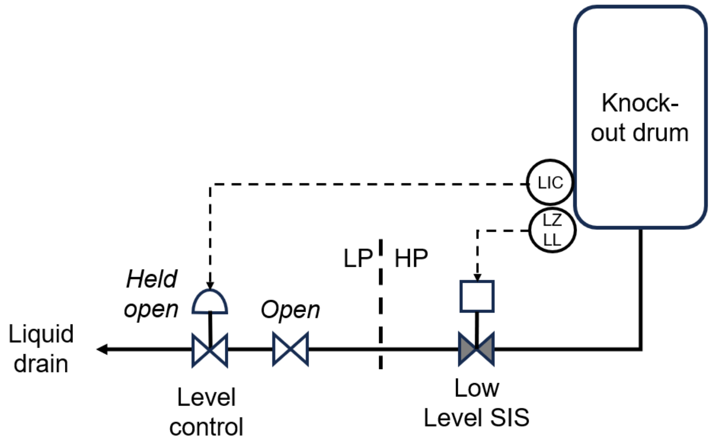

Figure 5 - Valve status in drain line required when leak testing the knock-out drum

Discussion

There were two key objectives with this paper:

1. Demonstrate that safety critical task analysis is an effective way of assessing critical, complex tasks like leak testing;
2. Highlight that leak testing can be more complicated than you think.

In the case study full reinstatement testing using nitrogen was recognised as good practice consistent with latest guidance, and accepted as a reasonable objective. A procedure had been prepared that appeared to satisfy the requirements. However, the scrutiny provided by SCTA uncovered a number of potential issues that highlighted full reinstatement testing can introduce some potentially significant risks that could outweigh the benefits of alternative leak test methods (e.g. service testing, hydraulic testing or pneumatic gross leak testing). In many cases the dilemma is how to balance the risks of process safety as a result of leaks from plant during return to service with personal safety risks created during testing. There is no simple answer but it is clear that blindly following good practice or guidance is not acceptable.

The starting point for determining ALARP when planning a leak test assessment should begin when initially planning the isolation for maintenance. At this point the team involved must identify the worst-case foreseeable pressure excursion that could occur during operation in order to apply a suitable isolation standard and then determine the leak test pressure, ensuring the applied isolation will also provide adequate protection to downstream lower rated systems during testing. The pressure at which the reinstatement testing is carried out may not be as straightforward as simply identifying the nameplate Maximum Allowable Working Pressure (MAWP). In a gas producing installation, MAWP may be based on Shut In Well Head Pressure (SIWHP) or failure of compressor control systems, for example.

In ageing installations where reservoir pressures have depleted, SIWHP may no longer be anywhere close to the original or documented MAWP. In these cases, The Company should be considering derating to reduce large gaps between layers of pressure protection (high pressure SIS and PSV) but this tends to be exerted with caution depending on future development opportunities. In these types of cases there is no value in carrying out a leak test at a pressure up to 110% of the original MAWP if only say, 50% of that pressure is actually achievable. This type of identification is critical in reducing risk when leak testing.

Where practicable, the elimination of stored energy risks by substitution of test gas with liquid is the next step in reducing risk. Where this is not practicable due to plant incompatibilities then a thorough review of the isolation to consider the leak test boundary in order to reduce required test envelopes, eliminate any HP/LP interfaces and review the potential for engineering modification to improve the design either before or during the planned maintenance activities. The use of reverse integrity test (RIT) gaskets is an effective way of significantly reducing the required test envelope and should be considered as a tool to use alongside a full reinstatement test or potentially in place of one after consultation with the relevant piping and process technical authorities. RIT gaskets are a significant step forward in risk reduction, but their use should not be considered ALARP as a standalone leak test without further consideration. The test ports of RIT gaskets are particularly vulnerable to damage and without completing a full reinstatement test, the system will not have been put under the same stress as may be achieved during operation and the potential for unrevealed failures.

Only after elimination, substitution and engineering changes have been considered should consideration then be given to potentially reducing leak test pressures if the assessment so far has not determined the risks of the leak test to be ALARP. It should be noted that any reduction from the baseline standard (i.e. full reinstatement pressure) should require independent authorisation from a technical authority level of seniority to ensure correct assumptions have been made and a fully informed risk assessment has taken place.

Leak testing is potentially prone to human error and the additional complexity of full reinstatement testing when compared to other methods has the potential to increase the likelihood of error. Even worse would be if it were to create a false sense of security that may lead to a perception that good practice in joint integrity management are not so important.

To reduce the amount of work in preparing an isolation and/or leak test it is common practice to copy what has been done on the plant previously and use that as the starting point. This can lead to assumptions that what was carried out previously was fit for purpose and still so without undergoing sufficient challenge. No two situations should ever be considered identical, even on the same test envelope. Plant modifications, changes in operating conditions and personnel turnaround and/or competency can all contribute to creep.

One unanswered question from this is the true risk of plant failure during reinstatement. Maintenance work that does not make any changes to the design of the pressure envelope should mean that the integrity of most of the system has been proven through previous operation. The only area of vulnerability is the joints that have been disturbed. In many process systems achieving the minimum standard of isolation to allow breaking of containment (DBB or positive) to take place for maintenance activities creates an isolation envelope with an extensive inventory.

There are two types of human error that can occur during reinstatement that leak testing is intended to detect:

1. Failure to make the joint (e.g. missing gasket, bolts not replaced or tightened);
2. Joint made incorrectly (e.g. wrong type of gasket, sealing faces damaged, bolting out of sequence, mis-aligned joints, incorrect/incompatible SBT fittings).

The first failure can result in significant loss of containment but is easy to detect from tests at low pressures. The second failure would be far more difficult to detect and at normal operating pressures may not be apparent but even at high pressures may only result in relatively small leaks. This could call into question the real benefit of full reinstatement testing when the potential issues highlighted in this paper are taken into account.

Conclusions

Leak testing is a hazardous activity essential for preventing loss of containment following intrusive maintenance on a pressure system. Guidance issued by the Energy Institute [EI 2023] has gone someway to highlighting critical aspects of the reinstatement process. However, due to the differences in process design, operating conditions, plant condition and hazards across industry it is not possible to have a 'one size fits all' approach. A full reinstatement test may not be the ALARP solution when all risks are taken into account. The responsibility lies with The Company to determine the best solution, which may require setting acceptable thresholds where full reinstatement tests can be substituted with a lower integrity test. SCTA is a tool that can aid in the demonstration The Company is doing as much as reasonably practicable to prevent harm to people during and after leak testing activities.

Leak testing is a frequent activity carried out in the oil and gas industry and the use of SCTA has been demonstrated in this paper as beneficial in identifying complexities and risks not necessarily immediately obvious. However, it could be argued that these risks could have, and should have been identified by a competent operations team during the development of the leak test workpack. This is where SCTA comes into its own, as the pressures of day to day operations and time constraints are removed, allowing for a focussed and methodical approach to a procedure task based risk review. Human factors are not always obvious, and it can be taken for granted that a competent person will always remember to do the right thing without verification or checks. The use of SCTA may not be practical for every situation, controls need to be proportionate to the risk and SCTA requires competent human factors practitioners to lead a study, a competency not widely achieved to a standard within the oil and gas industry considered to be sufficient. Therefore, to ensure SCTA is utilised where it will provide the most value it should be targeted at high risk leak testing activities, i.e. high pressures, large inventories, multiple HP/LP interfaces, or where lower integrity test options such as service testing have been identified as the preferred leak test method. A reasonable recommended approach would be for operators to complete a screening exercise of leak tests completed over a period of time, with assistance from a competent HF practitioner, to determine where the boundaries would lie for SCTA to provide value. Operators should also consider training their operations teams in basic SCTA techniques so the principles of the study can be applied when generating and reviewing less hazardous leak test procedures.

Full testing at high pressure is clearly a requirement for commissioning new plant or following changes or maintenance work that could have affect integrity (welding on a pressure vessel). But it is an inherently hazardous activity. The risks must be balanced. Suitable, sufficient and effective controls that are proportionate for both leak testing and reinstatement are essential. Failures occurring during leak testing are more likely due to the high reliance on human performance at each stage and can be fatal. Failures following reinstatement after completing any type of integrity testing are less likely. However, higher pressures further increase the risk in both cases.

This case study has aimed to highlight the potential complexities and any procedure for reinstatement testing must have very close scrutiny. SCTA can be very effective in the more complex and critical circumstances.

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