Pressure Systems

GUIDELINES

Guidelines for Competent Persons involved in witnessing of Pressure Tests

Pressure Testing Guidance

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Forward

This guidance has been prepared by SAFed in consultation with the Health and Safety Executive and builds on the best practice advice given in guidance note GS4.

Contents

1. Introduction

Pressure testing makes use of Mechanical stored energy, in either fluid (hydraulic) or gaseous (pneumatic) form. A pressure test is a procedure intended to verify an unknown, by either establishing the quality, performance, or reliability of something, before it is put into use, or can be recommended as part of a thorough inspection undertaken as identified in a Written Scheme of Examination (however repeatedly exceeding the Maximum Working Pressure may reduce the ongoing structural integrity of the pressure system).
Stored-energy hazards occur when confined energy is unintentionally released. Sudden pressurisation or depressurisation of such stored-energy systems can result in incidents that cause serious injury or death. Attention has concentrated on pneumatic testing due to the greater potential stored energy. The common misconception is that Hydraulic pressure testing is safe.

There are reasons for carrying out a pressure test. For certain vessels and systems, the law (Pressure Equipment Safety Regulations 2016) requires testing to verify the design. Pressure testing is also widely used as part of in-service examination, to provide assurance over the ongoing integrity of a vessel or system, to confirm it is suitable for continued service. Additionally, where a repair or modification is made to a system, or it is re-assembled, the first time it is energised in the new configuration, it is effectively a pressure test.

The Competent Person is there in the role of an independent witness to the test, they are not there to contribute to the design review of the test arrangement, however they would be expected to advise on any matters that cause immediate concern.

The Organisation/ Notified Body employing the Competent Person would be expected to clarify arrangements for their staff interaction with equipment under test, so that appropriate review of the identified hazards are made and an appropriate Method Statement for intervention during a pressure test is available. The Competent Person's Organisation should clarify with those in charge of (or requesting) the pressure test, the responsibility for producing the work method for any intrusive inspection. The extent of Risk Assessment will vary considerably, and include factors based on:

- The quantity of stored energy (pressure x volume)
- The test medium
- The type of test being undertaken
- The nature of the intended interaction with the vessel/ system under test (such as the extent of intrusive inspection)

2. Determining risks

Whenever completing a pressure test the Competent Person should assume the vessel or system ***will fail*** and they should be prepared for component failure.

Hazardous Event: - Is the unintended energy release that may take the form of:

- A rupture of the assembly, whilst persons are in the danger zone
- Failure of a fitting or component forming part of that assembly which is then ejected under force (i.e. energy out) creating missiles
- Detachment of a test hose and consequential hose whip
- Sudden release of test fluid (hydraulic) causing eye injury or pressure injection into tissue

Different levels of stored energy - The following denotes the particular categories of pressure test, to be used in qualifying the level of stored energy that may be involved in the pressure test.

Proof pressure test
Such a test has historically been referred in lieu of formal design calculation, to demonstrate the structural integrity of a vessel or system. Under these circumstances, this type of test should only be carried out hydraulically due to the significant risks and potential unknown design factors.

Within this category, a sample of the vessel or system may be pressurised to destruction, to determine its yield capacity.

Standard pressure test

Where a vessel or system has undergone design assessment, a standard pressure test has historically been used to check/ verify its construction and quality. Testing is carried out at its maximum rated pressure multiplied by either 1.25 or 1.5.

For pressure vessels, the hydrostatic test pressure referred to within Pressure Equipment Safety Regulations 2016, Schedule 2, paragraph 40 must be no less than whichever is greater of the following:

(a) that corresponding to the maximum loading to which the pressure equipment may be subject in service taking into account its maximum allowable pressure and its maximum allowable temperature, multiplied by the coefficient 1.25; or

(b) the maximum allowable pressure multiplied by the coefficient 1.43 (*at the test temperature*)

Leak test
Used to verify the vessel or system can hold its pressure without leakage. Leak testing of a vessel or system is normally carried out at a pressure not exceeding x 1.1 maximum rated pressure.

Functional test
Used to check or simulate the normal performance of a vessel or pressure system to provide evidence of service application. A functional test would normally be carried out on a pressure system with moving parts (or controlled via valves, plc). It should be carried out at normal safe operating pressure. This value will be at, or below, the design pressure.

Nature of the test – Close inspection for leaks should ONLY be undertaken after a successful proof or standard pressure test. GS4 specifies criteria for risk reduction when considering intrusive inspection, to include:

44 Close observation for testing that deviates from the other measures above is acceptable only if:
You can demonstrate that risks can be controlled to acceptable levels; and a thorough technical review is completed. This includes:
- assessment of the geometry of the item under test;
- location of hose and all connectors – to determine the potential ejection and rupture points, residual risks from pressure concentration;
- temperature differential;
- the rupture pattern must be calculated using CRR 168/1998

45 Test pressure must also be reduced significantly beforehand. It is good practice to carry out a leak test only after the item under test has successfully held pressure as part of a proof pressure test (in order to identify initial integrity of the item under test). Close observation for hydraulic/pneumatic leak testing is acceptable only:
- after a successful proof/standard pressure test is carried out to verify the vessel integrity; and then
- the subsequent leak test result does not exceed the maximum rated pressure (and, ideally, it should be less than or equal to 10% of the maximum rated pressure).

Additional risks - Failure often occurs during de-pressurisation, as when the system is pressurised by the test medium, the materials expand (at potentially different rates). During stabilisation, all fittings are integral. During de-pressurisation, the contraction of the materials at different rates will reduce the tolerance of fit, so as the pressure is reduced between screwed fittings, friction interfaces between parts, and temporary bungs can slacken off, leading to release of fluid and/ or some attachments.

There are also risks created from component failure or energy release originating from the dynamic conditions of a functional test, involving moving parts that are exposed (such as stroking of a valve solenoid, extension and retraction of a ram, rotation of a handwheel or lever). During the functional test, the characteristics of that component will be changed – e.g. moving parts, seal compression/ expansion, axial loading distribution, pressure locking.

Reliance on whip check cables – These provide additional protection in restraining a failed hose or fitting, however these limit the extent of uncontrolled release of hoses, rather than prevent detachment. Whip-check cables are not therefore considered to be a primary safeguard. In particular, fluid can still release, resulting in the potential for hydraulic injection injury. This is a function of release pressure and jet size, with the potential for injection to occur at as little as 7 bar (see HSE Research Report RR976).

3. Incident history

There have been many instances of severe injuries and even death sustained when witnessing and carrying out pressure testing. Some examples are given below:

- August 2005 - Hydraulic fitter was killed when a pressure test fitting was ejected under force from a hydraulic cylinder under test.
- May 2008 - Worker was water testing a large process valve. A smaller vent valve forming part of the venting assembly ejected, striking the individual.
- December 2013 – A worker carrying out inspection of a boiler undergoing a pressure test received a leg injury, following ejection of a component forming part of the test assembly.
- January 2014 – University experiment involving a pressure test behind a protective screen. Overpressure occurred, shattering the screen which injured a student.
- May 2014 – A worker was killed by hydraulic injection following failure of grease nipple on a piling rig.
- June 2015 – A maintenance fitter was carrying out repairs to a hydraulic cylinder. Whilst checking for leaks under pressure, a component failed resulting in a fatality.
- October 2016 – a worker suffered serious burns whilst setting up an experimental hydrogen test rig, to test a prototype hydrogen storage vessel. The threads to a pipework connection stripped and the fitting ejected, causing ignition.
- July 2017 - Whilst pressure testing a heat exchanger forming part of brewery process machinery, a coil ejected injuring a member of staff who had been watching the activity.

4. Roles and Responsibilities

The Competent Person is there typically as an independent witness or assessor to verify the vessel or system which can include the following

- That the design of the system under test is sound
- The ability to withstand pressure
- That it does not leak
- That it functions correctly

Whereas the Test Engineer has a wider role in the contribution to the pressure test and can have some responsibility in the test preparation and the setup of the temporary pressure test equipment, to include:

- Set the test equipment up
- Fill the system (hydraulic) and vent
- Operate the test pump and monitor test progress (abort if necessary)
- Depressurise the system and disassemble the test equipment

There is a high interaction between the Competent Person and Test Engineer involved in a pressure test, with both parties being engaged by the owner/dutyholder responsible for the pressure system. It is important that both the Competent Person and Test Engineer CONFIRM OVERALL RESPONSIBILITY FOR THE TEST, INCLUDING INSPECTION and determine the authorisation and content of the PERMIT TO WORK to ensure appropriate interaction with the person(s) in charge of the overall activity. If at any time the Competent Person believes there is a risk to persons, the test should be abandoned until everyone is satisfied that all necessary precautions have been taken.

Following sentencing in August 2017 of an Inspection Body whose employee was involved in an incident involving the unintended rejection of a component during a pressure test, the Judgement of the Crown Court was that the Defendant had not undertaken any form of hazard analysis, nor had they ensured that others had undertaken that activity. Nor had they checked the analysis, or checked it themselves. The Competent Person had not had any form of briefing on the activities to be undertaken. The Competent Person was not briefed on the test procedure; nor was he given any diagram to identify that which was to be tested. The Competent Person was not briefed on the use of an exclusion zone, or its demarcation. He was not told beforehand who was going to perform this inherently dangerous pressure test. He was not told any pressure limits. Nor was he told of a “safe zone” where he should locate himself whilst the test was underway. Nor was there any confirmation given to him that control measures were in place, or briefed on these measures.

A risk assessment should be devised to cover the particular hazards faced by the Competent Person (and similarly the Test Engineer). This should focus on:

- The specifics of the test
- Justification for the need for intrusive inspection
- The approach to be adopted for intrusive inspection based on the risks identified in Section 2

Additionally the Competent Person and Test Engineer with need a Method Statement for any Intrusive inspection activities, whilst the system is under test. The Method Statement should detail the required preparation for the test and the nature of interaction during completion of the test (detailed in sections 5-7).

5. Preparation for the test

Both the Competent Person and the Test Engineer should either together or individually, conduct a visual inspection of the system prior to the test. Inspection would include some or all of the following:

Access and egress to the system under test, including location of the test pump and gauges. Always consider if it is feasible to install remote monitoring and control of the test pump, to afford the test personnel the same level of protection as other personnel, who are not directly associated with the test.

Look at the test equipment:

- How is the test pump safely turned on
- How is the pressure regulated and monitored
- How is the system drained
- What measures are in place to prevent over-pressurisation

Look at the system under test to evaluate potential weak points:

- Bolted and screwed joints
- What bits are new (and under test)
- Temporary blanks, bungs and plugs
- Interface with flexible hoses
- Sharp bends or reducers in pipework

Pressure regulators and relief valves provide a physical limit on the pressure that can be applied to any system. It must however be ensured that the relief valve is calibrated for the test.

Before any intrusive inspection is attempted, the Competent Person should have previously walked the system before the test, to ensure:

1. They know the system they will be inspecting/ testing
2. Keep a record of any temporary additions to the system such as blanks and plugs
3. Verify the system can be correctly isolated (double block and bleed)
4. How will the system be vented safely
5. Communication between the Competent Person and Test Engineer, to de-pressurise/ abort the test.

If the system test involves a repair or addition, the area of focus can be narrowed (and review of the implications to a potential modification)

If the system has already been inspected by NDT, and/ or fabricated by use of coded welders, these measures will help provide assurance on integrity, before intrusive inspection.

All preparation for the test should be completed in accordance with Health & Safety Guidance GS4. The Competent Person should be assured that the preparations are in fact safe and that their own risk assessments for pressure testing are complied with.

Anyone involved in intrusive inspection should evaluate the potential areas for “flying objects” and fluid release:

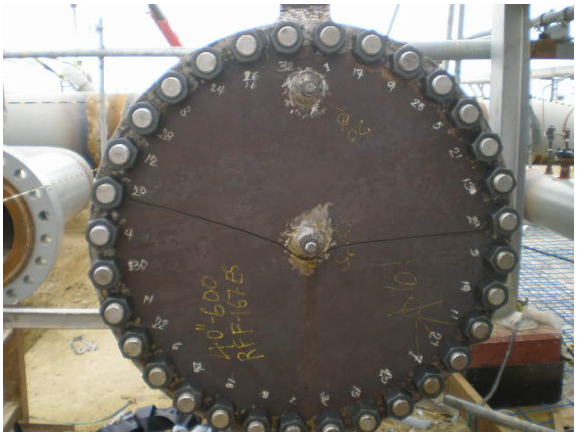
- Mark up the layout of a system under test on a P&ID
- Count number of blanks/ bungs/ plugs Out/ In and record their location
- Look for single isolation valves (potential passing of fluid)
- Verify how the system will be filled and vented
- Confirm the test temperature (this should be above 0 deg C with most recommending a minimum temperature of 7 Deg C, except in extraordinary conditions[1], the test temperature should not be over 20 deg C).

<u>For pressure equipment in compliance with Pressure Equipment Safety Regulations 2016 and Simple Pressure Vessels (Safety) Regulations 2016</u>

The test pressure should not be higher than that required by the design code of the vessel. A blanket 1.5 times must not be applied to all equipment as many later codes use a lower test multiplication factor. Also, where the safe operating limit has been reduced, then the test pressure should be based on the safe operating limit and not original design pressure. Once the test pressure is confirmed then the rest of the checks can be completed.

Blanks – As a guide, Blank flanges should be at least as thick as the connecting flange and ideally carry the makers marks that demonstrate they can safely withstand the pressure to be applied – If in doubt ASK those in charge of the test for confirmation and validation.

Flange thinner than the body flange.



Flange failed below the test pressure.

Bolting – During the pressure test the components may be pushed to its limits (almost to yield), it is therefore important the bolting is of adequate strength, the correct grade and that all bolts are fitted (none are missing). There are correct tightening techniques for a bolt ring, to ensure torque is evenly distributed between the individual bolts. Bolts used repeatedly for test purposes should be replaced at regular intervals.

Plugs, pipe fittings used for test purposes – Must be suitable for the test pressure. Standard screwed fittings are normally rated for approximately 20.0 bar when new but there are differences in tolerances between manufacturers. Fittings that have been repeatedly used for pressure testing should be changed out (scrapped) regularly to prevent failure during testing.

6. Completing the Test

The Competent person must confirm that risks from failure of the vessel or system under pressure test are minimised, especially where subsequent intrusive inspection is intended to check for leaks (i.e. visual examination as part of a leak test). To do this, the Competent Person should be provided with a pressure test specification, that includes details of the procedure for filling the system. When filling the system (hydraulic) ensure the methodology is documented, to include:

- Determine who is responsible for first filling and confirm how the system is vented
- Pressure rises should be Incremental. Apply pressure in stages, look at gradual rises - no more than 2 bar/ minute during initial stages and then only 0.5 bar/ minute at 90% completion
- A Stabilisation period between increments is essential
- Consider the affects of temperature on the system (PV/T)
- The proof/ standard test pressure should be held for a period of at least 30 minutes

At Pressurisation

- What is the intended method of approach to take for combined proof & leak tests
- Start by remotely verifying “proof test” (i.e. 1.5 x MWP)
- Safely depressurise and stabilise at leak test pressure (i.e. 1.1 x MWP)
- Check for leaks

Realistically the pressure gauge must be calibrated and has been maintained. (gauges as part of test apparatus can still present a risk)

A graphical plotter provides evidence of pressure stability (this should be positioned at a SAFE location)

Consider affects of pressure reduction (as the system expands and contracts) to leak test criteria 1.1 x MWP

When checking for leaks

- What do you do if you find them
- There should be a planned approach, with the level of preparation and planning (including written methodology and reference to marked up P&IDs) proportionate to the complexity of the system under test.
- Dye’s can be added to water and hydraulic oil to aide detection of leak origin.
- UV flashlight can be used
- Argon trace can be added to air, or use of soapy water
- Even a piece of cardboard can assist in hydraulic leak detection, where access is difficult

Avoid direct contact with a leak by maintaining a distance as far as possible away from the item under test. Use of PPE will assist in mitigating residual consequences of potential failure points.

At no time should a “hammer test” be completed on any equipment under any pressure!

7. Depressurisation

The Competent Person and the Test Engineer should be remote from the test area during depressurisation (as there is no need to be there).

Incidents have occurred during depressurisation, so the following steps are recommended:

- Prior assessment of joint interfaces
- Depressurise slowly, with stabilisation periods
- Review the potential for pressure locking – the nature of some quick connectors can force the internal components into the surrounding housing, to lock the fluid or gas in the system

8. General Pressure Test Safety

This paragraph should be read in conjunction with HSE Guidance Note 4 and HSE Report CRR 168/1998, Paragraph 6.7 Conduct of the Test.

For initial proof and standard pressure testing, the following measures should be in place when pressure testing -

- There should be a single person nominated as responsible for the test
- Briefing on the conduct of the test for all persons involved in or witnessing the test
- Only essential persons should be present during the test
- Risk assessment and appropriate method statement
- Physical safeguarding
- Safe system of work for monitoring the test
- Test procedures
- Maintenance and selection of test fittings and associated test equipment
- TEST IN QUIET HOURS with reduction in personnel in the test area
- All hoses are secured
- Temporary screens are available where required
- Monitoring during pressurisation and proof/ standard test is completed remotely

If a component or fitting leaks on start-up, the system must be evacuated before intervention to tighten it up.

Evacuating air from the system (hydraulic testing) – ensure there is a bleed valve, located in a safe position (and fill system up before applying pressure)

Safeguarding should be via full or local enclosure, or temporary screens. Wherever possible, identify leaks by monitoring remote pressure gauges. Consider use of digital gauges to detect the most minor of leaks. Flow can be monitored by flowmeter. This alerts the operator that a leak is present and indicates leakage rate.

When hydraulic testing, review the need to closely inspect whilst under pressure. There will be a fluid trail to origin of leak. Consider using a dye in the fluid to aide identifying leaks.

Pneumatic and hydraulic pressure testing should be considered within the scope of a specific permit to work issued by the site owner, to verify precautions and interaction between the various parties.

Pneumatic testing – Where there is a leak found, consider identifying its origin by:

- CCTV – item placed in water tank
- Enclosure - Soapy water applied to all joints
- Reducing pressure to as low as possible – use snoop (soapy water dispenser)

The item under test should have a suitable exclusion area to prevent those not involved with the test entering the danger area. This may need to be checked during the test as it is likely that persons may take an interest in the activity despite the dangers. In the case of high volume, high pressure testing barriers may need to erected, with suitable warning notices

On large vessels the volume can be reduced by placing solid articles within the vessel, one method is to use steel balls (Usually enclosed in a steel mesh bag(s) to prevent them becoming projectiles in the case of test failure). When using volume reduction methods make sure that they do not place additional stress on the component internals.

Pressure gauges should be large enough to be easily seen, calibrated within the last 12 months (min) and the units confirmed against the units used in the test plan. There have been cases where the wrong units have caused significant overpressure to equipment. Consider installing two pressure gauges at different points in the test system where possible, so as to verify pressure readings, particularly nil pressure upon completion of the test.

Review the maintenance and suitability of test equipment:

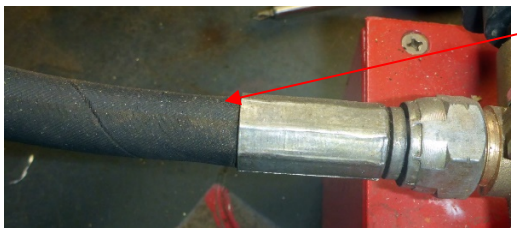
Pumps, hoses and pressure gauges – Test pumps must be in good condition and suitable for the pressures used during the test. The location of the test pump should be considered so that the operator is not exposed to significant risks and should be relocated where possible to a position of safety. All valves should be free to operate. Hoses must be in good condition, not kinked or otherwise damaged.

It should be noted that thread wear is non-uniform, such that as single thread portions wear, the remaining threads must withstand the stored energy. Release of stored energy occurs in both hydraulic and pneumatic testing, once the remaining threads are unable to contain the stored energy.

Is the hose suitable for the test pressure?

Maximum Pressure Marked

- Is the hose in good condition?



First signs of deterioration

- If necessary, test the pump and hose before connection to the component(s).

9. Competency

Those witnessing any pressure test should have the appropriate level of competency as defined in the document SAFed Standard SS01: Recruitment, Training and Competency of Engineer Surveyors

Competency is defined as having the necessary practical and theoretical knowledge and experience, relevant to the task being undertaken.

To assist in demonstrating the attributes for undertaking intrusive inspection, personnel will need to undertake relevant training courses on pressure testing and carry out the actual intrusive inspection work over a period of time, working under the guidance and supervision of more experienced personnel.

The Inspection Body shall maintain records of qualifications, training and experience of all staff associated with the pressure test inspection process, together with records of how and when each member of staff was authorised.

10. References.

Guidance Note GS4 Safety requirements for pressure testing (Fourth edition).
http://www.hse.gov.uk/pubns/gs4.pdf

CRR168/1998: Pressure test safely. HSL Contract Research Report.
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Pressure Equipment (Safety) Regulations 2016
https://www.legislation.gov.uk/uksi/2016/1105/contents

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HSE Research Report RR976 Hydraulic Injection Injury
http://www.hse.gov.uk/research/rrpdf/rr976.pdf

SAFed Standard SS01- Recruitment, Training and Competency of Engineer Surveyors- www.safed.co.uk

ISO/ TR 17165-2 (2006): International Standards Organisation - Hydraulic fluid power – Hose assemblies

BS EN ISO 4413 (2011): International Standards Organisation - Hydraulic fluid power –

General rules relating to systems

BS EN ISO 4414 (2011): International Standards Organisation - Pneumatic fluid power – General rules relating to systems

BS 14100 (2020): Control of hazardous energy on Machinery – Specification