Safety requirements for pressure testing

Guidance Note GS4 (Fourth edition)

Introduction

1 Pressure testing involves applying stored energy to an assembly of parts, in order to verify its strength, its integrity and/or its functionality.

2 This guidance is aimed at all employers, supervisors and managers responsible for pressure testing. It has been revised in response to two fatalities in the UK since 2005 resulting from failure to correctly provide and maintain test fittings. The test engineers were struck by components ejected during the test.

3 This guidance addresses safe systems of work, safeguarding and maintenance.

Action required

4 Pressure testing is covered by the Provision and Use of Work Equipment Regulations 1998 (PUWER).[1]

5 The action you need to take to comply with these regulations will depend primarily on:

- the size of assembly under test;
- its test pressure;
- the test medium.

6 Key issues relevant to all pressure testing activities are:

- determining risks;
- preparing a written safe system of work;
- segregating the item under test;
- maintaining test connectors.

Determining risks

7 Pressure testing is a high-risk activity. When applying stored energy to an assembly, especially for the first time, there is potential for an unintended or premature pressure release while people are in the danger zone.

8 Release of stored energy under pressure can cause:

- test assembly rupture, creating flying fragments;
- component or connector failure, creating missiles projected under force;
- test hose failure including detachment, with consequential hose whip, striking people;
- sudden release of the test medium (liquid, gas, vapour, dust or other substance under pressure) causing injury, eg burns, eye damage or pressure injection into bodily tissue.

Test assembly rupture

9 It is essential to evaluate the stored energy in the assembly under test and identify the areas that could result in its unintended release.

10 The potential risk from fragments and missiles must be assessed. This can be calculated by referring to HSL research report (CRR 168/1998),[2] which includes further information on theoretical calculations relating to blast energy.

11 You must assess the locations of the test assembly and of the controls for regulating pressure as part of the test. The testing location must either be sufficiently remote that there is no risk to people, or a form of enclosure must be provided to contain the unintended release of stored energy.

12 Any enclosure must be sufficiently strong to contain an uncontrolled release of energy. Enclosure strength can be calculated (see CRR 168/1998)[2] or, as a guide, use a minimum thickness of 3 mm mild steel plate.

13 Identify which part of the assembly is being tested – is it the whole system, and does the test relate to a repair of an existing assembly, replacement part, removal or addition of connectors (including seal replacement)?

14 Identify whether inspection for leaks is necessary. Can this be done remotely, or are additional safeguards and inspection techniques necessary?

15 To reduce the stored energy in the assembly during a test, pressurise with water (or other fluid) rather than a gas wherever possible.

16 The volume of pressurised fluid used in a test should also be reduced where possible. This may be achieved by placing metal balls or other loosely fitting pieces within the test assembly. Ensure that any such pieces do not prevent the correct pressure from reaching all test areas, or affect the fatigue life of the components (eg by shot peening the surfaces).

17 The volume of pressurised fluid used when testing pipework, may be reduced with blank inserts (‘spades’). These are used for pressurising and testing in-turn the individual sections of a system.

18 When an assembly has been repaired or modified the overall assembly will have already undergone a pressure test. However, you must determine how the system characteristics could have been affected and what possible failure points could have been created by the work being carried out.

Component or connector failure

19 Deterioration in the leading threads of connectors can reduce the remaining thread contact area sufficiently for it to fail under pressure with a sudden energy release. Typically, this takes place in test fittings and blanks (as these tend to be frequently tightened and released during pressure testing operations).

20 All test connectors are subject to cyclic loading, both from the pressure test application and from tightening torque loadings. Fatigue is a factor that must be addressed when test connectors are being inspected and assessed for continued use. Some signs of fatigue are clearly visible and measurable (deformed threads), and some are not.

21 When pressure is released from a compressed gas the gas will cool quite significantly. This will cause localised contraction in connectors and other structural components, creating additional risk (especially if different materials are involved).

Test hose failure

22 Test hoses can also deteriorate, leading to release of fluid. This often occurs from incorrect lengths of hose being used, where bend radius is too small, or hoses being stretched and twisted. Mechanical damage is also a significant cause of hose deterioration.

23 A similar risk of thread deterioration in the connecting hose fittings exists, described previously in paragraph 19. This deterioration results in sudden disconnection of the hose and consequential hose whip.

Sudden release of test medium

24 Contact with escaping fluids must be avoided. Risk assessment has to consider how leaks will be identified.

25 Fine streams of escaping pressurised fluid can penetrate skin and enter the body. These fluid injections can cause severe tissue damage and loss of limb. It only takes 7 bar (100 psi) to penetrate the skin surface.

26 If a fluid-injection accident occurs, you must seek medical treatment by a doctor immediately. Any fluid injected into the skin must be surgically removed within a few hours, or gangrene can result (clause 4.2 of ISO/ TR 17165-2[3] advises that doctors unfamiliar with hydraulic oil injection injury should consult a knowledgeable medical source).

Preparing a written safe system of work

27 A written safe system of work for pressure testing must be in place, summarising how the issues raised in this information sheet are to be dealt with.

28 The safe system of work provides written instructions to test engineers and requires sufficient information to ensure correct:

- test set-up;
- selection of fittings;
- carrying out the initial test;
- checking for leaks;
- supervision.

Test set-up

29 Your written safe system of work must identify how each assembly under test can:

- be safely energised;
- be safely monitored;
- have the test medium evacuated.

30 Identify measures to prevent over-pressurising the test assembly. This is normally achieved by connecting a pressure relief valve onto the assembly under test.

31 To prevent/reduce operator presence in the danger zone, determine and identify optimum positions for control valves and monitoring devices such as pressure gauges and flow meters, locating them away from the test area.

32 State how pressure will be safely exhausted after a test, before entry into the danger zone. This is normally achieved by fitting a remote drain valve on the test apparatus away from the danger zone, plus a pressure gauge downstream from

the assembly under test, to verify nil pressure. It must be safe to access the drain valve while the vessel or system is under pressure.

33 State how and where flexible hose assemblies – including plastic piping in the case of pneumatic testing – should be restrained or shielded to restrict whiplash hazard from failure (see clause 4.3 of ISO/ TR 17165-2,[3] clause 5.4.6.5.3.1 of BS EN ISO 4413[4] and clause 5.4.5.11.1 of BS EN ISO 4414[5]). Restraint may be achieved using whip-check cables, as shown in Figure 1. Hose restraint or shielding is additional to, and not in substitution for, protective enclosure (see paragraphs 9-18 above).

Figure 1 Examples of whip-check cables

Selecting fittings

34 Written instructions should contain sufficient information to verify that hose and connectors are suitable for their testing purpose, ie they are rated for the test pressures and test medium (see clause 5.4.6.5.1e of BS EN ISO 4413,[4] 5.4.5.9.1d of BS EN ISO 4414[5]).

35 Always use connectors showing the manufacturer's identification marks and keep the manufacturer's data accessible to verify safe working pressures.

36 Hose-fitting components from one manufacturer are not usually compatible with those from another manufacturer. You should ensure that only compatible components are assembled together (see clause 6.3 – 6.4 of ISO/ TR 17165-2[3]).

37 Ferrule type connectors with compression olives present an increased risk from incorrect assembly and it is preferable to avoid using them.

38 Where possible, always use newer type connectors that eliminate complex assembly procedures and reduce the likelihood of a test failure.

Carrying out the initial test

39 When using water, emulsion or oil for pressure testing, your procedures should ensure that the system is properly vented before pressurisation (see clause 7.8 of ISO/ TR 17165-2[3]).

40 Testing should always start by applying a low pressure (below safe operating limits) to verify initial integrity of the system. Raise the test pressure in stages (holding the pressure for a period of time) to reduce the potential energy release resulting from failure of the assembly and associated components under test.

Checking for leaks

41 Procedures for testing must include details of how leaks will be identified. For pneumatic testing it is more difficult to identify the origin of a leak. These circumstances require the use of physical safeguarding in combination with additional procedures.

42 There remains a significant risk to the health and safety of the test engineer from close observation while the assembly is under pressure (even if the test pressure is reduced significantly beforehand).

43 Wherever possible, eliminate the need for close inspection in order to verify the test pressure is being held:

- Using digital gauges provides an accurate means of identifying minor leaks.
- Using CCTV affords test-witnessing and leak-identification from a safe distance. It also provides a visual record of test performance.
- For hydraulic testing, fluid release/seepage will leave physical traces of a failure point. Where water is used, a dye can be added to assist identifying the origin of a leak, or porosity within a casting.
- For pneumatic testing identify the origin when a leak is found by:
  - CCTV, placing the item in a water tank to allow remote observation;
  - using an enclosure with inspection ports (insert the nozzle from a gas tester or apply soapy water to all joints).

44 Close observation for testing that deviates from the other measures above is acceptable only if:

- you can demonstrate that it is not practicable to implement the other measures; and
- 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.[2]

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).

Supervision

46 Clearly state the arrangements for supervision.

47 Supervisors have a crucial role to play in ensuring test engineers follow agreed safe systems of work. They must regularly audit the procedures and highlight circumstances where they cannot be followed or if they are not adequate for the tasks involved. In such circumstances, alternative arrangements must be made to adequately control the risks identified in this guidance.

Segregating the item under test

48 Physical means of segregation must normally be put in place before testing takes place. You should apply the following hierarchy, justifying circumstances where measures cannot be selected at the top of the scale:

- the use of a full enclosure to contain any projected missiles/blast energy, including protection between the test controls and the assembly under pressure;
- the provision of temporary barriers/screens and systems for excluding non-essential personnel from the area;
- exclusion of people from the blast/projectile area while an item is under pressure during a test. It is good practice to restrict personnel from the vicinity of any item while it is under pressure during a test.

49 Physical means of segregation will also prevent hydraulic fluid injection. Similar measures may be required as part of pneumatic pressure testing (see clause 4.2 of ISO/TR 17165-2,[3] clause 5.4.6.5.3.2 of BS EN ISO 4413[4] and clause 5.4.5.11.2 of BS EN ISO 4414[5]).

50 Where testing is carried out as part of the final inspection of a large machine or process (ie the repair of a hydraulic cylinder fitted to a bin lift vehicle), you must still ensure measures are in place to prevent failure of a component presenting a danger to others, such as adjacent building premises and members of the public. Where a permanent test enclosure cannot be used, provide temporary barriers, shielding and warning notices. Complete the test during quiet hours.

51 Examples of physical segregation are illustrated in Figures 2–5.

Figure 2 A converted steel container with remote regulation of the test apparatus provides a test booth for various-sized assemblies inside. Pressure indicators inside and outside the booth verify when pressure has been exhausted

Figure 3 An enclosure for hydraulic cylinders fitted with access panels that are locked in place during a test to prevent access. Visual examination for leaks is done through a polycarbonate section in the panels

Figure 4 An enclosure for valve testing includes a hinged polycarbonate section with access holes to allow a gas sniffer or soapy water applicator to be inserted inside, to check for leaks

Figure 5 Portable barriers (either single or interconnecting panels) can provide a temporary enclosure for unusual items, but this places high reliance on personnel to ensure there are an adequate number and they are correctly positioned

Maintaining test connectors

52 Thread inspection is an essential requirement for all test tools and connectors. Regular application of a thread gauge is useful to help assess wear and remaining integrity. Using protective thread caps will help reduce potential thread damage.

53 The service life for hose assemblies used in pressure testing operations should be specified (for established good practice, see clause 9.2 of ISO/TR 17165-2,[3] – 5.4.6.5.1c, d of BS EN ISO 4413,[4] 5.4.5.9.1b, c of BS EN ISO 4414[5]). This information must be made available to those inspecting hose assemblies.

54 To reduce reliance on the competence and experience of the test fitter to visually identify wear of test connectors and hoses, a combination of the following measures is appropriate:

- Organise test connectors in designated receptacles, including a rejected/damaged section (see Figure 6). This allows stocks replenishment on a 'new' for 'old' basis.
- Standard thread series test connectors should be issued in a smaller volume, with more frequently planned replacement on a batch-by-batch basis.
- Implement a formal recording system for controlling test connectors and hoses (this is particularly relevant for management of specialist fittings/high-cost connectors). This should document the frequency of usage, particular test applications, and include dates of any inspections completed.

Figure 6 Organising test connectors in a receptacle

55 Flexible hose assemblies must not be constructed from hoses which have been previously used as part of a hose assembly (see clause 5.4.6.5.1a of BS EN ISO 4413[4] and clause 5.4.5.9.1 of BS EN ISO 4414[5]).

56 Used hose reworking (re-ending) should never be undertaken at any time because even though a re-ended hose may look in good condition – and may even pass a pressure test – there are other factors affecting the ongoing integrity of a re-ended connection:

- **Degradation**. All hoses degrade over time. Chemical changes in the hose compound mean that cutting and inserting a new end can alter the molecular structure and weaken it.
- **Reinforcement**. Inserting a new end can reduce integrity by changing the angle of any internal reinforcement.
- **General condition**. There is no way to determine the exact detail of service life of the previously-used hose, so the material can be worn, previously overloaded, heavily cycled etc, leading to an inferior connection.
- **Hose length**. Cutting a hose will reduce its length to below that installed by the original manufacturer, with the result that it can be overstressed when refitted.
- **Swaging**. During the swaging process there is a controlled collapse of the insert which, if re-used, will not provide the correct performance even when used with a new ferrule.

References

1 *PUWER 1998: Provision and Use of Work Equipment Regulations 1998. Open learning guidance* (Second edition) HSE Books 2008 ISBN 978 0 7176 6285 2

2 CRR168/1998: *Pressure test safely*. HSL Contract Research Report www.hse.gov.uk/research/crr_pdf/1998/crr98168.pdf

3 ISO/TR 17165-2 (2006): International Standards Organisation *Hydraulic fluid power – Hose assemblies* www.iso.org

4 BS EN ISO 4413 (2011): International Standards Organisation *Hydraulic fluid power – General rules relating to systems* www.iso.org

5 BS EN ISO 4414 (2011): International Standards Organisation *Pneumatic fluid power – General rules relating to systems* www.iso.org

Further information

You can find more information at www.hse.gov.uk/pressure-systems/index.htm

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