

Guide to pressure testing of equipment

Publication 168

Edition 3

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Engineering Equipment and Materials Users Association

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Comments are considered by the relevant EEMUA Technical Committees and may be incorporated in future editions of this Publication. New editions are publicised on the EEMUA website.

In memory of Stuart Turner



This EEMUA Publication on pressure test safety is dedicated to Stuart Turner, who sadly passed away in May 2021. On behalf of everyone in the pressure systems community, we would like to extend our sincere condolences to Stuart's family.

Stuart's involvement with EEMUA started back in 2009 when he took the EEMUA 159 TankAssessor™ course. Stuart was instrumental in persuading his company to join EEMUA that same year. Similarly, when he moved jobs in 2017; his new employer became a member in early 2018.

Over the years Stuart was an active member of the EEMUA User Inspectorates, Storage Tanks and Inspection committees and many working groups. As an EEMUA non-Executive Director he particularly focused on projects and training, helping to implement initiatives around EEMUA's training offering.

The work on pressure test safety was initiated following an IMechE Pressure Systems Group (PSG) seminar held at IMechE HQ in 2017. Stuart delivered an excellent lecture at the seminar entitled "Pressure Testing in the Real World", during which he highlighted various schemes and methods for controlling and ensuring safety during pressure testing. The feedback from the event — and in particular Stuart's lecture — was overwhelmingly that a competence scheme for operators involved in pressure testing was one of the missing pieces in the pressure test safety jigsaw.

Following the seminar, Stuart convened an EEMUA Working Group to address the issue of pressure test competence and update EEMUA Publication 168. It is in Stuart's memory that, following his passing, the Working Group continued to work on the topic — up to its completion in 2022 — and published the document you are reading now.

Stuart was a great friend of EEMUA, the IMechE PSG, and the wider pressure systems community. He actively served on the PSG Board for many years, giving up his personal and work time to frequently travel across the UK to attend meetings and events, in order to share his knowledge and experience of pressure systems safety. He was a true champion of pressure systems safety and genuinely believed that, as a collective, we could make the world of pressure systems a safer place to be and work.

His keenness and enthusiasm rubbed off on people, and he brought a tremendous energy to whatever he did and whatever he was working on. Stuart owned the room whenever he was speaking, and had an innate ability to convey technical information in a manner that was understandable by all.

It was a pleasure to work with Stuart on both the PSG Board and EEMUA Working Group, and to work closely with him on the topic of pressure test safety. Stuart was an enthusiastic advocate for all things EEMUA and PSG. He was a larger-than-life character who gave tremendous support to the Association, and to its staff. He will be much missed, and we dedicate this document to his memory.

Paul Smith, Chair, IMechE PSG

Stefan Kukula, Chief Executive, EEMUA

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EEMUA Policy is to evaluate new publications for their contribution to sustainability. Equipment may be pressure tested at various stages of its life cycle to provide some degree of assurance of equipment integrity and avoid unnecessary leakage of inventory (which may include greenhouse gasses), equipment renewal and associated wastage of resources and energy.

Scope

EEMUA Publication 168 provides guidance on if, when and how pressure testing can be carried out on pressure equipment and systems, based on risk assessment and a safe system of work. It applies to the complete life cycle of pressure equipment and systems, from manufacture, installation and throughout its operating lifetime (in-service). Some alternatives to pressure testing are also considered, and when it may be appropriate to employ them.

Due to the risk of serious injury and fatality, the organisation and competency of those involved in pressure testing is paramount; this guidance gives advice for assessing and maintaining competency.

The guidance is applicable to all types of non-transportable industrial pressure equipment and systems, including pressure vessels and pipework.

This Publication is aimed primarily at the operatives, supervisors and leaders managing and carrying out pressure testing at manufacturers' works, repair shops and on industrial sites. Various standards and guidance are referred to in this publication. Members should satisfy themselves of the detail requirements of standards and guidance and that they are applying the most up to date versions.

Exclusions from Scope

The following topics are either excluded from the scope of this Publication or not dealt with in any great detail:

- Definition of pressure terms in standards, the test levels required by different standards or at points of interaction between standards. Readers should satisfy themselves of all these requirements
- The pressure testing of atmospheric storage tanks is considered a special case, and therefore not included in the scope. The subject is dealt with in EEMUA 159
- Routine testing of transportable pressure equipment, such as gas containers, at a facility with dedicated equipment for that purpose designed to manage the risks (typically at an accredited test facility). Likewise, routine testing of similar type components using dedicated, certified equipment designed and maintained to manage the risks. Both cases would use trained and competent staff
- Standard pressure testing of equipment designed to operate in the creep regime, where thickness is based on material creep strength, will not produce stresses as high as it would for equipment where thickness is based on proof strength. Special pressure testing to achieve high levels of stress is not dealt with
- Proof testing is excluded. This is a special kind of pressure test used to establish the maximum allowable working pressure of a system where this has not been calculated. The same principles for safety and competency would apply as for other pressure tests. As proof testing often involves deliberately pressurising a component to failure, special precautions, such as specifically designed enclosures and test cells, may apply

- Test waivers. It might be justifiable for equipment which would normally be pressure tested before returning to service to have the pressure test waived. For detailed guidance on the pressure test waiver, readers are referred to EEMUA 223.
- Subsea equipment: special circumstances may apply to subsea installations

Purpose of this Publication

Pressure equipment, systems and pipework, are abundant throughout industry. Following manufacture and installation, equipment will often remain in service for many decades and may be subjected to pressure testing through stages of its life.

Pressure testing of equipment after manufacture, assembly and when in-service, whether by hydrostatic or pneumatic means, presents hazards from stored energy and if failure occurs may result in significant harm to people – as, regrettably, a large and growing catalogue of accidents worldwide shows. There continues to be injuries and fatalities due to poor pressure testing practices. Root causes frequently include, poor planning, lack of competence and failure to properly risk assess or follow the rules. Many of these accidents could have been prevented had adequate training and risk management processes been in place.

Pneumatic testing is likely to involve a large amount of stored energy and therefore the potential for harm is much higher than the equivalent for hydrostatic testing. However, whilst the potential for harm is higher in pneumatic testing, incident history shows that a larger number of fatalities and serious incidents have occurred through hydrostatic testing. Any perceptions that hydrostatic testing is a low-risk activity are not correct. All types of pressure testing should be considered high risk activities.

If such accidents are to be avoided, then every opportunity should be taken to use the learning from such accidents and capture the combined knowledge and expertise of users across industry to better manage the risks involved. Whilst it may not be reasonably practicable to eliminate the risks altogether, this guidance aims to ensure that those involved at all stages of the equipment life cycle are fully aware of the risks and are able to use competent and qualified staff and formulate safe systems of work to reduce risks to as low as reasonably practicable.

Revision from the second edition

There are two main changes in this edition from the previous.

- First, the scope is enlarged to include the full lifecycle of equipment, rather than only in-service equipment. The guidance therefore extends to pressure testing at manufacturers' works, repair shops and during plant installation and commissioning
- Second, the guidance now includes a model framework for competence management of test personnel and a wider advice on risk awareness and controls. This is in response to calls from industry following an IMechE Conference in 2017

This edition also includes information on stored energy, exclusion zones for personnel for both hydrostatic and pneumatic testing and a list of lessons learned based on past incidents.

The working group preparing this publication considered it was very important to keep those involved in pressure testing aware of historical and new incidents occurring during testing and lessons that can be learned so that risks are reduced and safety is improved. EEMUA has therefore created a repository for collating all available lessons learned incidents. Readers of this document

are encouraged to contribute to the repository with lessons learned from their own experiences. To access and contribute to the repository, follow this link and the associated instructions:

<https://www.eemua.org/home.aspx>

Definitions

The terminology used for types of tests differs between regulations, standards and guidance and a consistent set cannot be applied. The following table defines the terminology adopted in this publication. Appendix B provides a comparison with other publications.

Standard pressure test	A test performed to ensure the gross integrity of components or assemblies of pressure equipment by subjecting them to a pressure, usually at or above the normal working pressure, in accordance with equipment design and construction standards, or in-service guidance (i.e. modified standard test typically at a lower test pressure)
Tightness test	A test that is performed to ensure overall leak tightness of the system or its connections before the process medium is introduced
Service tightness test	A test using the process medium of the pressure equipment performed at start-up of the equipment
Preliminary pneumatic test	A low-pressure pneumatic test used to locate gross leakage prior to carrying out a standard pressure test or tightness test
Sensitive leak test	A low-pressure tightness test using a bubble test technique or equivalent (e.g. mass spectrometer/helium/halide detection) that is capable of detecting very small leaks
Hydrostatic test	A pressure test where liquid, typically water is the test medium
Pneumatic test	A pressure test where a gas, generally nitrogen or air, is the test medium
Hydro-pneumatic test	A pressure test where a combination of liquid and gas is the test medium
Pressure Test Operator	Individual with training and experience qualified to perform a pressure test in accordance with an approved pressure testing procedure and risk assessment
Pressure Test Supervisor	Individual with training and experience qualified to write a pressure test procedure and carry out the associated risk assessment, with responsibility for test operator(s) and overall control of the test

Table 1 Terminology used in this publication

Acronyms/Abbreviations

ATEX	Explosive Atmospheres Directives
ACOP	Approved Code of Practice
AIChE	American Institute of Chemical Engineers
API	American Petroleum Institute
AS	Australian Standard
ASME	American Society of Mechanical Engineers
BCGA	British Compressed Gases Association
BS	British Standard
BSI	British Standards Institution
CEN	European Committee for Standardisation
CEng	Chartered Engineer
DBTT	Ductile to Brittle Transition Temperature
ECA	Engineering Critical Assessment
EEMUA	Engineering Equipment and Materials Users Association
EI	Energy Institute
EN	European Norm
EngTech	Engineering Technician
GDPR	General Data Protection Regulation
HF	Human Factors
HSWA	Health and Safety at Work etc Act 1974
HSE	Health and Safety Executive
IMechE	Institution of Mechanical Engineers
ISO	International Standards Organisation
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
MAWP	Maximum Allowable Working Pressure (ASME/API)
MHSWR	Management of Health and Safety at Work Regulations 1999
NDT	Non-Destructive Testing
NVQ	National Vocational Qualification
NZS	New Zealand Standard

PCC	Post Construction Committee (ASME)
PE(S)R	Pressure Equipment (Safety) Regulations
PNNL	Pacific Northwest National Laboratory
PPE	Personal Protective Equipment
PSSR	Pressure Systems Safety Regulations 2000
PT	Pressure Testing Personnel
PTC	Pressure Test Competence
PTE	Pressure Test Expert
PTO	Pressure Test Operative
PTS	Pressure Test Supervisor
PTW	Permit to Work
PUWER	Provision and Use of Work Equipment Regulations 1998
QA	Quality Assurance
QMS	Quality Management System
CMo	Carbon Molybdenum steel
RTJ	Ring-type joint
RVI	Remote Visual Inspection
SAFed	Safety Assessment Federation
TNT	Trinitrotoluene explosive
UKAS	United Kingdom Accreditation Service

1 Introduction

Equipment may be pressure tested at various stages of its life-cycle: at completion of manufacture; during service life when it has been exposed to degradation; and to demonstrate repairs and modifications are free of gross deficiencies. Design and construction standards require such testing, and national regulations may require periodic pressure testing once equipment is in-service.

It should be recognised that pressure testing does not demonstrate that equipment is free of defects nor verify quality of construction. It is not the case that defects in materials and weldments, for example, that are just above an acceptable level to the requirements of design and construction standards would subsequently fail during a pressure test. Generally, it is only gross defects (e.g. material strength well below that required, defects well beyond acceptable levels, or wall thickness well below the minimum design) that could fail during a pressure test. Defects may continue to develop in-service to failure. A successful test demonstrates the equipment can withstand the test conditions at the time without leaking and so provides a degree of reassurance that it will withstand in-service conditions, is free from through-thickness defects and that mechanical joints and seals are secure.

The greatest hazards during testing can arise from sudden failure and the release of a large amount of stored energy - fluid at high velocity, pressure waves, fragmentation of equipment and impact from large and small pieces of the equipment, gross movements and pipe whip, collapse of structures, etc. The likelihood of harm to individuals is reduced by minimising the number of individuals involved and minimising interventions undertaken in proximity to equipment under test. This publication reinforces the necessity to apply appropriate barriers and exclusion zones whilst pressure testing, both for hydrostatic and pneumatic procedures.

Testing exposes equipment to its first pressurisation after manufacture and first re-pressurisation after plant overhaul, repair and modification. As well as a possibility of equipment failure, testing often utilises temporary test equipment, temporary connections, arrangements and procedures that may be unfamiliar to the personnel involved. Accidents continue to happen during testing – see Lessons Learned appendix; the aim of this guidance is to prevent such accidents from happening by raising awareness of the hazards, the risk control measures that can be applied, and developing good practice. An important aim is to improve the competence of individuals performing testing as well those managing the process.

The situation under which testing is undertaken, e.g. component or assembly size, in factory, workshop, or on open site, can influence the practicability of precautions that can be taken to reduce the risk of harm. For example, small components and assemblies may be tested in specially designed or improvised enclosures (e.g. steel and concrete enclosures, water baths, steel shipping containers, test pits) that can safely withstand sudden failure; for larger components and assemblies this may not be practicable and reliance has to be placed on exclusion zones and protected control points around the equipment, and providing strict control of personnel access throughout testing.

2 Reasons for Pressure Testing

2.1 Manufacturers' Pressure Test

When new and before being placed into service, the quality of pressure equipment, such as valves, pumps, fabricated vessels and pipework, is assured through a combination of good design, selection of appropriate materials, approved fabrication techniques, inspection and testing and assurance systems. However, it is standard practice and a requirement of design and construction standards to pressure test new components and assemblies to a pressure higher than that at which they will be used. This is a part, and usually the final part of the acceptance process. Such tests may have to be witnessed by an independent inspection body.

The obvious aims are to check the pressure containment: -

- Expose major faults in the design, the materials or fabrication methods
- Ensure that no major assembly defects have been missed on inspection (e.g. through-thickness defects), either inadvertently or because of inadequate access for visual or Non-Destructive Testing (NDT) examination
- Ensure non-permanent joints such as flanges, glands and seals are properly assembled

Component distortion and leakage from flaws and joints must be observable or detectable to be able to pinpoint them.

A feature of new (as opposed to in-service) equipment is that the test pressure is not usually a simple fixed factor on the design or operating pressure. In order to maximise the benefit of testing new equipment, the following are factors:

- The pressure stress induced should be greater than the maximum stress in service at all locations and may take account of the corrosion allowance
- and/or
- The test pressure should be adjusted to compensate for the effect of temperature on the material strength (yield and ultimate tensile). Testing is frequently undertaken at a lower temperature than the operating temperature, when material is stronger, for which an additional factor is applied

For example, for components designed to EN 13445 (Unfired Pressure Vessels), the hydrostatic test pressure has to be the higher of 1.43 x the maximum allowable pressure, or 1.25 x the design pressure coincident with the design stress at the test temperature divided by the design stress at the design temperature. To ASME Section VIII (Rules for Construction of Pressure Vessels), it is 1.3 x the Maximum Allowable Working Pressure (MAWP) increased by the ratio of the allowable stress at the test temperature to the allowable stress at the design temperature. If the additional thickness of a corrosion allowance was factored in for a new vessel, it would further increase the test pressure.

Beyond demonstrating gross integrity and leak tightness, pressure testing after manufacture may achieve a beneficial pre-operational "shakedown" at positions of peak residual stresses in the structure, e.g. arising from forming and welding, or arising under pressurisation at discontinuities

such as openings or small cracks; localised yielding may occur to redistribute peak stresses and blunt crack tips, and the overall effect may contribute to improving in-service fatigue performance. It has already been observed that pressure testing does not guarantee the equipment is free of defects and that, generally, it is only gross defects (e.g. material strength well below standard, defects well beyond acceptable levels, or wall thickness well below the minimum design) that would fail during a pressure test.

2.2 On Site Assemblies' Pressure Test

Frequently, new components and subassemblies are finally assembled at site to create a process unit; this may involve large amounts of additional piping, valves, etc. Standards again generally require a pressure test of systems as part of the final acceptance procedure. Pressure testing of these additional elements, where not already tested, is usually carried out by sectionalising the system into smaller parts.

Where components and subassemblies are already tested at manufacturers:

- • Verification should be made to confirm that all the individual components have already been tested, and
- • The newly created assembly has not been tested as a whole, therefore the type of test would be regarded as a tightness or functional test of the overall assembly – allowing targeting of any intervention or analysis to be focussed on the jointing together of components

Application of controlled bolting procedures (e.g. EN 1591-4 and ASME PCC-1) are an effective means of achieving leak free joints and in some cases may avoid the need for further tightness testing.

2.3 In-service Pressure Test

2.3.1 Statutory Requirement

Periodic examination of pressure systems is part of an integrity management process. In some countries it is also a statutory obligation to carry out a pressure test on certain equipment at prescribed intervals. This may be part of a formal requalification of pressure vessels. The requirements vary across the European Union Member States as well as elsewhere. In some countries, including the United Kingdom for example, there is no statutory requirement to conduct pressure tests at prescribed intervals. In other countries a pressure test is excepted provided adequate examination is carried out. As a result of the different requirements and historical traditions from country to country, the practices applied by EEMUA Member companies vary considerably.

Statutory in-service testing is normally carried out using a simple factor on design or working pressure, typically in the range 1.1 – 1.3 times. The additional factor used after manufacture of the ratio of material strength at the test temperature to operating temperature is not normally applied. In-service pressure testing above the design pressure or MAWP could also be regarded as overloading. Therefore, any such in-service test should be considered in terms of potential detriment of equipment. The components and overall assembly should be assessed to consider effects from the extent of overload and frequency of application.

2.3.2 Integrity Management

Over time, equipment can be subjected to degradation mechanisms that may, for example, reduce wall thickness, reduce strength, cause material embrittlement, initiate and grow cracks. In these circumstances, a pressure test may be considered to be a way of demonstrating the continuing integrity of the pressure boundary. However, note should be taken of the caution given previously and that testing may cause an increment of crack growth if cracks are present or cause failure (where equipment condition was not fully considered or not known about). Actual in-service stress conditions are not likely to be reproduced in the test (in-service stresses include thermal stresses, system stresses (often bending) and installation stresses as well as pressure stresses) and defects present may still continue to grow to failure in service. In general, the degree of confidence given by such tests is therefore hard to quantify.

The integrity of the equipment to be tested should be assessed as part of a risk assessment before pressure testing. Serious defects may need to be evaluated by NDT and fitness for service (i.e. testing) calculations if necessary.

It may be possible to apply fracture mechanics to indicate the types and size of defects likely to survive a pressure test and then develop in-service safety cases. However, this is likely to require equipment specific knowledge of material properties, residual stresses, etc. and is normally only carried out in special circumstances, typically where access for reliable NDT is not available. The use of the in-service pressure test has been abandoned in some countries and replaced by alternative methods that give an equivalent or better safety level. This has been due to progress in: NDT methods; knowledge of metallurgy; risk-based inspection and fitness for service analysis. A summary comparison of the advantages and disadvantages of various inspection techniques is provided in Appendix A.

It should be recognised that in-service pressure testing of equipment designed to operate in the creep regime, where thickness is based on material creep strength will not produce stresses as high as it would for equipment where thickness is based on proof strength. In that sense, the test may less searching, except for demonstrating there are no leaks, and alternative NDT strategies may be employed.

A pressure test should generally not be considered as a substitute for the appropriate inspection or NDT examination. There are cases where the pressure test is justified, for example following significant repairs. However, there are also cases where the pressure test is impractical or would subject the plant and personnel to excessive risks.

The following circumstances can be considered when reviewing the use of a pressure test:

- Where statutory requirements make it mandatory for the test to be carried out
- Significant repairs or modifications have been carried out and the integrity of the pressure envelope needs to be verified
- Access limitations prevent a comprehensive visual and/or NDT inspection and a pressure test is an acceptable alternative
- The design conditions of the equipment have been changed for example pressure/temperature combinations
- Extent of knowledge of material properties and equipment condition as affected by degradation in service (including in-service embrittlement)
- There is a need to check the tightness of joints; for example, tube/tubeplate, plugs, threaded fittings or gaskets through tightness testing. A sensitive leak test may be superior to a tightness test in this regard

- There may be other situations where a pressure test is considered. For example, an item of equipment may have suffered impact damage, or may have been exposed to excessive temperature. These should be covered by in-house instructions and should also include appropriate procedures of authorisation

2.3.3 Repairs and Rerating

In some circumstances in-service pressure testing can play a role in the demonstration of the continuing integrity of the equipment after repair, maintenance or re-rating (see previous). For example, after retubing a heat exchanger, pressure testing may be used to demonstrate the integrity of new tube to tube sheet connections.

Repairs are generally made in accordance with design and construction standards and so the pressure test for new equipment may be appropriate. However, this will require a careful assessment of the risks to existing in-service equipment and alternative arrangements may be preferred.

For assemblies and repairs it is frequently the case that final closure welds are needed after pressure testing. For these welds (known as golden welds), reassurance of their integrity may be achieved by full volumetric and surface NDT and enhanced QA processes (see also 6.3).

2.4 Review

The main reason to carry out a pressure test is to demonstrate the overall strength, freedom from gross defects and freedom from leaks of pressure equipment and joints. Based on the premise that a failure or leak identified under controlled test conditions using a relatively benign test medium is less hazardous than a similar failure in service, a reduction of in-service risk may be achieved.

Testing after manufacture is generally mandated by design and construction standards, accounts for relative strength between test temperature and elevated operating temperatures, and, potentially, improves in-service fatigue performance by a process of shakedown. Repairs and modifications made to design and construction standards would fall into the same category.

The degree of confidence in equipment condition provided by in-service pressure testing is less easy to define. In-service pressure tests are usually carried out at lower pressures than used during manufacture and construction. Even large defects developed in service can survive the test and continue to grow in subsequent service and cause equipment failure. Condition assessment that can be achieved by advanced, reliable NDT techniques now available, combined with improved knowledge of material behaviour and fitness for service assessments now available, can provide better confidence of equipment integrity, without exposing service degraded equipment to excess pressure.

In-service testing specified in national legislation varies between countries, as well as the factor applied to design pressure. As far as UK practice is concerned, it is not common to apply such testing as a routine or scheduled part of in-service inspection (except for gas cylinders). Rather, pressure-testing is only applied under particular circumstances.

The potential hazard posed by an in-service pressure test is a combination of the stored energy and any ignorance of the suitability or compatibility of the equipment (including test equipment and connections) to contain the pressure. It is important therefore that a specific risk assessment

by competent persons knowledgeable in the risks of such testing is carried out before performing an in-service pressure test. This should include potential damage that may be caused to equipment operating nearby containing hazardous substances.

Older, service exposed equipment may present particular risk of failure under test from what would be benign in-service defects if temperatures were allowed to drop below the material Ductile to Brittle Transition Temperature (DBTT) during testing.

Application of controlled bolting procedures (e.g. EN1591-4 and ASME PCC-1) are an effective means of achieving leak free joints and in some cases may avoid the need for tightness testing. They will greatly reduce the likelihood of leaks occurring at joints during testing, making for a quicker and safer test overall.

3 Types of Pressure Test

The terminology used for pressure tests varies between standards and other published guidance - Appendix B gives some comparisons. Standards also base the pressure used to calculate the test pressure differently. For example, terminology includes MAWP, design pressure, maximum allowable pressure, operating pressure. Due to the broad considerations in this guidance, these terms are used somewhat interchangeably. It is the responsibility of the user to ensure they are applying the correct test pressure in accordance with the applicable standard or regulation they are working to.

In this guidance the following is used:

3.1 Standard Pressure Test

The standard pressure test is performed to ensure the gross integrity of new pressure equipment before entering service, or on previously manufactured pressure and piping equipment that has undergone an alteration or repair to its pressure boundary. It is usually a hydrostatic test performed at a specified pressure above design pressure, in accordance with the applicable standard, at typically between 1.2 to 1.5 times the design pressure (and greater when the ratio of strength at test temperature/strength at operating temperature and corrosion allowance is accounted for). Some standards permit a lower pressure to be applied if the test is performed pneumatically.

As noted previously, this test may be required by legislation in some countries as part of a requalification exercise for vessels after a period in service (for example, 10 years). The maximum test pressure is usually lower than that of the standard pressure test and above the design, operating or maximum operating pressure, typically in the range 1.1 – 1.3 times.

3.2 Tightness Test

A test performed by the application of a pressure differential to detect leakage and sometimes measure leakage rates, usually from joints (including tube to tube sheet joints) and glands. It may also be carried out once components that were removed for the standard pressure test are refitted. It is normally performed at pressures up to the design pressure or up to 10% above, where the standard pressure test has been completed, and undertaken prior to putting the equipment into service.

3.3 Service Tightness Test

A service tightness test uses the process medium of the pressure equipment, where the risk of leakage is considered to be acceptable.

3.4 Preliminary Pneumatic Test

This is a low pressure test performed to identify gross leakage at joints, undertaken prior to a standard pressure test or tightness test. The test pressure is limited to typically to 0.5 -1.7 barg (7.5- 25 psig) (or a small percentage of design pressure, as appropriate) depending on the standard followed. Higher pressures may be used after the standard pressure test has been completed.

3.5 Sensitive Leak Test

This test is performed at a relatively low pressure and uses techniques that can detect very small leaks (for instance, ASME quotes a sensitivity not less than 10^{-3} std mL/s). The test pressure is typically the lesser of 1 bar (15 psig) or 25% of the design pressure. Techniques include the bubble test and tracer gas injection using, for example, helium. It is often used prior to a tightness test, particularly for equipment with high hazard contents.

For process piping under ASME B31.3, a Sensitive Leak Test in combination with enhanced NDT of welds and flexibility analysis may be considered when both hydrostatic and pneumatic testing are considered impracticable.

3.6 Acceptance Criteria

The criteria for passing a pressure test should be agreed beforehand. Typical criteria are holding the test pressure for a defined period or the test pressure falls within an allowable pressure drop over a defined period.

Leaks are located by sight (liquid medium), wash/spray bubbling (gaseous medium) or specific gas spray/sniffer, e.g. helium medium. Helium testing, due to its small molecule size, is very searching and more sensitive than pressure drop detection.

Criteria for leak testing methods are given in the EN 1779. The bubble test is specified in EN 1593, helium testing in EN 13185 and the pressure change test in EN 13184. ASME also describes methods and requirements for leak testing.

3.7 Functional Test

If equipment contains seals, where moving parts penetrate the pressure boundary (e.g. valve stems, pump shafts, stirrers) a functional test would check for leakage during such movement. The test would normally follow or be a part of the tightness test using the test fluid or if in-service and acceptable, the process medium.

3.8 Test Medium

Where the test medium is water, oil or another liquid or mixture of liquids, the test would be a hydrostatic test. The great advantage of a hydrostatic test is that it uses a relatively incompressible fluid and so the stored energy is low. Where a gas is used, typically air or nitrogen or a mixture, the test would be a pneumatic test. The great disadvantage of a pneumatic test is the high stored energy involved. A hydropneumatic test uses a combination of liquid and gas and also has the disadvantage of high stored energy.

3.9 Test Type Selection

Figure 1 outlines a flow chart that may be followed when determining the appropriate test type for new equipment. In all cases the applicable design standard and regulatory requirements should be followed.

Figure 2 outlines some of the considerations for pressure testing of pressure equipment that is in service, typically when bringing back into operation following an outage or turnaround. In all cases applicable standards, guidance and regulatory requirements should be followed.

Both these figures are later referred to in Section 7.

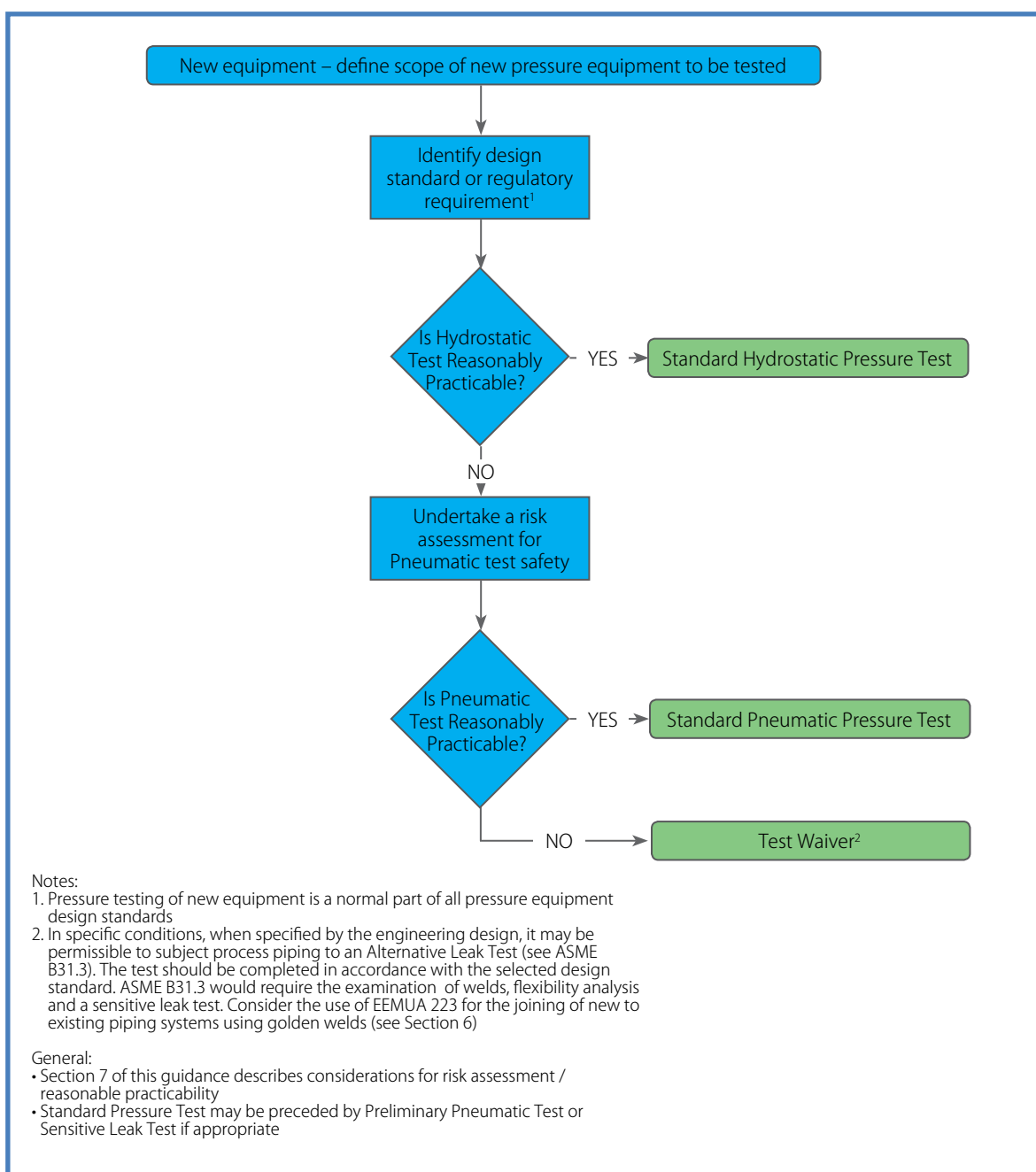


Figure 1 Pressure test type considerations for new pressure equipment

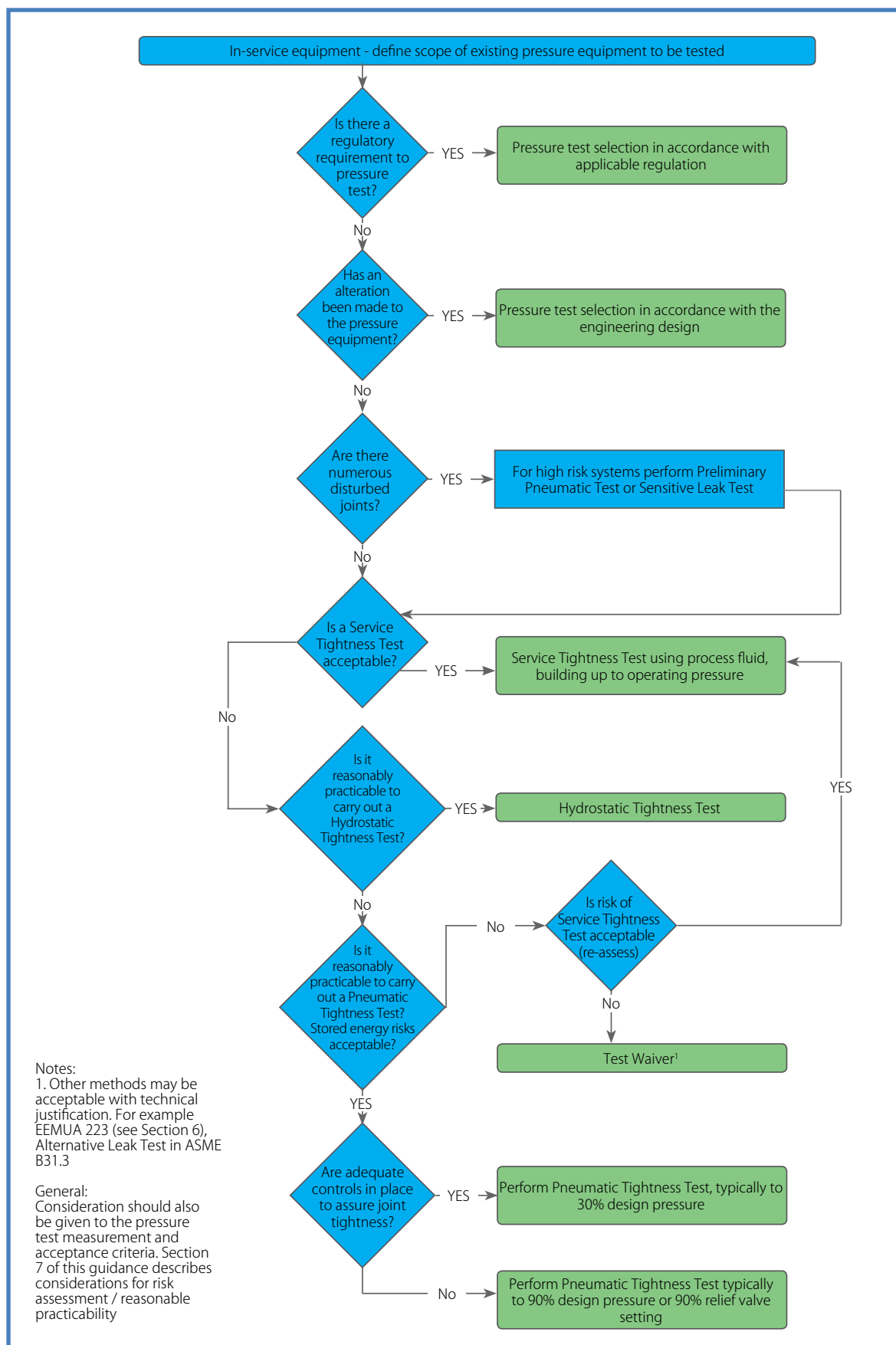


Figure 2 Pressure test type considerations for pressure equipment that is in service

4 Hazards of Pressure Testing

Pressure testing can be a high-risk activity. The major hazard arises from the sudden release of stored energy and its effects should any part of the equipment under test, the test rig itself or connections fail.

Release of stored energy under pressure can cause:

- Should brittle fracture occur: -
 - A large number of airborne fragments of the equipment (should widescale brittle fracture occur), and/or
 - Large airborne fragments, e.g. a closure head, a piece of vessel wall, a branch piece

Either, creates the threat of injury to personnel (puncture wounds, cuts and bruises, broken bones, other impact injuries and fatality) and impact damage to other equipment (with, potentially, further consequences). This risk arises mainly when the equipment being tested is at a temperature below the Ductile to Brittle Transition Temperature (DBTT) of its materials.

- A sudden release of the test medium should widescale brittle fracture occur, which in pneumatic tests can create a pressure wave and/or blast wave. This can cause structural damage and personnel injury, e.g. to ear drums, eyes, lungs, or fatality
- Should ductile failure occur
 - Ejection of larger airborne fragments of equipment. For example: failure of a longitudinal seam weld potentially running out to and around a circumferential seam weld and parting of equipment; a circumferential seam weld failure parting the equipment; ejection of a closure head, ejection of a branch piece

This again creates the threat of injury to personnel and impact damage to other equipment (with further potential consequences). The formation of a blast or pressure wave is less likely from ductile failure in pneumatic tests

- Should failure involve ejection of a piece of the equipment (e.g. flying objects such as a blind flange or flange assembly, valves, plugs (often fitted for the test), gauges, valve stems), the resulting large or small airborne missiles create the threat of injury to personnel or impact damage to other equipment, generally in line-of-sight, with, potentially, further consequences
- Reaction forces from the escaping medium creating hazards from pipe whip, gross movements of vessels and piping, collapse of structures, etc.
- Connector failure, creating missiles projected under force
- Test hose failure or detachment, with consequential hose whip

Even in the event of a leak, the test medium can also create hazards: -

- high pressure jets can cause physical damage to personnel
- fine streams of escaping pressurised fluid can penetrate skin and enter the body.
- Gaseous medium may also be hazardous, e.g. asphyxiation from the release of a large quantity of nitrogen. Release of large quantity of water could create electrical hazards from nearby equipment

- Poisoning, fire and explosion may result if a hazardous medium is used for the test (more likely for the service tightness test)

Other hazards arise in pressure testing typically due to working practice errors. Section 7 covers these types of risk. Examples include:

- Disassembly of equipment when the pressure has not been fully released
- Pulling a vacuum when hydrostatic test fluid is released when vents are inadequate or blocked, causing buckling or collapse
- Valves used as isolation points may leak and components not part of the test are pressurised
- Overpressurising downstream piping when the pressure is released too rapidly

4.1 Stored Energy Comparisons

This section is based on HSE Research Report CRR168 Pressure Test Safety and other sources (as referenced).

In order to carry out risk assessment and devise a safe system of work to avoid injuries from stored energy release it is advisable to understand the amount of stored energy present in the equipment during the test, as this determines the potential for harm. This particularly applies to considering failure of vessels and an example vessel is used to present comparisons.

The primary sources of stored energy are the test medium expansion energy and the strain energy in the vessel. A secondary source could arise from the released medium, if, for example, a flammable fluid was used that led to an explosion. In considering stored energy only the primary sources will be considered based on the assumption that a benign medium is used for the test.

The actual amount and rate of stored energy released depends very much on the mode of failure and how the expansion energy is released. In the examples, it is assumed that the expansion is reversible and occurs rapidly for heat transfer to the surroundings to be negligible. This is considered to be typical of a brittle failure or large ductile failure.

Examples will be based on a steel vessel and test conditions as used in CRR168, as follows: -

Internal diameter	1 m (39 ins)	Material	Carbon steel
Shell thickness	25 mm (1 ins)	Young's Modulus	200,000 MPa (29,000 ksi)
Internal length	3 m (118 ins)	Poisson's ratio	0.28
Internal volume	2.36 m ³ (83 ft ³)	Test pressure (gauge)	10 MPa (100 bar) (1,450 psi)

Table 2 Vessel and pressure test details for stored energy comparisons

In assessing the likelihood of harm, the potential stored energy release is often converted to an equivalence of an explosion of TNT (trinitrotoluene), where a large amount of data on the effect of blast energy on structures and the human body is available. It is commonly assumed that 4.27 MJ (3.15 Mft-lb) of stored energy is equivalent to an explosion of 1 kg (2.2 lb) of TNT.

The strain energy in the vessel is usually small compared with the expansion energy of the test medium and is independent of the medium used. Using equation 2.21 given in CRR168, calculation of the strain energy for the example vessel gives a value of 0.024 MJ (0.018 Mft-lb). This gives an equivalence to the energy released from the explosion of 6 g (0.2 oz) of TNT.