GUIDELINE FOR PRESSURE TESTING OF FIELD-INSTALLED PIPING AND EQUIPMENT

128/24

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GUIDELINE FOR PRESSURE TESTING OF FIELD-INSTALLED PIPING AND EQUIPMENT

As part of a program of harmonization of industry standards, the Asia Industrial Gases Association (AIGA) has published AIGA 128, *Guideline for Pressure Testing of Field-Installed Piping and Equipment, jointly produced by members of the International Harmonization Council,* and originally published by European Industrial Gases Association (EIGA) DOC 254/24, "*Guideline for Pressure Testing of Field-Installed Piping and Equipment".*

This publication is intended as an international harmonised publication for the worldwide use and application by all members of the International Harmonisation Council whose members include the Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), European Industrial Gases Association (EIGA), and Japan Industrial and Medical Gases Association (JIMGA). Regional editions have the same technical content as the EIGA edition, however, there are editorial changes primarily in formatting, units used and spelling.

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1 Introduction

Pressure testing of components and systems is an essential part of the activities of the industrial gases industry to demonstrate the integrity of equipment. Pressure testing typically involves introducing sufficient gas and/or liquid into an assembly of parts to increase internal pressure and verify the strength, integrity, and/or functionality of the assembly.

Pressure tests are required when equipment is first placed in service or to confirm its integrity during service, after equipment repair, and modification to satisfy code, company, or legal requirements.

The stored energy of pressurised systems creates a hazard that could result in injury to personnel or damage to property. Most of the hazards associated with pressure testing come from the sudden, unintended release of stored energy. Safe work procedures and practices should be implemented to ensure that the pressure test activity is planned carefully and completed safely.

Management systems are necessary to ensure that procedures are in place for energized systems to be isolated and that personnel involved in the pressure test activity are trained in the hazards, procedures, setup, and equipment necessary to complete a pressure test.

This publication provides guidelines to ensure that hazards inherent of pressure tests are mitigated, risks are managed and exposure to personnel and public is limited.

The goal of this publication is to provide a framework for users to develop specific pressure and leak testing procedures for piping and equipment that cannot be isolated from the piping being tested.

2 Scope

This publication provides guidelines for managing and planning pressure tests (leak tests and proof tests) of field-installed process piping. This includes all operations necessary for planning, preparation, pressure test of the piping, depressurization, and restoring the system back to service.

The following are included in the scope of this publication:

- Field-installed piping connecting pieces of equipment and such equipment only if it is part of field testing for example, if the equipment cannot be isolated from the field piping;
- Proof testing for integrity of the piping system components; and
- Leak testing to confirm ability to contain fluid.

The following are specifically excluded from the scope of this publication:

- Pressure tests performed in the shop on fabricated pipe spools, manifolds, and assemblies;
- Pressure vessels and other equipment that have been shop-fabricated and pressure tested prior to delivery;
- Pressure vessels built to and tested under the local codes (ASME, etc.). This publication can be used as a compliment to those codes but is not intended to replace them; and
- Pressure tests completed at manufacturing locations or workshops. These facilities have their own procedures for pressure testing process equipment and are typically carried out indoors or in pressure test enclosures.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Authority having jurisdiction (AHJ)

Organization, office, or individual responsible for enforcing the requirements of a code or standard, or responsible for approving equipment, materials, an installation, or a procedure.

3.2.2 Dry, oil-free

Gas with a dew point of –40 °C (–40 °F) or less and an oil content of 0.5 mg/m^3 or less.

3.2.3 Maximum allowable working pressure (MAWP)

Maximum pressure at the coincident temperature to which a piece of equipment or piping is designed for during a normal operation cycle.

NOTE—For the purposes of this publication, design pressure is synonymous with maximum allowable working pressure [1].[1]

3.2.4 Owner

Any person, firm, or corporation legally responsible for the safe operation of any pressure-retaining item.

3.2.5 Pressure test

Application of pressure to determine if components have acceptable integrity and/or leak tightness.

NOTE—For the purposes of this publication, pressure testing encompasses both leak testing and proof testing.

3.2.5.1 Leak test

Pressure test of equipment and piping to determine if an unacceptable amount of fluid is able to escape through mechanical connections or flaws in metal joining, cracks, and other escape paths.

[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3.2.5.2 Proof test

Pressure test of equipment and piping to test the mechanical integrity of the components and welded connections at some pressure greater than the MAWP. Typically, proof test pressure is in the range of 110% to 150% of MAWP.

NOTE—Proof testing is also commonly known as strength testing in some regions.

3.2.6 Test fluid

Fluid being introduced into the system to perform a pressure test.

3.2.7 Working fluid

Fluid that the system will contain during normal operation.

3.2.8 Test manifold

Assembly of piping, valves, regulators, relief devices, pressure indicators, and other components required to control the introduction of test fluid into the piping system being tested.

3.2.9 Pressure test execution personnel (PTEP)

Personnel who are actively involved in pressure testing, both leak testing and proof (strength) testing.

NOTE—They are aware of the hazards from pressure testing and wear appropriate personal protective equipment (PPE) such as hard hats, hearing protection, and safety glasses.

3.2.10 Non-pressure test execution personnel (NPTEP)

Personnel who are not actively involved in pressure testing.

NOTE—They might not be aware of the hazards from pressure testing and may not be wearing PPE appropriate for pressure testing.

3.2.11 Restricted access distance

Minimum separation distance for any personnel from any points of the piping system that will be pressure tested. This separation distance is determined from a source such as ASME PCC-2, *Repair of Pressure Equipment and Piping*, and *New Criteria for Safety Distances During Pneumatic Pressure Testing of Vessels and Pipes*, or owner requirements and is a function of the maximum test pressure and the pipe size [2, 3] or as per the local country applicable codes.

3.2.12 Restricted access area

Area bounded by the restricted separation distance from the piping system to be tested.

NOTE—Also designated the PTEP access area.

3.2.13 Non-restricted access area

Any space not located within the restricted access area.

NOTE—Also designated the NPTEP access area.

4 Types of Testing

The purpose of pressure testing is to check that, at a pressure with a defined safety margin in relation to the maximum allowable working pressure (MAWP), the equipment does not exhibit significant leaks or deformation exceeding a permissible threshold.

Pressure equipment shall be tested before its first use. This can happen for individual sections of the final assembly separated by detachable connections, or the whole assembly. A risk analysis shall be done, and safety precautions have to be taken accordingly. Testing is typically done in pressure steps to the MAWP, then increasing up to a pressure greater than MAWP (and all personnel shall be a safe distance away or behind a barrier).

4.1 Leak testing

A piping system is leak tested to verify that it can operate at its operating pressure while not suffering an unacceptable loss of product through leaks. This is done by pressurizing the system with a suitable medium (for example, dry oil-free air, nitrogen, or helium). Leak testing is performed at or less than the MAWP of the system. Leak testing is frequently pneumatic, but hydrostatic leak testing is possible. Refer to ASME B31.3, *Process Piping*, Section V, Article 10 or EN 13480-5, *Metallic industrial piping Inspection and testing* for more details [1, 4] or locally applicable country codes.

Typically leak testing is conducted at the final system location when all the process piping has been installed and connected.

To check for leaks, a visual inspection with a leak detection spray may be done. Only use approved leak detection fluid (see AIGA 070, *Leak Detection Fluids with Gas Cylinder*) and confirm that it does not cause stress corrosion cracking [5] Other methods of leak detection may also be used, such as helium leak detection where the system is pressurised with helium or a mixed gas containing helium and helium detectors are placed adjacent to the tested system to detect leaks.

Another method is to test for leaks over time. Once the pressure is set, the system is closed and monitored. If the system is sealed, the pressure reading should not change by more than an allowable amount over time. Any change in temperature shall be considered when evaluating the pressure gauge reading, if the tested system is not at a constant temperature. The allowable change in pressure shall also include acceptable levels of leakage through mechanical seals.

Leaks can also be detected by pressurizing with inert gas or air, immersing in water, and checking the rate of bubble formation.

Personnel may be present for this testing.

4.2 Proof testing

Proof testing is done in connection with leak testing and visual inspection to ensure that the pressure equipment is safe to use.

Proof testing verifies the system’s mechanical integrity at a pressure greater than its MAWP. Proof testing is often required by the code of construction and may also be required by the authority having jurisdiction (AHJ). The proof test pressure is usually prescribed by the code of construction.

There are two types of proof testing, hydrostatic and pneumatic. Hydrostatic testing uses a liquid, typically water, as pressure test medium, whereas pneumatic testing uses a gas, typically dry, oil-free air or nitrogen.

Whenever practicable, hydrostatic testing should be used in preference to pneumatic testing. While hydrostatic testing is generally safer than pneumatic testing due to lower stored energy, it is not without risk and appropriate safeguards are required. Where hydrostatic testing is not practical or possible, for example for piped plant systems or for cryogenic systems, pneumatic testing may be preferred. If a complete system dry out is essential, as in cases where water residue will cause operating problems, then pneumatic testing is preferred.

The pressure levels used in testing will depend on the testing method (hydrostatic or pneumatic) and the design code used for the equipment. Different design codes call for different testing pressure levels, for example ASME B31.3 uses a test pressure of 1.5 times the MAWP for hydrostatic testing whereas equipment designed to the *Pressure Equipment Directive* uses a test pressure of 1.43 times the MAWP for hydrostatic testing [1,6].

Pneumatic test pressures are typically lower due to the higher stored energies and risks associated with pneumatic testing.

In general, design codes call for a proof test pressure that exceeds MAWP or design pressure

5 Hazards associated with pressure testing

Hazards of pressure testing include:

- Catastrophic failure;
- Domino effects (chain reactions) that occur when a small change causes a similar change nearby, which then will cause another similar change, and so on in a linear sequence;
    - Contact with released liquid or gas, such as steam or cryogenic liquids or damaged electrical power lines
    - Fire resulting from the escape of flammable liquids or gases
- Systems that have been in hydrogen service are susceptible to hydrogen embrittlement for certain materials of construction, see AIGA (087), Standard for Hydrogen Piping Systems at User Locations [7]. The likelihood of embrittlement increases as a material's tensile strength increases above 483 MPa (70 psi). Embrittled piping is more likely to crack during a pressure test. It can also crack after being completely depressurised, meaning the system could pass the pressure test and fail shortly thereafter for mitigation techniques see ASME B31.12, *Hydrogen Piping and Pipelines* [8]. Cryogenic systems exposed to hydrogen at temperatures near –200 °C (–328 °F) are also at risk for hydrogen embrittlement; and
- Temperature fluctuations resulting from Joule-Thomson cooling or adiabatic compression heating can exceed allowable temperature limits for system components.

5.1 Hydrostatic testing hazards

Hazards of hydrostatic testing include:

- Difficulty in completely removing water after testing;
    - Water might not be compatible with the working fluid. Working fluid reacting with leftover water can result in uncontrolled reactions
    - Residual water can cause the working fluid to exceed desired moisture levels
    - Residual water can damage soft goods, especially if the water freezes
    - Residual water can act as a breeding ground for bacteria
    - Wet particles can combine together and plug strainers or damage valve seats
    - Pockets of water or ice can restrict fluid flow
    - Freezing water can expand due to low ambient or working fluid temperatures, and damage piping;
- Pipe support failures and inelastic deformation of piping can occur under the weight, when the piping system is filled with water, if not designed for hydrostatic testing;
- Spilled water can create slipping hazards;
- If water is not correctly treated, it can contribute to piping corrosion;
- "Water hammer" effects can cause damage to system components and pipe supports if valves are closed too quickly; and
- Residual air is compressed as water is introduced to the system, which can result in higher pneumatic pressures than intended. This can result in additional stored energy and higher

velocity water flow when draining lines after the pressure test is complete or during a pressure relief event. Residual air can result from not venting at high points and traps.

5.2 Pneumatic testing hazards

CAUTION: *All personnel involved in pneumatic testing shall exercise caution and adhere to all safety requirements of pneumatic testing procedures.*

Hazards of pneumatic testing include:

- Possible release of energy stored in compressed gas. Pneumatic testing is generally considered to be inherently more hazardous than a hydrostatic test of the same conditions of volume, pressure, and temperature because of the potential release of stored energy;
- Impact from the blast wave of a loss of containment or release of compressed gas. When a vessel or piping system ruptures, the explosion results in a blast wave that can cause structural damage and serious physical injuries. The primary measure of the damage potential of a blast wave is found at the peak pressure intensity which occurs when the blast wave pressure exceeds the ambient pressure as the shock passes, otherwise known as over pressure. The peak intensity of the blast wave from a bursting pressure vessel depends on the energy in the pressurised gas and on the vessel geometry and breakup geometry. The damage potential from the blast wave over pressure is a function of distance from the failure and decreases rapidly with distance. Similar to a ripple in water, the blast wave intensity decreases with greater distance. Therefore, the farther away from the rupture, the less the overpressure will be and the less damage that will result;
- Impact from parts of equipment that fail or any flying fragments:
  - Like a blast wave from a loss of containment, fragmentation (for example, pieces of a failed vessel, piping, etc.) can also cause serious structural damage or injury
  - According to the U.S. Department of Defense, there are two types of fragments depending on their origin:
    - Primary fragments are formed as a result of the shattering of the failed piping or vessel. These fragments can be small in size and travel initially at velocities of the order of thousands of feet per second
    - Secondary fragments are formed as a result of high blast pressures on structural components and items in close proximity to the failure. These fragments are somewhat larger than primary fragments and travel initially at velocities in the order of hundreds of feet per second;
  - Determining potential injury or damage from fragmentation is difficult because it is dependent on the fragment size, trajectory, and velocity of the object; and
- Movement of equipment and piping due to reaction force during an expected or unexpected release of the test fluid can pose a hazard to personnel and facilities.
- Asphyxiation hazards associated with nitrogen and other inert gases. See EIGA Doc 23, *Inert Gases (Nitrogen & Argon)* and CGA P-9, *The Inert Gases: Argon, Nitrogen, and Helium* [9,10]; and
- One hazard associated with clean dry, oil-free air is the potential oxidizing atmosphere due to increased partial pressure of oxygen at greater pressure. However, the potential for an oxygen-deficient atmosphere is a greater hazard.

6 Safe practices for pressure testing

6.1 General

Some of the general safe practices for pressure testing include:

- To the extent possible, prefabricated piping spools and equipment should be pressure tested before delivery to the construction site;
- Management of any field pneumatic testing at a job site shall be the responsibility of the owner's inspector as defined by ASME B31.3 [1] or locally applicable country codes;
- Assurance that a pneumatic test can be safely executed is highly dependent on complete code compliance to the requirements of ASME B31.3, Chapter VI "Inspection, Examination and Testing" [1] or as per locally applicable country codes. As such, the owner's inspector shall be able to access records of all piping, vessel, and equipment construction activities throughout the project cycle; and
- To manage risk associated with pneumatic testing, inspection, and examination requirements of the applicable codes for pressure vessels and piping shall be strictly applied with supplementary requirements. By application of supplementary inspection and examination, the Probability value will be reduced such that the risk is determined as acceptable, and the consequences will also be reduced by utilization of minimal distances for pressure test execution personnel (PTEP) and nonpressure test execution personnel (NPTEP) [1].

6.2 Personnel training

Personnel in the testing area, personnel performing the test, and those responsible for managing work practices shall be trained and competent to recognize hazards and complete the pressure test activity assigned safely.

Only qualified personnel should be responsible for planning, coordinating or executing the pressure test activity. A qualified test personnel is one who is trained and knowledgeable in the requirements of the pressure test, the hazards inherent to pressurised systems and safe practices associated with pressure testing.

The owner should determine the required competency of those personnel involved in the pressure test activity and of those personnel required to coordinate or supervise its operation. Competency should be determined by formal training and/or relevant experience in the activity. Qualified test personnel shall maintain their competency level.

Training for test personnel can be facilitated using internal training resources or external training organizations. Training should include:

- Pressure test hazard awareness that should provide information on:
  - Hazards of working on pressurised systems
  - Risks involved in pressure testing (either by hydraulic or pneumatic)
  - Causes of pressure test failures
  - How to mitigate the hazards identified
  - Safety precautions to be taken when pressure systems are tested
  - Appropriate personal protective equipment (PPE) for the work carried out;
- Pressure test equipment, which should include:
  - How to isolate the test equipment from live systems and depressurize it safely
  - Acceptable pressure test configurations
  - How to select correct fittings, valves, test gauges and piping required for the test pressure

  - Correct sizing and appropriate setting of protective devices
  - Type and quality of test mediums used in the test; and
- Pressure test procedures, which should include:
  - Company procedures for pressure testing and establishing safety distances/exclusion zones
  - Company requirements for process isolation
  - Company procedures for job risk assessments and permits
  - Company or code requirements for pressurization, testing and depressurization of equipment.

6.3 Restricted access area and safety distances

The user shall determine safety distances based on these or other appropriate references:

- ASME PCC-2 [2]; or
- *New Criteria for Safety Distances During Pneumatic Pressure Testing of Vessels and Pipes* (as presented at the 2018 AICHE Global Congress on Process Safety and published in Process Safety Progress) [3].

ASME PCC-2 provides a methodology for determining the safe exposure distances for personnel [2]. ASME PCC-2 considers a brittle failure of the piping or equipment [2]. Testing has shown that piping and vessels fail in a ductile mode, with the energy release lower than that from brittle failure. The safe exposure distances calculated from ASME PCC-2 are more conservative (greater distances) than those taken from the *New Criteria for Safety Distances During Pneumatic Pressure Testing of Vessels and Pipes* [2, 3].

For example, the restricted access distance may be 30 m (100 ft). In this case, the restricted access area comprises all space within 30 m (100 ft) of all parts of the system to be tested. While the non-restricted access area is all space greater than 30 m (100 ft) from all parts of the system to be pressure tested. NPTEP may work in the non-restricted area during pressure testing.

Restricted access area requirements apply with any untested system that is applied with a pressure of 103 kPa (15 psi) or greater:

- PTEP are allowed to be in the restricted access area. PTEP shall wear appropriate personal protective equipment (PPE), follow written and verbal procedures, and shall be aware of hazards whenever inside the PTEP access area;
- NPTEP shall remain outside the restricted access area. They shall not enter the PTEP access area unless authorized PTEP verify that the piping is not under pressure, that the test pressure source has been locked out and tagged, and that the PTEP team is aware that NPTEP are in the PTEP access area;
- PTEP are permitted to enter the restricted access area during leak testing. However, PTEP personnel should remain outside the restricted access area while the pressure is being increased and enter the area after the desired pressure has been reached;
- Where possible, PTEP shall remain outside the restricted access area during the proof testing (after the leak test). If site conditions require that PTEP work within the restricted access area during the proof testing, they shall stay behind a safety barrier during the proof test. The safety barrier may be a steel-reinforced concrete wall or any structure or equipment that provides protection from pressure waves caused by loss of containment, as determined by engineering analysis;
- Test plan shall establish the restricted access area for any piping system that is being tested;
- Barriers, barricades, warning signs, and DANGER tapes shall be used to indicate the restricted access area; and

- All pressure test activities shall be documented and reviewed to determine acceptability by owner-designated personnel through a work permit process.

6.4 Job safety analysis

A job safety analysis (JSA) shall be prepared and reviewed with those completing the testing. Onsite safety briefings, outlining all specific activities to be performed during the shift, associated hazards and hazard control measures, shall be conducted at the beginning of each shift with all personnel involved in the pressure testing. Specific tasks, roles, and responsibilities for all personnel involved in the pressure testing activity shall be reviewed.

A number of factors that should be considered (see EIGA SA 33, *Pressure Testing*) include, but are not limited to [11]:

- Risk assessment should be carried out. This shall consider the test method used, whether hydrostatic or pneumatic. The assessment should take into account the gas service the system is going into, for example, use dry, oil-free air or nitrogen for oxygen systems;
- Having a written procedure in place;
- Assess the risk of sudden loss of containment due to equipment failure;
- Whilst a hydrostatic test has less stored energy, a loss of containment can still lead to as serious injuries as would the loss of containment using a gas;
- Personnel who are involved in the pressure testing shall be at a safe distance from the equipment while it is being pressurised. During pneumatic testing, personnel should be located out of direct line of sight from the equipment under test;
- Protection of the component or system against over pressurization. Pressure tests shall never be left unattended when equipment is being pressurised;
- Before pressurizing circuits, the whole system to be tested shall be inspected to ensure that it is ready and safe to test and it shall be verified that all valves are in the correct position for the test, and the location of vent valves are known in the event that a rapid venting of the system is necessary;
- Where the system to be tested ties into any system of a lower MAWP, the lower test pressure system shall be either opened to the atmosphere or have appropriate overpressure relief protection to avoid accidental overpressurisation caused by leakage or component failure;
- Pressure in the equipment shall be increased gradually. It is recommended that the pressure be raised in stages;
- Personnel involved in organizing, setting up, and conducting pressure testing shall be trained in the appropriate pressure testing procedures;
- Being aware that high pressure air can have oxidizing properties similar to oxygen due to the partial pressure of oxygen, which can cause any contaminants in systems undergoing a pneumatic test using air to ignite;
- Depressurization when using gas as the test fluid shall consider a number of factors such as noise, jet particles, and possible increases in temperature if venting against a dead end; and
- Results of the pressure test inspection findings and details of any repairs made shall be recorded.

At the beginning of each shift a risk review shall be performed and compared to the original risk assessment. The risk assessment shall be reviewed and updated as necessary in accordance with the user's management of change when:

- each new task is begun;
- there is a change in how a task is performed;

- changes in site or environmental conditions occur; or
- new specific need or concern is identified (i.e., as needed to ensure the safety of personnel or property).

6.5 Risk assessment

Prior to performing any pressure test, a risk assessment should be performed to review the testing plan. The risk assessment should address the considerations raised within this publication. Any risk assessment should include the following considerations:

- Test fluid shall be compatible with the working fluid. Common test fluids include nitrogen, air, and water. Consider whether the proposed test fluid is compatible with the working fluid of the system. When analyzing for compatibility, consider not just the test fluid itself, but also its impurities. For example, plant air could contain moisture or oil that would render it incompatible with the working fluid. The use of non-inert material as a test fluid, like toxic or flammable gases, shall not be used, even where such test fluid will be the working fluid of the piping system. Consider whether the piping system needs to be purged before and/or after the test.
- Piping system shall be tested to the appropriate pressure. A MAWP shall be defined for each section of piping and documented. The pressure test will validate the MAWP as the maximum permissible pressure in that system. The MAWP is typically greater than the operating pressure. For example, it could be the pressure to which a PRD is set, or the maximum outlet pressure of a pressure regulator.
- PRDs shall be installed to protect the piping during the pressure test. While a pressure test is typically a slow and controlled procedure, administrative controls are not a substitute for engineered controls. If the test fluid’s source pressure is greater than the test pressure, ensure that an appropriately sized pressure relieving device is installed either on the test manifold or on the piping system.
- Method to depressurize the system after testing shall be developed. Ensure that there is a safe means to depressurize all sections of the piping system. Pay particular attention to sections of piping downstream of non-return devices like check valves or pressure regulators. Ensure that the pressure is vented to a well-ventilated area. Ensure that the system is designed and constructed to withstand the reaction forces during depressurization; and
- Protecting personnel from loss of containment. The piping system would rapidly release a significant amount of stored energy if it were to fail at test pressure. Consider the effects of this release and implement protections to mitigate them. The testing area should be sized appropriately (see 7.3) and cordoned off from the rest of the facility. Signs should indicate that pressure testing is in progress and to keep out. Pressure should be introduced to the piping system slowly by a remote operator through the use of an automated system, where possible. Otherwise, the testing area should be limited to the person introducing the pressure. Anyone inspecting the piping at regular intervals for leaks should wait to enter the area until the pressure is steady.
- Nature of adjacent equipment or materials within the testing area; and
- Loss of containment during the pressure test result in another hazard;
  - Could the piping to a toxic or corrosive gas processing system be sheared?
  - Could a large structure be knocked over?

A complex piping system, one that features several networks of piping carrying multiple fluids at varying operating pressures, deserves particular attention during a risk assessment. More so than with a simple piping system, the PTEP performing a pressure test on a complex piping system run the risk of:

- failing to identify all energy sources and adequately isolating them;
- overpressurising a section of piping not rated for the test pressure;

- underpressurising a section of piping that will be operated at a greater pressure;
- failing to pressure test a section of piping;
- contaminating a section of piping with an incompatible fluid; and
- failing to return the entire piping system back to normal working order (for example, removing all blinds, replacing relief devices).

For complex piping systems, and particularly for the initial pressure test upon commissioning a new system, the risk assessment should be performed by a team, which includes at a minimum: an engineer familiar with the design, an operator familiar with the process, and a person with experience performing pressure tests. A written pressure testing procedure should form the basis of the review. The team should document their risk assessment and validate any changes to the procedure.

6.6 Written procedures

The owner should develop and maintain written procedures that set the standards for the different operations necessary to safely execute the pressure test. The procedures shall consider relevant industry knowledge, the owner's knowledge and experience, code requirements, local regulatory safety standards, and the guidelines established in this publication.

The procedures should provide a documented approach of its established safe work practices and methods used to mitigate risks. Personnel shall be required to understand and follow the procedures applicable to the pressure test operations.

The documents necessary to cover the various pressure test activities include safety, operations, and pressure test procedures. These procedures should include the items discussed in the following paragraphs.

Safety procedures shall outline the methods for energy isolation and de-energizing of systems. This shall include how to isolate energy sources and pressurised systems to prevent unexpected energization or release of stored energy in the equipment that is being tested. Valve position, blank types, materials of construction, blank thickness, locations, as well as any temporarily removed or disabled safety devices should be included in the safety procedures. The procedures shall establish how the isolation is ensured, documented, and checked before work commences on the system.

Operations or maintenance procedures shall include the requirements for risk assessment, work permit system, and necessary PPE requirements. Risk assessments should be detailed and should exhaustively assess the specific pressure test hazards and risks. The procedures shall allow for control measures identified to be documented. A communication plan that ensures that all personnel involved in the activity are made aware of the reporting/escalation process.

The test plan shall establish the pressure test procedure requirements including test equipment and configuration, pre- and post-test inspections, checklists, requirements for trained personnel, restricted access area, and barriers. The procedure should establish the roles/responsibilities of those involved in the pressure test and should clearly identify any supervisory and approval requirements.

It should include the recommended format of the test plan (for example, test pressures, system markups, steps for pressurizing, checking, testing, and depressurizing the system). Any required checks for the tested equipment and temporary test equipment should be stated in the procedure. Required signoff or approval for the test steps and return to service should be clearly identified. Where applicable, the procedure should also include a table detailing preliminary, primary, and secondary pressure steps, hold times, and inspection requirements.

The procedures should also state how pressure test documents, pressure test permit and checklist, and certificates are documented and stored.

6.7 Lockout/tagout and risk mitigation

Prior to performing a pressure test, energy sources shall be isolated in accordance with the test plan. To prevent overpressurisation of the test circuit, the following potential causes of overpressurisation shall be mitigated:

- High pressure source plumbed to the test circuit is opened (for example, process or utility gas or liquid);
- Low pressure test circuit is inadequately isolated during testing of a high-pressure test circuit;
- Do not rely on an automated system or its interlocks to prevent a valve from opening or a device from turning on. Particularly during the initial pressure test of a new system, the logic of the control system might not have been fully tested and so the system might not operate as expected. A physical isolation provides positive isolation;
- Inline heat source is turned on (for example, electric heater, fluid to a heat exchanger); and
- Inline pump or compressor is turned on.

When developing the pressure test lockout/tagout plan the following should be considered:

- For fluid hazards, use an appropriate level of isolation for the hazard presented. Isolation can be accomplished by: single valve isolation, double valve isolation, double block and bleed, or blinding, for instance. When possible, manual valve(s) that provide a visual check that the valve has been closed for isolation is recommended.
- Where pneumatic valves are to be used for isolation, understand what will happen when the air source and/or electrical signal is disconnected. Valves that require an air source or electrical signal to remain closed should be avoided as isolation valves due to their potential to open upon disruption of the plant’s air or control system. Manual overrides or other mechanical means might be required to hold such valves in position.
- Valves that are spring-return-closed or double-acting (in the closed position), can have their air source disconnected and tagged out for isolation. Reconnecting the air supply at the conclusion of testing is required; and
- Where a heat source, pump, compressor, or other powered device capable of increasing pressure is located inline, disconnect the device where possible.

The lockout/tagout plan shall ensure that the isolation scheme has not isolated the test manifold PRD from the test circuit.

7 Equipment

All testing equipment and fluids shall be sufficiently cleaned or filtered to prevent contamination of the system being tested.

7.1 Test fluid

All process piping shall be hydrostatically or pneumatically tested with the fluid medium as specified in the project-specific pressure test guideline. In some governmental jurisdictions, change of test media can also require submittal of new test procedure for approval.

Whenever practicable, hydrostatic testing shall be used in preference to pneumatic testing. While hydrostatic testing is generally safer than pneumatic testing, it is not always feasible, particularly for piped plant systems or for cryogenic systems. If dry out is essential, as in cases where water residue would cause operating problems, then pneumatic testing is preferred.

7.1.1 Hydrostatic test

Hydrostatic test medium shall be from a source of water that is clean and filtered of such quality as to minimize corrosion of the materials in the piping system.

Chloride content of the water should not exceed 50 ppm to avoid problems of corrosion for stainless steel (or equivalent) pipelines or equipment. When testing piping of all other materials, a chloride ion content of less than 200 ppm should be used. The water temperature should not exceed 50 ˚C (122 ˚F) for stainless steel equipment to further mitigate possible chloride stress corrosion cracking.

Ensure that all air is expelled from the system via a high point vent prior to pressure being applied.

Equipment that is undergoing hydrostatic testing shall be fitted with suitable drains to permit removal of water after testing. Equipment shall be dried out after testing to remove water remaining in dead-ended cavities or circuits. Corrosion effects of residual water remaining in the equipment can be particularly significant for aluminum (see AIGA Doc(073), *Water Corrosion of Composite Cylinders with AA 6061 Liners*) [12];

All piping and equipment shall be adequately supported during hydrostatic testing. Additional supports can be necessary because of the weight of the test fluid. Care shall be taken to avoid overloading any supporting structure during testing. Spring supports shall be blocked to prevent movement prior to testing. For equipment, the foundations shall be verified capable of withstanding the weight of the equipment full of water.

Hydrostatic testing should not be carried out during periods of rain or fog, unless under suitable cover, as resulting surface moisture can allow small amounts of leaking test liquid to go undetected.

Hydrostatic tests should not be carried out at a water temperature of 2 °C (35 °F) or less, or if the air ambient temperature is 5 °C (40 °F) or less. When testing must take place at ambient temperatures below 5 deg C, 40 deg F, additional precautions shall be taken to prevent the test liquid from freezing during the test. Precautions could include limiting the time of the test and continuously monitoring the temperature of the test liquid and piping. A water/glycol mix can also be used. A pneumatic test in lieu of hydrostatic test should also be considered.

When conducting tests at temperatures below 10 °C (50 °F) or if the water temperature is below 10 °C (50 °F) the possibility of a brittle fracture of equipment shall be considered including the minimum design metal temperature (MDMT) for example, ASME recommends that the metal be 17 °C (30 °F) above the MDMT [1]. The water temperature should not exceed 50 ˚C (120 ˚F). See 8.1 for additional information.

When it is necessary to leave a large system partially filled (not pressurised) with liquid overnight, and temperatures below freezing are likely, a suitable antifreeze should be added to the test liquid. Before being used, the compatibility of the antifreeze with all materials in the system shall be evaluated. A detailed proposal, which includes the antifreeze mixture to be used, system rinsing and drainage procedures, and antifreeze mixture disposal plan, shall be prepared. The flashpoint of the antifreeze mixture shall be no lower than 50 ˚C (122 ˚F).

7.1.2 Pneumatic test

Pneumatic testing can be performed with either air, or inert gases such as nitrogen or helium (or a mixture of these). When inert gases are used as a test medium, a review is required to ensure hazardous confined spaces are not created and that adequate ventilation is provided as leaks can create an asphyxiating atmosphere. Oxidizing gases, carbon dioxide, flammable, and toxic gases shall not be used as the test fluid. Gas mixtures containing flammable gas less than the lower explosive limit (LEL) may be used, but a risk assessment shall be performed. The gas operating temperature shall be within the limits of the piping and components being tested.

When multiple gases are available, the user shall determine which is the best one to use based on equipment and piping layout.

The test medium shall normally be dry filtered to at least a level of 5 microns. Compressed air or an inert gas such as nitrogen for hydrocarbon processing lines and dry, oil-free compressed air or an inert gas such as nitrogen for air separation processing lines. However, an argon customer supply system may use argon.

Other test mediums such as a nitrogen/helium mixture required to perform a sensitive leak test (per ASME B31.3 paragraph 345.8 on a specialist flammable gas system) or filtered nitrogen (to perform a pressure test on an ultra-high purity (UHP) gas system) shall only be used when specified in the project-specific pressure test guideline [1].

Helium and hydrogen systems should be tested with a 10% helium/90% nitrogen mixture using pressure decay to determine acceptance. Where gas mixtures are used containing helium for leak detection, leak detection shall only take place after the pressure test has been completed and pressure reduced from test value.

When nitrogen or another inert gas is used, precautions shall be taken to avoid creating an asphyxiating atmosphere. Before entering any confined area, atmospheric testing shall be performed in accordance with confined space requirements. Compressed air shall be used when adequate ventilation is not practical. See AIGA (008), *Hazards of Oxygen-Deficient Atmospheres* for safety information regarding oxygen-deficient atmospheres [13].

All equipment shall be adequately supported during the pneumatic testing. Care shall be taken to avoid overloading any supporting structure during testing. Spring supports shall be blocked to prevent movement during testing. Reactive forces shall also be considered.

In addition to a pressure relief device (PRD), a regulator shall always be used when pressurizing lower pressure circuits with high pressure cylinders or other sources with pressures higher than the circuit or equipment being tested. When using a regulator to reduce pressure, pressure indication and a relief device(s) shall be provided (see 8.2).

The piping and equipment metal shall be kept 17 °C (30 °F) greater than the MDMT and shall not exceed 50 °C (120 °F) for the duration of the testing.

The working fluid should be checked prior to use to verify it is still within specifications.

7.2 Test manifold

Figures 1 and 2 provide illustrations of typical test manifold setups for hydrostatic and pneumatic tests.

Test manifold MAWP shall be greater than the test pressure by at least 10% and subjected to a pressure test prior to its initial use.

High pressure hose may also be used if suitably rated for the service and pressure. It shall be secured, provided with hose whip protection, and protected from damage during use. A manufacturer's pressure test certificate shall be obtained before its use. If the hose is not new, a hydrostatic test shall be performed to verify its pressure rating.

Before pressurizing circuits, the whole system to be tested shall be inspected to ensure that it is ready and safe to test and it shall be verified that all valves are set correctly, and the location of vent valves are known in the event that venting is necessary.

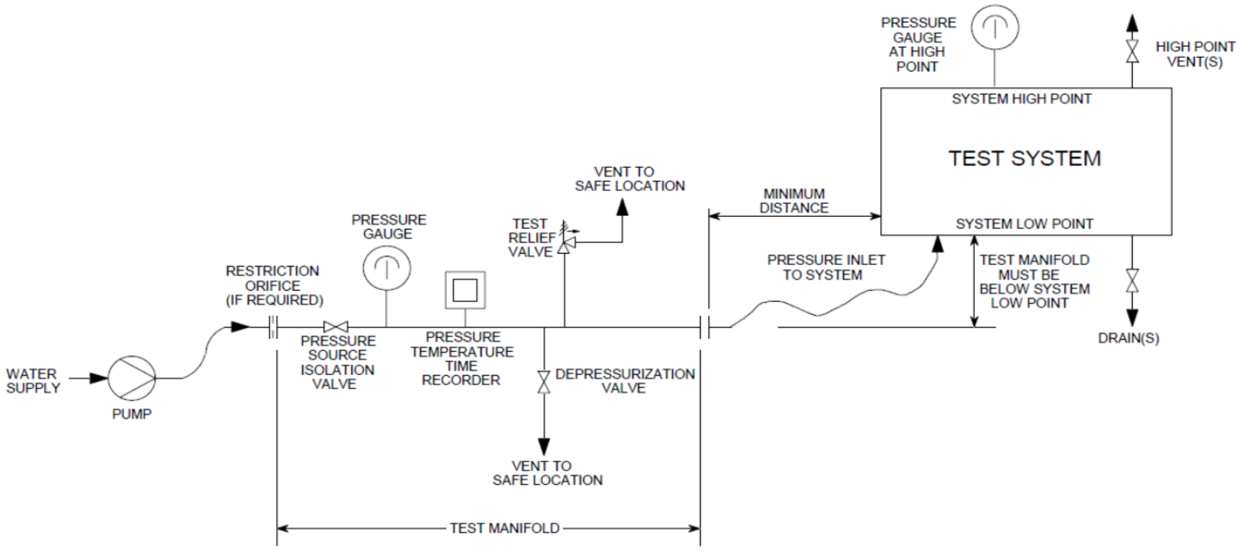

Figure 1—Typical hydrostatic test manifold setup

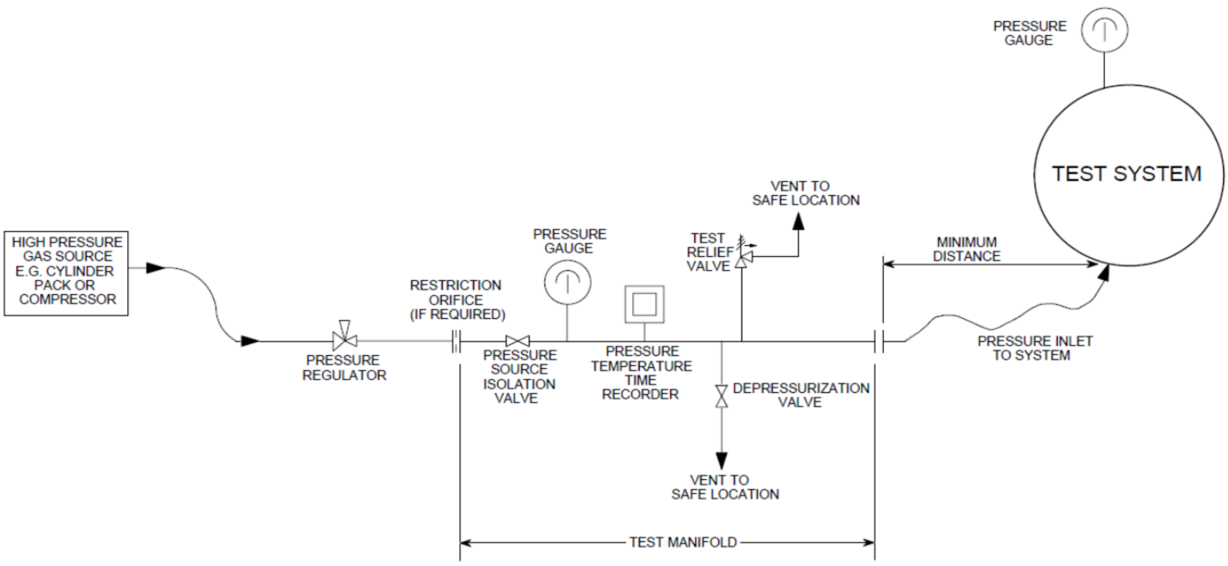

Figure 2—Typical pneumatic test manifold setup

7.2.1 Pressure relief devices

All system relief valves, burst discs, and in-line instruments that are not rated for the test pressure shall be either removed or adequately isolated prior to pressure test and a test PRD shall be installed in the test circuit or on the discharge side of the test manifold.

Test relief devices for hydrostatic and pneumatic proof test, with a set pressure of no more than 10% above the test pressure (as stated in ASME B31.3), shall be installed [1]. The test relief device and discharge piping shall be positioned so as not to cause injury or damage to equipment during discharge and be adequately supported to accommodate the reaction forces due to discharge.

Circuits shall not be pressure tested without an appropriate flow pressure relieving device installed (such as a relief valve or burst disk) as an integral part of the circuit or equipment. The PRD shall be sized for the maximum media supply available from the high-pressure media source used for the test. The sizing of the PRD shall consider the piping resistance and the wide open resistance of any regulator, control valve, or manual valves between the pressure source and the test circuit. A flow restricting orifice may be added to the test manifold to reduce the maximum flow rate of the test manifold and allow for a smaller PRD.

The PRD shall be connected directly to the equipment and not be isolated by valves or blinds.

Test manifold PRDs shall be subjected to periodic testing and reset as necessary, not longer than every 5 years. PRDs shall be visually inspected prior to each test.

Relief valves should be tagged with set pressure and capacity.

7.2.2 Pressure measurement devices

A pressure measurement device (gauge, transmitter, etc.) of suitable range shall be available on the system at the pressure inlet line. When testing large piping circuits, it is recommended the farthest point in the piping system be tubed back to the test stand and terminated in a second pressure measurement device. This assures that the entire circuit being tested is pressurised and free of obstruction. The measuring range of a test pressure measurement device is preferably twice the test pressure. It should not be less than 1.5 times or greater than 4 times test pressure. The measurement device calibration shall be verified.

For hydrostatic testing, another measurement device should be installed at the highest point in the system (where the measured pressure will be lowest due to liquid head pressure loss). This measurement device allows the person performing the test to confirm that the desired test pressure has been achieved where the pressure is expected to be lowest.

The pressure indications shall be visible to the PTEP when pressurizing the piping system.

A calibrated pressure recorder to record the test pressure may also be added when required by the test procedure.

7.3 Test blanks and blinds

All temporary blanks used to isolate piping and/or equipment for pressure test shall be numbered for traceability, and the blank numbers shall be entered on a pressure test blank log.

Blanks can be:

- paddle blinds;
- forged or wrought caps; or
- blind flanges (per mating flange class or plate thickness equal to mating blind flange).

To determine paddle blind thicknesses the appropriate local piping pressure code shall be used such as ASME B31.3 [1] or applicable local country codes.

Blinds of lesser thickness may not be stacked together to meet a thicker blind requirement.

Unless specified otherwise, all blanks should be of carbon steel construction.

Short sections of piping that have been removed to permit the installation of test blanks shall be pressure-tested separately.

7.4 Personal protective equipment

In addition to any site-specific requirements, recommended PPE for pressure tests includes:

- hard hat;
- gloves;

- steel-toed shoes;
- safety glasses with side shields;
- personal atmospheric monitor for pneumatic testing with gas other than air; and
- hearing protection.

For further information, see AIGA (066), *Selection of Personal Protective Equipment* [14].

8 Testing procedures

8.1 Test preparation

Prior to pressure testing, the following activities shall be completed.

NOTE—These activities may be incorporated into a testing permit and checklist.

8.1.1 Risk assessment

The following items are essential for any risk assessment:

- For a pneumatic proof test, the use of hydrostatic testing has been considered and has been deemed impractical;
- Risk assessment of the test procedure has been completed. In particular for pneumatic testing, the stored energy of the equipment being tested has been evaluated and the magnitude of any blast and the penetrating power of any fragments due to system failure have been calculated based on recognized methods;
- Suitable protection method has been specified (for example, protective enclosures, barricade plan, restricted access areas) to protect affected workers from the potential risk of blast pressure and from fragments identified in the risk assessment;
- Restricted access area has been established;
- Risk assessment has identified all other potential hazards during testing and a safety plan has been established to protect affected workers from each of the identified hazards; and
- Lockout/tagout procedure has been written and approved.

8.1.2 Approval of test system and test procedure

- Qualified personnel have examined and approved the design of the system being tested, the procedure for the test and the safety plan;
- Piping installation, including its components and pressure vessels conform to recognized standards (for example, ASME B31.3) and intended test pressure is suitable for the MAWP [1];
- Mechanical properties of materials used for the piping system and vessels have been evaluated and are not at risk for brittle failure under the specified test conditions (for example, at low temperatures);
- Rate of pressurization and depressurization of the system has been specified;

- Approved testing permit has been issued by a qualified person (for example, pressure systems manager); and

- Individual system documentation i.e., test procedure shall be available prior to any testing and shall include information such as schematics, equipment specifications, installation manuals, test limits, test pressure, test medium, duration, test blinds, blind flanges, vents, and drains.

8.1.3 Communication, personnel, and test area security

- System of communication has been established;

- List of emergency personnel and contact information is available;

- All affected personnel have been notified as to the location, time, and duration of testing and the associated hazards;

- All personnel performing the test procedure have been adequately trained;

- JSA was performed with affected personnel;

- All testing personnel are equipped with the correct PPE;

- Arrangements have been made to exclude nonessential personnel from the testing area;

- Test permit is posted;

- Barricade plan and restricted access areas are in place; and

- Warning signs are posted.

8.2 Test execution

Pre-test system check, see Figure 3 for an example:

a) Comparison of the piping and instrumentation diagram (P&ID) drawings and the piping isometrics to the system under test shall be made to determine if there are any discrepancies. Recheck all in-line components to verify they can withstand the required test pressure;

b) System to be tested includes a PRD in accordance with ASME B31.3 [1] or as per locally applicable country codes;

   - 4Verify correct pressure relief valve (PRV) location

   - Verify capacity and set pressure comply with test documentation

   - Installation includes specified discharge routing, discharge supports, riser material, etc.

c) Verify correct test fluid source, available flow, pressure, temperature, and cleanliness. If compressed air is used as the test medium and is supplied by means other than on site compression, then the oxygen content of the gas shall be verified for each source container (for example, tube trailer, cylinder, etc.) before use. A certificate of analysis for the container is sufficient. Confirm water chemistry for hydrostatic tests;

d) Verify the test fluid, if not air, is not flammable, toxic, or corrosive;

e) Flow capacity of the PRD is at least equal to the pressure source;

f) Adequate controls (for example, pressure regulator) are installed and operating to prevent over pressurization of the system;

g) Test gauges are calibrated and certified, reading zero prior to installation and have a full scale range as specified in 8.2.2;

h) There is a method for continuously monitoring the test pressure to ensure the pressure never exceeds the designated test pressure of the system;

i) Before applying test pressure, all piping fittings, connections, flanges, bolts shall be checked for proper installation. Confirm that, at a minimum:

- Bolts and nuts have correct torque
- Any compression fitting ferrules are adequately swaged into the tubing
- Pipe threads have correct thread engagement
- Pipe threads have compatible and rated sealant for the application (if necessary);

j) Verify that any required non-destructive examination (NDE) has been completed;

k) All low-pressure piping and other components connected to the system not rated for the test pressure have been disconnected or blocked from the test system. Blocking valves shall be locked out/tagged out in accordance with control of hazardous energy systems such as Title 29 of the U.S. *Code of Federal Regulations* (29 CFR) 1910.147 [15]. Isolated equipment shall be vented;

l) Preliminary leak test of the system has been performed at a pressure no greater than 170 kPa (25 psi) to locate major leaks in the system;

m) Method to correct for pressure change due to temperature changes in the system is present;

n) All welded, flanged, threaded joints and connections not previously tested are left uninsulated and exposed for examination during testing;

o) Test blanks and blinds installed for testing purposes shall be designed to withstand the test pressure without distortion. The presence of blanks and blinds shall be clearly visible during testing. The recommended practice is to use standard blind flanges in accordance with ASME B16.5, *Pipe Flanges & Flanged Fittings,* or ASME B16.47, *Large Diameter Steel Flanges: NPS 26 through NPS 60*, and spades according to ASME B16.48, *Line Blanks* [16,17,18];

p) Check valves shall have the flap or piston removed for testing, where pressure cannot be located on the upstream side of the valve. The locking device of the flap pivot pin shall be reinstated together with the flap and a new cover gasket shall be installed after completion of the test;

q) Verify a safe means exists to vent and discharge the test fluid from the system under test. If the test gas is an asphyxiant, it shall be vented to a safe location;

r) Verify the piping system has sufficient flexibility and support;

s) Verify necessary precautions are in place to accommodate for thermal expansion of the test fluid;

t) Verify flexible piping connections have the necessary restraints in the event of detachment from the system to prevent hose whipping;

u) Verify the assembly of systems have been performed in accordance with approved written procedures and work instructions;

v) Verify all system components are of good quality and have not been compromised by previous use or alteration. All components used in testing that serve to contain pressure shall be inspected and maintained in accordance with an established quality system;

w) Verify the system under test has been cleaned and contains no combustible material (this is of particular concern if air is used as the test gas);

x) Verify the method for controlling the required rate of pressurization and depressurization is operating; and

y) Verify that all areas are demarcated by the use of DANGER or WARNING tape, signs, banners, or another approved barrier device, to prevent inadvertent access into the test area, consistent with minimum safe distance.

8.3 Test report

Pressure tests shall have a test report. The test report shall be retained for the life of the equipment. At a minimum, the test report shall consist of the following:

- test date;
- location of test;
- name of person performing test;
- MAWP;
- test pressure, medium, and duration;
- pressure test result;
- list of all relief devices that were removed or disable during the test, and confirmation that they were restored to normal service; and
- list of all temporary blanks, caps, plugs, valves, etc. that were installed for the pressure test, and confirmation that they were removed.

8.4 Return to service

To avoid errors, there shall be a documented procedure for returning a system to service. At a minimum, the following shall be considered when returning to service:

- After a hydrostatic test, water can come to rest in dead legs and filter housings. These should be individually drained. It may be necessary to purge lines with warm dry gas to remove trace moisture;
- Water from a hydrostatic test shall be disposed of in accordance with local code requirements;
- Lines should be purged with inert gas (or evacuated depending on system design) to expel air prior to introducing flammable working fluids into the system;
- Depending on the specific gravity of the working fluid, the test fluid can accumulate at high or low points in the system. Those points should be drained/purged as working fluid is added to the system; and
- If the working fluid is an oxidizer, it will be necessary to pressurize slowly to control temperature rise from adiabatic compression and to restrict the initial gas velocity to allowable limits. Oxidizer systems are most likely to experience an energy release during initial pressurization and venting. Compressed air can also act as an oxidizer (see ISO 10156, *Gases and gas mixtures*) [19].

<table>
<tr><th colspan="6">Pressure Test Permit and Checklist</th></tr>
<tr><th colspan="6">Copy to be posted at test location</th></tr>
<tr><th colspan="3">Emergency Information</th><th colspan="3">Permit Information</th></tr>
<tr><td>Emergency contact</td><td>Phone</td><td>Title</td><td>Authority issuing permit</td><td colspan="2">Permit no.</td></tr>
<tr><th colspan="6">Test Information</th></tr>
<tr><td>Date and time of test</td><td colspan="2">Test type
☐ Pneumatic ☐ Hydrostatic ☐ Other</td><td>MAWP/Design pressure</td><td>Test pressure</td><td>Test fluid</td></tr>
<tr><td>Test duration</td><td colspan="2">Test supervisor</td><td>Design temperature</td><td colspan="2">Test temperature</td></tr>
<tr><td>Test location</td><td colspan="2">Room/floor number</td><td>Test procedure number</td><td colspan="2">System and test approved by</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="9">Risk Assessment</td><td colspan="2">Risk assessment report number</td><td colspan="3">Approval authority (e.g., pressure systems manager)</td></tr>
<tr><td>Stored energy estimate</td><td></td><td>MJ</td><td colspan="2">Details on energy and safe distance calculations</td></tr>
<tr><td>Energy equivalent in TNT</td><td></td><td>kg</td><td colspan="2" rowspan="5">For example: Stored energy calculated based on Baker isentropic gas expansion calculation. Safety distances are calculated based on calculations from Lee's Fire Protection Handbook</td></tr>
<tr><td>Blast wave pressure</td><td></td><td>MPa</td></tr>
<tr><td>Maximum distance debris and missile damage</td><td></td><td>m</td></tr>
<tr><td>Maximum distance for eardrum rupture</td><td></td><td>m</td></tr>
<tr><td>Maximum distance for lung damage</td><td></td><td>m</td></tr>
<tr><td colspan="2">Blast wave protection method</td><td colspan="3">Missile protection method</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="5">Communication, Safety and Security</td><td colspan="2">☐ System of communication in place</td><td colspan="3">☐ Restricted access zones secured</td></tr>
<tr><td colspan="2">☐ Affected employees notified</td><td colspan="3">☐ Safety barricades and enclosures in place</td></tr>
<tr><td colspan="2">☐ Safety plan completed</td><td colspan="3">☐ Warning signs posted</td></tr>
<tr><td colspan="2">☐ JSA completed</td><td colspan="3">☐ Necessary PPE available</td></tr>
<tr><td colspan="2">☐ Testing permit obtained and posted</td><td colspan="3">☐ Personnel trained on test procedure</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="11">Pre-test System Inspection</td><td colspan="2">☐ System matches P&ID</td><td colspan="3">☐ Vent valve closed</td></tr>
<tr><td colspan="2">☐ Components approved for test pressure</td><td colspan="3">☐ Test fluid venting location safe (not confined if test fluid is an asphyxiant)</td></tr>
<tr><td colspan="2">☐ Proper pressure relief (see ASME B31.3) [1]</td><td colspan="3">☐ Components are in good condition</td></tr>
<tr><td colspan="2">☐ Test gauges calibrated and proper range</td><td colspan="3">☐ All fittings, plugs, and flange bolts are mechanically tight</td></tr>
<tr><td colspan="2">☐ Test gauges are visible</td><td colspan="3">☐ Bolts are not overstressed</td></tr>
<tr><td colspan="2">☐ System is clean and purged</td><td colspan="3">☐ Pressure vessels properly restrained</td></tr>
<tr><td colspan="2">☐ Pipes and hoses are restrained</td><td colspan="3">☐ Piping system is properly supported</td></tr>
<tr><td colspan="2">☐ Low pressure leak test completed</td><td colspan="3">☐ Test fluid is correct (e.g., nitrogen)</td></tr>
<tr><td colspan="2">☐ Insulation removed from fittings</td><td colspan="3">☐ Pressure source is set properly</td></tr>
<tr><td colspan="2">☐ Check valves opened or flaps removed</td><td colspan="3">☐ Rate of pressurization specified</td></tr>
<tr><td colspan="2">☐ Low pressure sections blocked or disconnected</td><td colspan="3">☐ Pressure stages specified</td></tr>
</table>

Figure 3— Example of test permit and pressure test check list

9 References

Unless otherwise specified, the latest edition shall apply.

[1] ASME B31.3, *Process Piping*, American Society of Mechanical Engineers. www.asme.org

[2] ASME PCC-2, *Repair of Pressure Equipment and Piping*, American Society of Mechanical Engineers. www.asme.org

[3] Miller, D., Jallais, S., Pham-Huy, M., and Geng, J., *New Criteria for Safety Distances During Pneumatic Pressure Testing of Vessels and Pipes, Process Safety Progress* vol. 38, no. 3, 2018. www.wileyonlinelibrary.com

[4] EN 13480-5, *Metallic Industrial Piping - Part 5: Inspection and testing*, Deutsches Institut für Normung. www.din.de

[5] AIGA 070, *Leak Detection Fluids with Gas Cylinder Packages*, Asia Industrial Gases Association. www.asiaiga.org

NOTE—This publication is part of an international programme for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonised regional references.

[6] DIRECTIVE 2014/68/EU, *Pressure Equipment Directive.* European Commission. ec.europa.eu

[7] AIGA 087, *Standard for Hydrogen Piping Systems at User Locations*, Asia Industrial Gas Association. www.asiaiga.org

[8] ASME B31.12, *Hydrogen Piping and Pipelines,* American Society of Mechanical Engineers. www.asme.org

[9] EIGA Doc 23, *Inert Gases (Nitrogen & Argon)*, European Industrial Gases Association. www.eiga.eu

[10] CGA P-9, *The Inert Gases: Argon, Nitrogen, and Helium*, Compressed Gas Association. www.cganet.com

[11] EIGA SA 33, *Pressure Testing*, European Industrial Gases Association. www.eiga.eu

[12] AIGA 073, *Water Corrosion of Composite Cylinders with AA 6061 Liners*, Asia Industrial Gases Association. www.asiaiga.org

NOTE—This publication is part of an international programme for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonised regional references.

[13] AIGA 008, *Hazards of Oxygen-Deficient Atmospheres*, Asia Industrial Gases Association. www.asiaiga.org

NOTE—This publication is part of an international programme for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonised regional references.

[14] AIGA 066, *Selection of Personal Protective Equipment*, Asia Industrial Gases Association. www.asiaiga.org

NOTE—This publication is part of an international programme for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonised regional references.

[15] *Code of Federal Regulations*, Title 29 (Labor), U.S. Government Printing Office. www.gpo.gov

[16] ASME B16.5, *Pipe Flanges & Flanged Fittings,* American Society of Mechanical Engineers. www.asme.org

[17] ASME B16.47, *Large Diameter Steel Flanges: NPS 26 through NPS 60*, American Society of Mechanical Engineers. www.asme.org

[18] ASME B16.48, *Line Blanks*, American Society of Mechanical Engineers. www.asme.org

[19] ISO 10156, *Gases and gas mixtures*, International Standards Organization. www.iso.org