

## Chapter 15. Proof and Leak Tests

### Proof Tests

Proof tests of weldments can be made to determine whether the weldment will withstand application of service loading without failure or acquire a permanent deformation in any part. Such tests are usually designed to subject the parts of the weldment to stresses above those they are expected to carry in service, but below the yield strength of the metal. The manner in which such tests are applied varies with the type of weldment and the service for which it is designed.

In most cases, proof tests are applied in connection with visual examination (or at least some visual examination is required). Details of any tests required are usually specified by the drawings, specifications, or contract for the weldment.

**Closed Containers:** For proof testing of closed containers, some form of internal pressure is usually used. This pressure may be obtained by applying compressed air (pneumatic test) or water pressure (hydrostatic test). Ordinarily, air is used only for relatively low-pressure testing because of the possibility of extensive damage and danger to life if failure occurs.

In hydrostatic testing, the pressure used is usually the design working pressure plus a certain percentage in excess of design pressure. Visual inspection is employed to determine whether leakage occurs during the test, although this is not the primary leak test determinant.

Closed containers that would be proof tested by internal pressure include storage tanks for liquids and pressure vessels of various sorts

(such as oil-cracking stills and tanks for compressed gases).

**Open Containers:** Open containers may be tested hydrostatically (by filling with water) and visually examined for leakage. Examples are water or oil storage tanks or containers for other liquids. Watertight bodies for amphibious vehicles are usually tested by running the vehicle fully loaded into water and examining the seams for leakage while the vehicle is floating.

**Structural Weldments:** Weldments designed as structural members to carry certain loads in service may be proof tested by setting them up and loading them in a testing machine. Sometimes, with large members, the weldment is set up and loaded (e.g., sand bags or scrap iron) to determine whether calculated deflections are obtained at a prescribed load. Loading in excess of that expected in service is applied to determine whether any part of the weldment acquires any objectionable permanent set or deformation.

**Machinery Parts:** Weldments associated with rotating machinery parts or equipment are proof tested by overspinning the component and permitting centrifugal force to provide the desired stress levels, such as "150 percent design stress." Visual and nondestructive examination plus dimensional measurements are employed to determine the acceptability of the part.

### Leak Tests

Leak tests of weldments are used to determine if discontinuities extend completely through a weld. These tests range from such simple pro-

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cedures as pressurizing to create a pressure differential and visually examining the welds, to sophisticated methods using electronic equipment for detection of leaks.

One of the simplest leak tests consists of increasing the internal pressure (to get a pressure difference) of a vessel or a piping system and examining the welds for evidence of leaks. Water, oil, air, or non-flammable gases can be used for pressurizing. Before leak testing, all welds and surfaces should be in a finished condition, but without final painting.

The media used for leak testing may be any liquids that are not hazardous to personnel or harmful to the weldment. Naturally, water is the most widely used medium for pressure vessels because of its ready availability and low cost. However, a light oil may be more effective than water and may require less pressure than water to penetrate a given discontinuity. Water is most useful for the location of gross leaks. The use of chemicals to lower the surface tension of water is helpful in improving the sensitivity of this test method.

Evidence of relatively small leaks is often overlooked due to the presence of water on the outside of the vessel prior to filling and testing. Addition of small quantities of water soluble fluorescent dyes to the test medium and inspection of the outer surfaces of the vessel with ultraviolet light is sometimes used to increase the sensitivity of the method.

Liquid leak testing using water is usually conducted as part of the standard hydrostatic proof test for a pressure vessel. The test is conducted by filling the vessel to capacity and inspecting the outer surfaces for evidence of moisture.

When a pressure vessel is tested hydrostatically, caution should be exercised to provide the necessary vents at the high points of the vessel to permit removal of air prior to pressurizing. Industry experience and manufacturer, customer, and code rules should be consulted to determine the time required under pressure.

This leak test method has the advantage of being a relatively safe procedure if all fittings are securely fastened and air entrapment during filling is minimized. In the event of catastrophic

failure, only a low level of energy is available. Thus, the damage that can occur in the test area is limited.

When air or inert gas is used, leaks frequently are located by means of bubbles in a soap or detergent film on the outside of the vessel or by immersion of the pressurized vessel in a liquid to detect bubbles of escaping air or gas. This is known as the "bubble leak test."

Testing of vessels by immersion is limited to small vessels. Soap film testing is accomplished by pressurizing a vessel to some level above ambient and applying an aqueous soap (emulsified) solution to all main vessel seams and vessel wall penetrations. The solution is applied slowly and carefully to prevent formation of a lather in the area to be inspected. Soap in the form of a lather will screen very small leaks. The solution is maintained as a film over the area being inspected for a specified minimum time. Bubble growth indicates a leak.

In high pressure vessels such as heat exchangers, the time factor may be as long as 30 minutes. High pressure vessels may be pressurized as long as 4 hours before the soap solution is applied.

When gas is used as a test medium and the proper procedure is employed, it is possible to detect an extremely small leak. However, compressed gases are hazardous. They have the inherent disadvantage of an explosive-like effect in the event of catastrophic failure of a vessel. This test method, unless carefully set up and administered, is usually limited to vessels that cannot be tested by means of a hydrostatic head, because tank foundations or soil bearing, or both, are inadequate to support the water load. Gas pressure could also be used to test vessels that would be contaminated by water, or vessels that could have a leak too small to be detected by a liquid.

It is recommended that special precautions be taken in the selection of test equipment and in the observance of safe practices.

All testing should be done in accordance with a test procedure written specifically for the product to be tested. The procedure should include a diagram of all instrumentation, plumbing lines and connections, valves, pressure relief

valves or other safety devices, and pressure gages or other indicating equipment. The procedure should also include chronological step-by-step operations, holding times, observations, and readings required. Pressure indicators and relief devices shall have been tested and calibrated. Safety precautions include the following:

(1) If water is the test fluid, fluid and ambient temperatures must be above freezing to avoid frozen valves, gages, lines, etc.; antifreeze solutions are useful in cold temperatures.

(2) If a liquid is the test fluid, provide adequate drainage so that if vessel fails, flooding is avoided.

(3) If air or other gas is the test medium, provide an adequate personnel safety shield at a practical distance away from the pressure vessel to avoid possible injury if vessel fails. Instrumentation and pressure controls should be behind such shield. The shield should have a viewing port. Tank pressure gauges can be read through the port with binoculars or other suitable optical devices.

(4) Tests should be conducted in a test area away from other manufacturing facilities and personnel.

(5) If the metal temperature of carbon or ferritic alloy steel components to be proof tested is below +60° F (16° C), the metallurgical properties of the steel and especially the notch ductility values should be reviewed to prevent a catastrophic or brittle failure. (Cr-Mo pressure vessels that have been exposed to elevated temperature service may require special safety considerations to compensate for temper embrittlement.)

(6) Inspectors should never remain near a vessel to be proof tested during pressurization; this is especially important if the minimum tensile strength exceeds 70 000 psi (480 MPa) where delayed or underbead cracks can exist.

Leakage of gases can be determined, in some cases, by simple observation. The hissing noise of escaping gas, the wavering of a flame passed close to the surface, and a drop in the reading of a pressure gage over a short period of time are all evidence of the presence of leaks. Modern practice includes halide leak detection instrumentation (calibrated sniffers), which uses a tracer gas as an indicator. Tracer gas mixtures can

be as low as 1 percent for vessels in non-critical applications. Except when helium is being used, these tests are always conducted under conditions of a pressure differential.

The test procedure for this type of leak detection consists of introducing a tracer gas (usually mixed with air or some other carrier gas) into a vessel and increasing the pressure to a predetermined level. A sensing probe is then passed over the outside of the vessel to detect evidence of the tracer gas. Precaution must be taken that the surrounding air is relatively uncontaminated. Adequate ventilation will improve sensitivity; but drafts under the sensing probe will detract from it.

The helium mass spectrometer can be used for leak detection or for calibrating the size of a leak in a vessel. This test method may be employed for leak detection by either introducing a pressure or evacuating a vessel. Helium leak detection, which can detect the presence of one part of helium in 200,000 parts of air, is usually used when the maximum possible guarantee of tightness of a vessel is required.

The above outlines the most commonly used procedures that determine the presence of leaks; however, other procedures exist and may be more appropriate for certain applications. It is important to select a procedure that best evaluates the acceptability of the particular weldment under test for the particular service intended. For example, in ASTM Standard E432 (latest revision), "Selection of a Leak Testing Method," Fig. 1 shows various currently feasible leak test methods ranging from simple soap or detergent bubble films to sophisticated sonic, mass spectrometer, and halogen detectors; ASTM E425 covers "Standard Definitions of Terms Relating to Leak Testing"; there are other pertinent ASTM leak testing standards.

Pressure vessels must comply with ASME codes or other specifications in various applicable "Sections." Section V covers "Nondestructive Examination." Specification SE-432 therein is essentially identical to ASTM E432. Section V includes Article 10, "Leak Testing." API Standard 620, "Design and Construction of Large Welded Low-Pressure Storage Tanks," covers hydrostatic-pneumatic tests. API Standard 650, "Welded Steel Tanks for Oil Storage,"

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includes information on inspection, testing, and repairs. AWS-AWWA D5.2-73, Standard for Welded Steel Elevated Tanks, Standpipes, and Reservoirs for Water Storage, includes information on inspection and testing.

Contract specifications generally include specific requirements for testing, inspection, and

repair in accordance with applicable codes and specifications.

If repair welding is to be done after testing, reference is made to AWS A6.0, Safe Practices for Welding and Cutting Containers that have held Combustibles, to ensure that hazardous environments are not present.