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Determining Code Compliance and Pipe System Leak Testing

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(From a paper dated October 4, 2001 in response to leak test questions that were raised on a project)

In determining the leak test requirements for piping systems a governing Code needs to be determined. The reason being that leak test requirements vary from Code to Code. In a March 12, 2001 letter I wrote, "The difference, and distinction, as to which Code should apply to a particular project lies with the definition and scope of the project itself. If, with respect to a particular project, the design includes only the installation of a refrigeration system, B31.5 would apply. If a project's scope of work consists of an office, laboratory, research facility, or any combination thereof, B31.9 and possibly B31.5 would apply. A laboratory or research facility might also require fluid services beyond the range limits of B31.9. In that case, B31.3 would be adopted for those services only.

"In the case of a process manufacturing facility, B31.3 would be the governing Code. Since B31.3 covers all piping, B31.5 or B31.9 would not be included, not even necessarily with associated lab, office and research facilities. The only time B31.5 or B31.9 would become governing Codes, in association with a manufacturing facility, is if a refrigeration unit, or an office, lab and/or research facility were under a separate design/construct contract from the process manufacturing facility. Or they were a substantial part of the overall project.

"As an example, project XYZ consists of a process manufacturing facility, office and lab facilities. If the utility service piping for the office and lab facilities is a small percentage of the overall project, and/or the design and construction contracts for those facilities are a part of the overall process manufacturing facility, all piping, with Code exclusions, would be governed by B31.3.

"If, however, the office and lab facilities were a substantial part of the overall project it may be more beneficial to determine battery limits for those facilities and designate anything inside those battery limits as B31.9. In such a case, separate Pipe Schedules would have to be issued for those portions of the project designated as being governed by B31.9.

"For Pipe Schedules that could be issued for both the B31.3 portion of a project as well as the B31.9 portion of a project a suffix, along with an edited statement within the Pipe Schedule, would have to be added to the Pipe Specification number. As an example, FA123 used for the B31.3 portion of a project could be edited and identified as FA123.1.1 for the B31.9 portion of the project.

Once the governing Code is established for a piping system it will be necessary, except for refrigerant piping under ASME B31.5, to determine the design conditions for each service. For refrigerant piping under ASME B31.5 leak test pressures are predetermined based on the type of refrigerant used. However, for fluid services, other than B31.3 Category D, under ASME B31.3 and B31.9 the leak test pressures will be determined based on deign pressure and temperature of the fluid.

Determining the design conditions (pressure/temperature) of an operating system is also required in determining the material of construction (MOC) and pressure rating classification for a piping system. ASME B31.3 states, under Section 301.2 - Design Pressure, in Para. 301.2.1: *(a) The design pressure of each component in a piping system shall be not less than the pressure at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service except for allowable variations as described in para. 302.2.4 (later); (b) The most severe condition is that which results in the greatest required component thickness and the highest component rating; (c) When more than one set of pressure-temperature conditions exist for a piping system, the conditions governing the rating of components conforming to listed standards may differ from the conditions governing the rating of components designed in accordance with para. 304.*

As a general rule the design pressure is equal to the maximum anticipated operating pressure, plus 10% or 30 psi, whichever is greater. The design temperature, for operating temperatures between 32°F and 750°F,

shall be equal to the maximum anticipated operating temperature, plus 25°F rounded off to the next higher 5°.

The Codes that you will normally be working with are ASME B31.1, B31.3 and B31.9. And while B31.9 is basically derived from B31.3 the only leak test they agree on, somewhat, is the hydrotest requirement. Following are key points, relative to leak testing, taken from the three primary piping Codes:

B31.1:

137.4 Hydrostatic Testing

137.4.5 Required Hydrostatic Test Pressure. The hydrostatic test pressure at any point in the piping system shall not be less than 1.5 times the design pressure, but shall not exceed the maximum allowable test pressure of any non-isolated components, such as vessels, pumps, or valves, nor shall it exceed the limits imposed by para. 102.3.3(B). The pressure shall be continuously maintained for a minimum time as may be necessary to conduct the examination for leakage. Examinations for leakage shall be made of all joints and connections. The piping system, exclusive of possible localized instances at pump or valve packing, shall show no visual evidence of weeping or leaking.

137.5 Pneumatic Testing

1375.4 Preliminary Test. A preliminary pneumatic test not to exceed 25 psig may be applied, prior to other methods of leak testing, as a means of locating major leaks. If used, the preliminary pneumatic test shall be performed in accordance with the requirements of paras. 137.5.2 and 137.5.3.

137.5.5 Required Pneumatic Test Pressure. The pneumatic test pressure shall be not less than 1.2 nor more than 1.5 times the design pressure of the piping system. The test pressure shall not exceed the maximum allowable test pressure of any non-isolated components, such as vessels, pumps, or valves, in the system. The pressure in the system shall gradually be increased to not more than one-half of the test pressure, after which the pressure shall be increased in steps of approximately one-tenth of the test pressure until the required test pressure has been reached. The pressure shall be continuously maintained for a minimum time of 10 minutes. It shall then be reduced to the lesser of design pressure or 100 psig and held for such time as may be necessary to conduct the examination for leakage. Examination for leakage detected by soap bubble or equivalent method shall be made of all joints and connections. The piping system, exclusive of possible localized instances at pump or valve packing, shall show no visual evidence of weeping or leaking.

B31.3:

345.4 Hydrostatic Leak Test

345.4.2 Test Pressure. Except as provided in para. 345.4.3 the hydrostatic test pressure at any point in a metallic piping system shall be as follows:

(a) not less than 1 ½ times the design pressure;

(b) for design temperature above the test temperature, the minimum test pressure shall be calculated by Eq. (24), except that the value of S_T/S shall not exceed 6.5:

$$P_T = \frac{1.5PS_T}{S}$$

where

P_T = minimum test gage pressure

P = internal design gage pressure
S_T = stress value at test temperature
S = stress value at design temperature

(c) if the test pressure as defined above would produce a stress in excess of the yield strength at test temperature, the test pressure may be reduced to the maximum pressure that will not exceed the yield strength at test temperature.

345.4.3 Hydrostatic Test of Piping With Vessels as a System

(a) Where the test pressure of piping attached to a vessel is the same as or less than the test pressure for the vessel, the piping may be tested with the vessel at the piping test pressure.

(b) Where the test pressure of the piping exceeds the vessel test pressure, and it is not considered practicable to isolate the piping from the vessel, the piping and the vessel may be tested together at the vessel test pressure, provided the owner approves and the vessel test pressure is not less than 77% of the piping test pressure calculated in accordance with para. 345.4.2(b).

345.5 Pneumatic Leak Test

345.5.2 Pressure Relief Device. A pressure relief device shall be provided, having a set pressure not higher than the test pressure plus the lesser of 50 psi or 10% of the test pressure.
345.5.4 Test Pressure. The test pressure shall be 110% of design pressure.
345.5.5 Procedure. The pressure shall be gradually increased until a gage pressure which is one-half the test pressure or 25 psi is attained, at which time a preliminary check shall be made, including examination of joints in accordance with para. 341.4.1(a). Thereafter, the pressure shall be gradually increased in steps until the test pressure is reached, holding the pressure at each step long enough to equalize piping strains. The pressure shall then be reduced to the design pressure before examining for leakage in accordance with para. 345.2.2(a).

345.7 Initial Service Leak Test. This test is only applicable to piping in Category D fluid service, at the owner's option.

345.7.1 Test Fluid. The test fluid is the service fluid.
345.7.2 Procedure. During or prior to initial operation, the pressure shall be gradually in steps until the operating pressure is reached, holding the pressure at each step long enough to equalize piping strains. A preliminary check shall be made as described in para. 345.5.5 if the fluid is a gas or vapor.

There is also a Sensitive Leak Test, which I won't go into here. I have called for this test in earlier letters and in the new Section 15114 – Cleaning and Testing of Pipe, for hydrogen service. Additionally there is a Hydrostatic-Pneumatic Leak Test and an Alternative Leak Test, which I won't go into. In trying to focus on the basic testing procedures I didn't want to try and cover too much. If information on the other tests is needed I can follow up.

B31.9

937.3 Hydrostatic Testing

937.3.4 Hydrostatic Test Pressure.

(a) Minimum Pressure. Except as limited in (b) below, a piping system shall be subjected to a hydrostatic test pressure which at every point in the system is not less than 1.5 times the design pressure.

(b) Maximum Pressure. The test pressure shall not exceed the maximum test pressure for any vessel, pump, valve, or other component in the system under test. A check shall be made to verify that the stress due to pressure at the bottom of vertical runs does not exceed either of the following:

(1) 90% of specified minimum yield strength;
(2) 1.7 times the *SE* value in Appendix A (for brittle materials)

937.3.5 Examination for Leakage. Following the application of hydrostatic test pressure for at least 10 minutes examination shall be made for leakage of the piping, and at all joints and connections. If leaks are found, they shall be eliminated by tightening, repair, or replacement as appropriate, and the hydrostatic test repeated until no leaks are found.

937.4 Pneumatic Testing

937.4.1 General. Compressed gas poses the risk of sudden release of stored energy. For that reason, pneumatic testing shall be used only within the following limitations:

(a) The piping system does not contain cast iron pipe or plastic pipe subject to brittle failure;
(b) The system does not contain soldered or solvent cement joints over NPS 2;
(c) The test pressure does not exceed 150 psig;
(d) The system will be used in gas service, or for other reasons cannot be filled with water;
(e) Traces of test liquid would be detrimental to the intended use of the piping.

937.4.4 Preliminary Test. Prior to application of full pneumatic test pressure, a preliminary test of not more than 10 psig shall be applied to reveal possible major leaks. (This preliminary test is not subject to the limitations in para. 937.4.1, and may be used in conjunction with hydrostatic testing or initial service testing.)

937.4.5 Pneumatic Test Pressure.

(a) Except as limited in (b) below, the test pressure shall not exceed 1.25 times the design pressure. Pressure shall be applied in several stages, allowing time for the system to reach equilibrium at each stage.
(b) The test pressure shall not exceed the maximum allowable pneumatic test pressure for any vessel, pump, valve, or other component in the system under test.

937.4.8 Examination for Leakage. After the preliminary test, pressure shall be raised in stages of not more than 25% up to full pneumatic test pressure., allowing time for equalization of strains and detection of major leaks at each stage. Following the application of test pressure for at least 10 minutes the pressure may be reduced to design pressure and examination be made for leakage of the piping. Leaks may be detect by soap bubble, halogen gas, scented gas, test gage monitoring, ultrasonic, or other suitable means. If leaks are found, pressure shall be vented, appropriate repair or replacement shall be made, and the pneumatic test repeated until no leakage is found.

937.5 Initial Service Leak Test

937.5.1 General. For gases and steam and condensate service not over 15 psig, and for nontoxic, noncombustible, nonflammable liquids at pressures not over 100 psig and temperatures not over 200°F, it is permissible to conduct the system testing with the service fluid as outlined in para. 937.5.2.

937.5.2 Service Testing. A preliminary test with air at low pressure (937.4.4) may be used. In any event, the piping system shall be brought up to operating pressure gradually with visual examination at a pressure between one-half and two-thirds of design pressure. A final examination shall be made at operating pressure. If the piping system is free of leaks, it will have met the requirements of para. 937.1.

As you can see there are distinct differences between the B31.3 and B31.9 with respect to leak testing. However, there are two paragraphs, one in B31.3 and the other in B31.9, I do wish to point out. Both paragraphs provide for a little wiggle room.

The first is B31.3, para. 345.4.3 Hydrostatic Test of Piping With Vessels as a System. In (b) of that paragraph it states, "*Where the test pressure of the piping exceeds the vessel test pressure, and it is not considered practicable to isolate the piping from the vessel, the piping and the vessel may be tested together at the vessel test pressure, provided the owner approves and the vessel test pressure is not less than 77% of the piping test pressure calculated in accordance with para. 345.4.2(b)".*

If confronted with a situation in which the leak test has to include a vessel you may be able to reduce the test pressure of the piping system to coincide with the piece of equipment in the system that has a lower test pressure. Doing so would require a thorough review of the systems design requirements.

The other point is in B31.9 para. 937.4.5 Pneumatic Test Pressure. In (a) of that paragraph it states, *Except as limited in (b) below, the test pressure shall not exceed 1.25 times the design pressure.* The key point here is that the test pressure shall not exceed 1.25, which allows for a lower test pressure, such as the 110% of design used in B31.3.

To simplify the selection process I have created a quick reference chart on the following page that will more readily provide key information for leak testing based on Code and type of test required.

GENERAL PROCEDURES FOR PIPING SYSTEM LEAK TESTING

Code	Leak Test	Test Procedure	
B31.1	Hydrostatic Test	Test procedure	1. Calculate test pressure at 1.5 x design pressure. 2. Fill system with test liquid gradually, allowing piping strains to equalize and high points to be vented. 3. Once the system has been filled and vented, increase pressure gradually allowing piping strains to equalize. 4. After reaching the test pressure hold for 10 minutes or for a period of time required to examine all joints and seals for leaks. 5. If leaks are found, release pressure, drain system, repair leaks and start again. If not, the system is either ready for service or *pre-service preparation.
	Pneumatic Test	Test procedure	1. Calculate test pressure at a pressure not below 1.2 nor in excess of 1.5 x design pressure. 2. Gradually pressurize test circuit with a non-flammable and non-toxic gas to a gage pressure not to exceed one-half the test pressure. 3. After reaching one-half the test pressure, gradually increase pressure in steps of one-tenth the test pressure until the test pressure is reached. 4. Hold test pressure for 10 minutes then reduce to the lesser of the design pressure or 100 psig.. 6. Hold that pressure for a period of time required to examine all joints and seals for leaks. 7. If leaks are found, release pressure, repair leaks and start again. If not, the system is ready for service.
	Initial Service Test	Test procedure	1. This test applies only when specified by the Owner when other types of test are not practicle. 2. The test fluid is the service fluid. 3. With the system connected to its permanent supply gradually fill the system with service fluid. If it is liquid, vent the system as it fills. 4. Once the system is filled and vented (if required), continue to pressurize in stages, allowing piping strains to equalize, until the operating pressure is reached. 5. During fill and pressurization, continually walk system down checking for leaks. 6. Once filled and brought to operating pressure hold for a minimum of 10 minutes or until all joints are examined.
B31.3	Hydrostatic Test	Fluid design temperature up to 200°F.	8. Calculate test pressure at 1.5 x design pressure. 9. Fill system with test liquid gradually, allowing piping strains to equalize and high points to be vented. 10. Once the system has been filled and vented, increase pressure gradually allowing piping strains to equalize. 11. After reaching the test pressure hold for 10 minutes or for a period of time required to examine all joints and seals for leaks. 12. If leaks are found, release pressure, drain system, repair leaks and start again. If not, the system is either ready for service or *pre-service preparation.
		Fluid design temperature 201°F and above.	1. The procedure is the same as above except that the test pressure shall be calculated in the following manner: $P_T = \frac{1.5PS_T}{S}$ where P_T = minimum test gage pressure P = internal design gage pressure S_T = stress value at test temperature S = stress value at design temperature
	Pneumatic Test	PSV as part of temporary test manifold.	1. Install a temporary pressure relief valve in the test circuit with a set pressure not to exceed the test pressure plus the lesser of 50 psi or 10% of the test pressure.
		Test procedure	5. Calculate test pressure at 1.1 x design pressure. 6. Pressurize test circuit with air or nitrogen to a gage pressure, which is the lesser of one-half the test pressure or 25 psig. 7. Perform a preliminary check of all joints. 8. If no leaks are found, or all leaks are repaired, continue to increase pressure in stages, allowing piping strains to equalize until the test pressure is reached. 9. Hold test pressure for 10 minutes then reduce to the design pressure. 13. Hold design pressure for 10 minutes or for a period of time required to examine all joints and seals for leaks. 14. If leaks are found, release pressure, repair leaks and start again. If not, the system is either ready for service or *pre-service preparation.

	Initial Service Test	Test procedure	7. This test applies only to Category D fluid services. 8. The test fluid is the service fluid. 9. If this is a liquid system and is not being tested immediately after cleaning it may require a preliminary pneumatic test at 10 psig to ensure that none of the components have been tampered with or removed. 10. With the system connected to its permanent supply fill the system with service fluid. If it is liquid, vent the system as it fills. 11. Once the system is filled and vented (if required), continue to pressurize in stages, allowing piping strains to equalize, until the operating pressure is reached. 12. During fill and pressurization, continually walk system down checking for leaks.
B31.9	Hydrostatic Test	Test Procedure	1. Calculate test pressure at 1.5 x design pressure. 2. Fill system with test liquid gradually, allowing piping strains to equalize and high points to be vented. 3. Once the system has been filled and vented, increase pressure gradually allowing piping strains to equalize. 4. After reaching the test pressure hold for 10 minutes or for a period of time required to examine all joints and seals for leaks. 5. If leaks are found, release pressure, drain system, repair leaks and start again. If not, the system is either ready for service or *pre-service preparation.
	Pneumatic Test	Test Procedure	1. Calculate test pressure at no greater than 1.25 x design pressure. 2. Pressurize test circuit with air or nitrogen to a gage pressure, which is the lesser of one-half the test pressure or 25 psig. 3. Perform a preliminary check of all joints. 4. If no leaks are found, or all leaks are repaired, continue to increase pressure in stages, allowing piping strains to equalize until the test pressure is reached. 5. Hold test pressure for 10 minutes then reduce to the design pressure. 6. After 10 minutes the pressure may be reduced to the design pressure. The examination can be done at test pressure or at design pressure. 7. If leaks are found, release pressure, repair leaks and start again. If not, the system is either ready for service or *pre-service preparation.
	Initial Service Test	Test Procedure	1. This test is for gases, steam and condensate not over 15 psig, and for nontoxic, noncombustible liquids at pressures not over 100 psig and temperatures not over 200°F. 2. Perform a preliminary pneumatic check at 10 psig to ensure that there are no major leaks. 3. After the preliminary check, and with the system connected to its permanent supply fill the system with service fluid gradually. If liquid, vent system as it fills. 4. With system filled and vented, pressurize to between one-half and two-thirds the (operating) pressure. Perform visual examinations during the entire process. 5. Continue to pressurize system until it reaches operating pressure then perform final visual examination.

Notes: *Pre-service preparations include, among other possibilities, passivation for hygienic services and evacuation procedures for hydrogen.

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