Inspectioneering Journal

ASSET INTEGRITY INTELLIGENCE

FEATURED ARTICLE

TO TEST OR NOT TO TEST: A COMPARISON OF THE PRESSURE TESTING REQUIREMENTS BETWEEN ASME B31.3 AND ASME SECTION VIII, DIVISION 1

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VOLUME 21, ISSUE 1

JANUARY | FEBRUARY 2015

TO TEST OR NOT TO TEST: A COMPARISON OF THE PRESSURE TESTING REQUIREMENTS BETWEEN ASME B31.3 AND ASME SECTION VIII, DIVISION 1

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Are you still hitting the welded joints of pressure vessels with a hammer during hydrostatic testing? If yes, then you're due for a refresher on the pressure testing requirements of ASME Section VIII Division 1 since this requirement was for pressure vessels back in the mid 1940's[1]. This article will help you by highlighting the main requirements of, and differences between, the hydrostatic test for new pressure vessels fabricated according to ASME Section VIII, Division 1 and the hydrostatic leak test for new piping systems made under ASME B31.3. Since it is the most popular way to test a pressure vessel or piping system, the focus of this article will be on the hydrostatic test, article UG-99 of Section VIII Division 1 (2013 Edition), and the hydrostatic leak test, paragraphs 345 & 345.4 of B31.3 (2012 Edition). Please refer to these Codes and their interpretations for the complete requirements. Moreover, verification with the local jurisdiction is essential to ensure that their requirements are not stricter than those of the Codes.

PRESSURE TESTING DURING THE FABRICATION PROCESS

In Section VIII Division 1, the hydrostatic test is considered the final step in the fabrication of a pressure vessel before the application of the U-code symbol stamp. The test has to be done after completion of the vessel, after all pre-test examinations have been performed and, when required, after post-weld heat treatment (PWHT). Note that a preliminary hydrostatic test prior to the PWHT is allowed to prevent an additional PWHT cycle when repairs are required following an unsuccessful hydrostatic test[2]. For pressure vessels that cannot be safely filled with liquid or adequately dried when used in a service that cannot tolerate the test liquid, the alternative to a hydrostatic test is a pneumatic test as described in UG-100. The code requires special care for this type of test considering the amount of energy stored in compressed gas. The other alternative for vessels or vessel parts that cannot be accurately calculated is a proof test that follows UG-101.

Vessels can be tested either in the vertical or horizontal position, independent of the in-service position[3]. When vessels are made of multiple parts, welded or bolted, the parts can be hydrostatically tested independently and U-Part stamped, but they must be tested assembled before the application of the U-Code symbol stamp for the whole unit[4].

As in Section VIII Div. 1, ASME B31.3 requires that all new piping systems, defined by the code as "interconnected piping subject to the same set or sets of design conditions," be subject to a hydrostatic leak test before initial operation. This has to be done after any heat treatment and code required examinations, excluding owner-specified examination[5]. Before the hydrostatic leak test, a preliminary pneumatic test at 25psig[6] can be performed in order to reveal major leaks. During the leak test, a pump can be used to maintain the test pressure[7].

The hydrostatic leak test, as required by paragraph 345.4, is not required in the following cases:

1. For category "D" fluid (non-flammable, non-toxic, not damaging to human tissues, design pressure lower than 150 psig and temperature lower than 366 °F but higher than -20 °F, unless caused by atmospheric conditions), the owner can choose to subject the piping system to an initial service leak test done according to paragraph 345.7.
2. When the owner considers a hydrostatic leak test impracticable, a pneumatic test or a combined hydrostatic-pneumatic test can be done. In such cases, the owner must consider the danger associated with compressed gas.
3. Under special circumstances when hydrostatic and pneumatic tests are deemed impracticable[8], such as when the hydrostatic test would damage the lining or internal insulation, when the test can contaminate the process, when the test would require major support modifications, or when there is a risk for brittle fracture. Under one of these considerations, the hydrostatic or pneumatic test can be replaced by additional welds examination, piping flexibility analysis and leak test.
4. When the lines are open to atmosphere[9].

Unlike Section VIII Div. 1, ASME B31.3 allows the assembly of certain types of joints between piping components and

1 API-ASME, UNFIRED PRESSURE VESSELS for PETROLEUM LIQUIDS AND GASES, Fourth Edition, 1943, paragraph W-525(e)
2 Section VIII, Division 1, interpretation VIII-1-81-37
3 Section VIII, Division 1, interpretation VIII-1-95-27
4 Section VIII, Division 1, interpretation VIII-1-89-281
5 B31.3, interpretation 12-03
6 B31.3, paragraph 345.2.1(c)
7 B31.3, interpretation 22-14
8 B31.3, paragraph 345.1(c)
9 B31.3, paragraph 345.1(d)

sub-assemblies that have been tested separately without the need for a hydrostatic test afterward[10]. The first type is flanged joints that have been previously tested, or flanged joints where a blank or a blind flange was used to isolate the equipment or the piping system. Flanges that have been hydrostatically tested can be disassembled and reassembled after the test or, if the flanges have been tested separately, they can be joined together without the need to leak test that joint[11].

The other type of joint that does not required a leak test is the closure weld[12]. The closure weld must be done between piping systems or components that have been successfully tested. The weld must be examined in-process and pass 100% radiographic or 100% ultrasonic examinations. In-process examinations, to be performed by personnel other than those performing the production work[13], include joint preparation and cleanliness, preheating, fit-up of the joint, welding procedure variables, root pass condition, slag removal, weld conditions between passes, and the appearance of the finished joint. The examination has to be done visually in accordance with BPV code, Section V, Article 9.

The closure weld can be advantageous for large diameter piping systems where the supports are not designed for lines full of liquid or when a new section of piping is connected by weld to an old piping system for which a hydrostatic leak test would prove impracticable. In these cases, the subassemblies are tested at the fabrication shop. Having more than one closure weld on a piping system is permitted[14].

The decision to use closure welds must be made knowing that this type of weld will not benefit from the high stresses generated during the hydrostatic test. These high stresses result in increased hardness (strain hardening) and compressive localized residual stress which increases brittle fractures[15].

VISUAL INSPECTION AFTER TESTING

After a pressure vessel has been subjected to a hydrostatic test pressure, all joints and connections must be inspected. No time limit for this test is specified in Section VIII Div. 1. With the exception of leaks at temporary welds of temporary test closures on openings intended for welded connections[16], leakage is not allowed during the visual inspection. Most of the time, this visual inspection will be done at hydrostatic test pressure; but the code allows reducing the pressure by a factor of 1.3 for the inspection[17, 18]. So, if a leak is observed at test pressure and it stops when lowering the pressure to hydrostatic test pressure divided by 1.3, the test is considered acceptable according to the Code. The purpose of the 30% increased stress caused by the hydrostatic test is to measure the integrity of the pressure boundaries and not leak tightness.

The visual inspection can be waived when all three of the following conditions are met:

1. An appropriate gas leak test is done and agreed upon by the manufacturer and the inspector.
2. For welded seams that will be hidden during assembly, a visual inspection for workmanship is done before assembling.
3. The substance contained in the vessel will not be lethal.

The inspector is not required to check the quality of the gasket of bolted connections prior to the hydrostatic test[19]. However, it is good engineering practice to verify that the gaskets used for the hydrostatic test have the same characteristics as the gaskets that will be used in service[20]. If different gaskets are used for the test, they might prevent leaks that could be revealed in service when the required operating gaskets are installed.

In ASME B31.3, the leak test pressure must be maintained for at least 10 minutes while all joints, connections, and structural attachment welds[21] are visually examined. It is recommended that the leak examination be conducted by personnel qualified for visual examination[22]. If no leaks are observed, the piping system is considered acceptable[23].

When a welded pipe is made in accordance with a document listed in Table 326.1 (which includes ASME B36.10M and B36.19M), the longitudinal weld joint does not have to be exposed during the leak test. Those welded pipe sections have already been subjected to a hydrostatic test and/or NDE examination at the end of their manufacturing process according to the ASTM recognized standards (ex. A53, A106, etc.). This exemption does not apply to pipe made of rolled plates.

REPAIRS AND ALTERATIONS FOLLOWING TESTING

For pressure vessels made according to Section VIII, Division 1, the Code is adamant that no welding can be made on the pressure boundary following the hydrostatic test. Many interpretations have been made on this:

- VIII-1-89-51: cannot repair minor defect with weld build-up after hydrostatic test
- VIII-1-89-310: cannot perform tube-to-tubesheet welds after the hydrostatic test
- VIII-1-92-65: cannot install stiffening rings after the hydrostatic test
- VIII-1-92-84: cannot install vacuum stiffening rings after official hydrostatic test even if a pneumatic test at 1.1 times MAWP is done after welding

The code prevents welding on the pressure boundary of the vessel

[10] B31.3, interpretation 20-24

[11] B31.3, interpretation 22-18

[12] B31.3, paragraph 345.2.3(c)

[13] B31.3, paragraph 342.2

[14] B31.3, interpretation 20-07 and 22-16

[15] Fitness-for-Service Evaluations for Piping and Pressure Vessels: The ASME Code Simplified, by George Antaki, paragraph 4.20

[16] Section VIII, Division 1, UG-99(g)

[16] Section VIII, Division 1, UG-99(g)

[17] Section VIII, Division 1, UG-99(g)

[18] Section VIII, Division 1, interpretation VIII-1-01-02

[19] Section VIII, Division 1, interpretation VIII-1-86-189

[20] Section VIII, Division 1, interpretation VIII-1-86-189

[21] B31.3, interpretation 19-23

after the hydrostatic test, but it does not prevent welding on the vessel's non-pressure parts. Welding after the test can be made possible by welding pads onto the vessel walls prior to the test and performing post-test welding on these pads. Since these pads are non-pressure parts, welding on them does not require a hydrostatic test. However, the welded pads need to be thick enough to avoid any heat-affected zone on the pressure boundaries after welding on it. The only post-hydrotesting modifications allowed by Section VIII Div. 1 on pressure parts are weld end preparation on the first circumferential joint of nozzles intended for welded connections, and cosmetic grinding that does not affect the required thickness of base metal[24] and welded joints[25]. However, those modifications must be done before signing the Manufacturer's Data Report[26]. If repairs are required due to a leak during the hydrostatic test, the test must be done again for the entire vessel and not only on the repaired part[27].

Since the final step in the fabrication process of a pressure vessel is the installation of the nameplate (or stamping) and the Manufacturer's Data Report signature with the Authorized Inspector (AI), modifications or repairs done afterward are not required to follow the rules of Section VIII Division 1. If authorized by the local jurisdiction and accepted by the owner, these can be done according to the National Board Inspection Code NBIC NB-23, part 3, and be exempt from being hydrostatically tested. The same applies for repair of old pressure vessels.

For ASME B31.3 piping systems, the Code does not allow modifications after the leak test. However, the Code permits the owner to waive a retest for minor repairs or alterations providing precautionary measures are taken regarding welding, examination, and other aspects that would ensure an adequate construction[28]. ASME B31.3's interpretation 1-2 defines minor repairs or additions as "those which would not affect the load carrying ability or leak tightness when precautionary measures are taken to assure sound construction". As with pressure vessels, repairs on an old piping system done according to NBIC NB-23, part 3, can be exempt from being hydrostatically tested.

TYPE OF LIQUID

Any nonhazardous liquid at temperatures below its boiling point can be used for the hydrostatic test of a Section VIII Div. 1 pressure vessel. The Code recommends that the temperature of the liquid used be at least 30°F above the vessel MDMT to lower the risk of brittle fracture. This temperature does not need to be higher than 120°F. The hydrostatic testing pressure should be applied when the vessel and the test liquid are at about the same temperature.

For B31.3, the testing liquid is water unless the risk of freezing or the water itself can cause damage, or the water can affect the process. In these cases, a non-toxic liquid may be used. B31.3 allows the use of flammable liquid with a flash point below 120°F. The Code does not give direct recommendations on the temperature, but it warns that brittle fracture should be considered when the test is done at low temperatures.

WELD SURFACE FINISH DURING THE TEST

Unless authorized by the user or jurisdiction, welds on the pressure boundary of a Section VIII Div. 1 pressure vessel cannot be painted or coated either internally or externally before the pressure test. When it is permitted[29] or when an internal lining is applied, such welds must first be subjected to a leak test per Section V Article 10 before the coating is applied[30]. This leak test can also be waived with user approval. Vessels in lethal service cannot be painted, coated, or lined, internally or externally, before the hydrostatic pressure test[31]. This requirement is applicable for the whole vessel and not only pressure retaining welds.

Prior to the hydrostatic leak test, B31.3 allows all joints to be primed and painted[32] unless a sensitive leak test (bubble test or other sensitive method) is required, such as for piping systems in lethal service. However, all joints, pressure retaining welds, welds between pressure retaining components and structural attachments, and bonds must be exposed for examination during the leak test with the exception of joints that have already been tested[33].

For Canadian installations, paragraph 8.3 of CSA B51, 2014 Edition says that no type of coating can be applied on any pressure piping system before the hydrostatic test.

BASIS FOR MINIMUM TEST PRESSURE

In Section VIII Div. 1, UG-99(b) requires the minimum test pressure of pressure vessels to be 1.3 times the maximum allowable working pressure (MAWP) multiplied by the lowest stress ratio (LSR) of the materials from which the pressure vessel is fabricated. The design pressure can be used instead of the MAWP when the MAWP has not been calculated. The LSR is the allowable stress at test temperature divided by the allowable stress at design temperature. Having different materials on a pressure vessel could result in a situation where a component having a low LSR will prevent other components with higher LSRs to be tested to their full extent. If the components with higher LSRs are major parts of the pressure vessel, consideration should be given to the material selection. UG-99(b) gives no consideration to the static head pressure of the vessel in the installed position. The static head pressure must be removed from the hydrostatic test pressure reading. Section VIII Div. 1 also states that all loading that may exist during the hydrostatic test must be considered.

Bolts are included in the LSR calculation only when 1.3 times the LSR multiplied by the bolt allowable stress is larger than 90% of

[22] B31.3, interpretation 8-31

[23] B31.3, interpretation 1-2

[24] Section VIII, Division 1, UG-99(a)(1)

[25] Section VIII, Division 1, interpretation VIII-1-10-09

[26] Section VIII, Division 1, interpretation VIII-1-89-27R

[27] Section VIII, Division 1, interpretation VIII-1-01-139

[28] B31.3, paragraph 345.2.6

[29] Section VIII, Division 1, interpretation VIII-1-86-66

[30] Section VIII, Division 1, UG-99(k)

[31] Section VIII, Division 1, UG-99(k)(3)

[32] B31.3, interpretation 2-6

[33] B31.3, interpretation 22-09

the bolt material specified minimum yield strength at test temperature. In this case, bolts could limit the hydrostatic test pressure and also prevent the other components from being tested adequately. Only bolts from Section VIII Div. 1, Appendix 2 flanges need to be considered[34]. Bolts for flanges designed to other ASME standards, such as B16.5, are excluded since the limiting test pressures of these components are established in the applicable code.

When agreed by the user and manufacturer, UG-99(c) offers the possibility of using what the Code calls a calculated hydrostatic test pressure. This test pressure is based on the cold and uncorroded maximum allowable pressure (MAP). For each component, a test pressure is obtained by subtracting the hydrostatic head pressure on that component from 1.3 times the MAP. The hydrostatic test pressure at the top then becomes the lowest test pressure of all pressure components. Since the calculated hydrostatic test pressure is independent of design temperature and corrosion allowance, these values can be lowered for an in-service pressure vessel to allow for a rerate to a higher pressure without requiring a hydrostatic test. This can be useful since a hydrostatic test on an erected pressure vessel can bring many complications.

The test pressure of a B31.3 piping system cannot be less than 1.5 times the design pressure multiplied by the highest value of Rr. Rr is the equivalent of LSR in Section VIII Div. 1, which is the ratio of allowable stress at test temperature to allowable stress at design temperature. The Rr ratio must be calculated for each component that has a different material or design temperature within the piping system, with the exception of bolting and pipe supports. For components with pressure ratings, such as flanges, Rr is the ratio of pressure rating at test temperature to pressure rating at design temperature. Unlike Section VIII Div. 1, which puts no limit on LSR, B31.3 limits the value of Rr to 6.5 which will lower the test pressure for high temperature systems. When the piping system is made of carbon steel with specified minimum yield strength not greater than 42 ksi, such as A106 Gr.B, the code allows the test pressure to be based on any value of Rr in the piping system. Excessive pressure caused by fluid expansion due to the duration of the test has to be considered, as when exposed to solar radiation.

It is a common practice in the industry to test a piping system at the maximum capacity of the weakest element, such as flanges. This should allow a piping system to be rerated in the future without requiring a leak test since the system has already been tested to the maximum capacity of the weakest element.

When a pressure vessel is included in the piping system and it is impracticable to isolate it from the piping, the vessel can be tested with the piping at the piping test pressure if its hydrostatic test pressure is greater than the piping test pressure. When the hydrostatic test pressure of the vessel is less than the piping calculated minimum test pressure, ASME B31.3 allows the piping test pressure to be lowered to the vessel hydrostatic test pressure, under the owner's and jurisdiction approval, but not less than 77% of the calculated piping test pressure. This results in multiplying the design pressure of the piping system by a factor of 1.155 instead of 1.5. The factor of 1.155 is still larger than the factor of 1.1 required for a pneumatic leak test, but a pneumatic leak test is a lot more sensitive to leaks than a hydrostatic leak test.

BASIS FOR THE TEST PRESSURE LIMIT

No upper limit on the hydrostatic test pressure is set for a Section VIII Div. 1 pressure vessel[35]. However, if the hydrostatic test pressure intentionally or accidentally exceeds the value calculated based on the MAP to a degree where there is visible permanent deformation, the authorized inspector has the right to reject the vessel. A strain gauge is not required to determine if there is permanent deformation[36].

As in Section VIII, Div. 1, no upper limit is set on the test pressure by the B31.3 code, but if the test pressure produces stresses higher than the yield strength or a pressure more than 1.5 times the component rating, the pressure can be reduced to the maximum pressure that will not exceed those limits. The static head pressure must be included when determining the maximum test pressure that will not exceed the yield strength[37].

EXTERNAL PRESSURE

For pressure vessels designed for vacuum only, MAWP less than or equal to zero, the Code offers two different ways of performing the hydrostatic test. Either an internal hydrostatic test where the test pressure is no less than 1.3 times the external design pressure or a vacuum test at the designed vacuum pressure combined with a leak test can be done. If the second method is chosen, the leak test has to follow the requirements of ASME Section V, Article 10 "Leak Testing," Article 1 "General Requirements," and the user's specification.

For B31.3 piping subjected to external pressure, it has to be tested internally at 1.5 times the designed external differential pressure, but not less than 15 psi. The external differential pressure is the same as for Section VIII Div. 1, i.e., the maximum differential pressure between any coincident internal and external pressure. Unlike Section VIII Div. 1, ASME B31.3 does not allow a piping system pressurized externally to be tested using an internal vacuum[38]. For external pressure, the ratio S_T/S does not need to be considered[39] because the allowable stress at design temperature is not from Table A-1, which is for tensile stresses. For the allowable stress for external pressure, which is based on temperature, diameter, thickness, and distance between stiffening rings, B31.3 refers to Section VIII Div. 1. It also refers to Section VIII Div. 1 for the calculation procedure for external pressure.

MULTI-CHAMBER VESSELS AND JACKETED PIPING

For vessels with multiple chambers or combination units, such as heat exchangers, Section VIII Div. 1 allows two different methods for testing depending on the design of the common elements between chambers. The first method is when the common

[34] Section VIII, Division 1, interpretation VIII-1-89-287

[35] Section VIII, Division 1, interpretation VIII-1-01-77

[36] Section VIII, Division 1, interpretation VIII-1-01-88

[37] B31.3, interpretation 4-04

[38] B31.3, interpretation 22-11

[39] B31.3, interpretation 19-30

components have been designed to the larger MAWP of their adjacent chambers or higher if one chamber is designed for full or partial vacuum. In this case, each chamber must be hydrostatically tested without pressure in the adjacent chamber. For the common elements, the hydrostatic test pressure has to be greater than the differential pressure between the adjacent chambers multiplied by the LSR.

The second method in Section VIII Div. 1 is used when the common components are designed for a differential pressure between the adjacent chambers less than the MAWP of these chambers. In this case, the common components must be subjected to a hydrostatic test pressure of at least the differential pressure multiplied by 1.3 corrected for temperature (multiplied by the LSR). After testing and inspection of the common element, each adjacent chamber must then be hydrostatically tested simultaneously with special consideration for the differential pressure between each chamber. When this second method is used, the vessel stamping and data report must include a description of the common elements with the limiting differential pressure. Note that for both methods the code does not specify on which side the common elements have to be tested.

For jacketed pipe in B31.3, the internal piping must be leak tested according to the more critical of the internal and external pressures. All joints of the internal line have to be accessible for visual inspection. Afterward, the jacket has to be leak tested on the basis of its internal pressure. In B31.3 the concept of differential pressure is not applicable for jacketed piping.

CONCLUSION

No matter the code, the owner should carefully consider his expectations regarding the pressure test, such as what the minimum test pressure should be based on. If the owner has no particular specifications, the fabricator will use the minimum requirements of the code which will provide a pressure vessel or piping system will less flexibility for future operating changes.

Apart from the many differences between ASME Section VIII Div. 1, and ASME B31.3, both codes have the same goal—to demonstrate that the design and the construction of the equipment is sound and safe. ASME B31.3 accomplishes this goal by making sure that its piping systems are leak-free and Section VIII Div. 1 does so by providing a pressure vessel that can sustain the internal pressure without failure. So put down your hammer, it is not required anymore and hasn't been for a long time. ■

References:

API-ASME, UNFIRED PRESSURE VESSELS for PETROLEUM LIQUIDS AND GASES, Fourth Edition, 1943

ASME B31.3, Edition 2012 and its interpretations

ASME BPVC Section VIII, Division 1, Edition 2013, and its interpretation

Fitness-for-Service Evaluations for Piping and Pressure Vessels: The ASME Code Simplified, by George Antaki

Acknowledgments:

Special thanks to Hugo Julien for his collaboration and comments.

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