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FEATURING:

NAVIGATING ASME SECTION VIII (DIV.1): MANAGING YOUR PRESSURE VESSELS - PART 1

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Navigating ASME Section VIII (Div.1): Managing Your Pressure Vessels - Part 1

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Inspections, repairs, modifications, or Fitness-For-Service (FFS) assessments on an old, unfired ASME Section VIII (Div. 1) pressure vessel - Which ASME Section VIII (Div. 1) Code Edition should you use?

INTRODUCTION

According to the National Board Inspection Code (NBIC), Part 3[1], paragraph 1.2(a): "When the standard governing the original construction is the ASME Code,…, repairs and alterations to pressure-retaining items shall conform, insofar as possible, to the section and edition of the ASME Code most applicable to the work planned." NBIC's interpretation 95-19[29] is more specific:

> **"Question:** When the NBIC references 'the original code of construction', is it required to use the edition and addenda of that code as used for construction? **Answer:** No. The term 'original code of construction' refers to the document itself, not the edition/addenda of the document. Repairs and alterations may be performed to the edition/addenda used for the original construction or later edition/addenda most applicable to the work".

But, recommended practice in API RP 572[4], paragraph 4.6 says: "A refinery or petrochemical facility inspector should be familiar not only with the latest editions of codes but also with previous editions of the codes and with other specifications under which any vessels they inspect were built". And finally, if a Fitness-For-Service (FFS) assessment is required, according to API 579-1/ASME FFS-1[5], paragraph 1.7.2 agrees with API RP 572's opinion by saying:

> "The edition of the codes, standards, and recommended practices used in the FFS Assessment shall be either the latest edition, the edition used for the design and fabrication of the component, or a combination thereof. The engineer responsible for the assessment shall determine the edition(s) to be used."

In other words, if you are performing an inspection, repair, alteration, or FFS assessment [5] on an unfired pressure vessel, you need the appropriate ASME Code edition to be able to fully understand the design limits and best support your engineering judgment.

The main purpose of this article is to give you as much knowledge and as many tools as possible to know when you are being conservative and when you are not being conservative enough when carrying out activities on your unfired pressure vessels. Hopefully, this information will also help you select the best plan of action even if the original edition of the construction code is out of print. API 510[2], Figure 8-1 and NBIC, Part 3[1], paragraph 3.4.2, can diminish the number of editions required for your library by authorizing the use of the latest edition of ASME Section VIII Div. 1[17] if all required conditions are met and understood.

Please remember that the post-ASME Section VIII Div. 1, 1999 addenda or pre-1999 addenda with the 2 following ASME Code Cases: 2278[24] or 2290[24] maximum allowable design stress, are based mainly on safety design margins of 3.5 instead of 4 (pre-1999 addenda) at room temperature, and can potentially result in thinner minimum thickness requirements than the original design.

The following article provides several important points you should consider in order to adhere to the NBIC Part 3[1] paragraph 1.2(a), API RP 572[4] paragraph 4.6, and API 579-1/ASME FFS-1[5] paragraph 1.7.2 recommendations previously mentioned.

WHICH ASME SECTION VIII (DIV. 1) CODE EDITION SHOULD I USE?

The following sections cover several major areas where it is important to recognize and understand the differences between the various ASME Section VIII (Div. 1) editions. Over the years we have had to reference many editions of ASME's unfired pressure vessel requirements dating as far back as 1943 (complete list in references of this article). Making effective use of these editions in accordance with NBIC Part 3[1] paragraph 1.2(a), API RP 572[4] paragraph 4.6, and API 579-1/ASME FFS-1[5] paragraph 1.7.2 is a difficult, yet necessary task. Please note that referencing post-1968 edition codes is one of the main conditions in API 510[2], Figure 8-1 and NBIC, Part 3[1], paragraph 3.4.2 (d), to permit the use of the latest ASME Section VIII Div. 1[17] for any inspections, repairs, alterations and FFS assessments where a minimum thickness calculation is needed. The thick bold dividing line in ***Tables 1 through 3 (part 1)*** and in ***Tables 4 through 8 (part 2)*** in this article shows the transition between ASME Section VIII (pre-1968) and ASME Section VIII div. 1 (post-1968) requirements.

BASED ON EXTERNAL LOADINGS (UG-22)

Let's start with an overview of which ASME Section VIII (Div. 1) paragraph UG-22 external loadings are required for all unfired pressure vessel designs. A complete list of the potentially missing external loadings is available in Table 1.
As a start, in 1943[6], only the following external loads were required to be included in the final design:

1) Internal pressure
2) Impact loads
3) Dead weight
4) Wind
5) Localized loads and temperature differences
6) Superimposed loads

ASME Code edition	*Potentially* missing external loadings that are included today (2014) in ASME Section VIII, Div. 1[17]
Editions previous to ASME Section VIII, 1950 Edition[7]	1) External pressure (ex.: vacuum) 2) Earthquake loads 3) Additional pressure due to static head of contained fluid 4) Piping static reaction at nozzles 5) Test pressure and coincident static head acting the hydrostatic test 6) Snow 7) Impact reaction such as those due to fluid shock, and cyclic and dynamic reactions due to pressure or thermal variations, or from equipment mounted on a vessel 8) Abnormal pressures, such as those caused by deflagration
Editions previous to ASME Section VIII, 1962 Edition[8]	1) Piping static reaction at nozzles 2) Test pressure and coincident static head acting the hydrostatic test 3) Snow 4) Impact reaction such as those due to fluid shock, and cyclic and dynamic reactions due to pressure or thermal variations, or from equipment mounted on a vessel 5) Abnormal pressures, such as those caused by deflagration
Editions previous to ASME Section VIII div. 1, 1982 Edition[11]	1) Snow 2) Impact reaction such as those due to fluid shock, and cyclic and dynamic reactions due to pressure or thermal variations, or from equipment mounted on a vessel 3) Abnormal pressures, such as those caused by deflagration
Editions previous to ASME Section VIII div. 1, 2002 Edition[15]	1) Abnormal pressures, such as those caused by deflagration

Table 1. Summary of all potentially missing external loads to be considered when repairs, alterations, etc. must be done on an old ASME, unfired pressure vessel.

To summarize, of the 14 different kinds of internal and external loads we need to consider in the 2013 edition[17], 8 are not mentioned and potentially not considered on every design before 1950, 5 before 1962, 3 before 1982, and 1 before 2002. The use of the ASME Section VIII, Div. 1, latest edition [17] (safety factor of 3.5 instead of 4) could be an unconservative choice for all pressure vessels built before 1968, because very important external loadings such as piping static reaction at nozzles, earthquake, external pressure, etc. may potentially have been missed in the original design.

For example, in the province of Quebec (Canada), every unfired pressure vessel built before the 1950s should be challenged with earthquake loads, especially if paragraph 4.1.8.18.2 of the National Building Code of Canada[30] (NBCC), 2010 edition, cannot be followed. If this condition can be met, then earthquake loads are negligible and no further FFS assessment is needed. But if it cannot, the Quebec Construction Code, Chapter B-1.1, r. 2[31] Article 1.06 (modifying the National Building Code of Canada (see note (a)), Div. B, Vol. 1, Paragraph 10.4.1.3 (Live Loads Due to Earthquakes) requirements), should be followed. This exercise could result in a redesign of the supports (legs, saddles, skirt, etc.) to reinforce them. If your pressure vessel is not located in the province of Quebec, rules can be different than described in this paragraph; please consult your jurisdiction.

BASED ON WELD JOINT EFFICIENCY

Tables 2 and 3 illustrate Type 1, 2, and 3 butt weld efficiencies (E). Weld type definitions are described in Table UW-12 of ASME Section VIII, Div. 1[17]. The ASME Section VIII committee decided to stabilize the weld joint efficiency values in 1962, 6 years before the main 1968 transition (bold line). Those important 1962 changes can also be observed in ASME Section IX[25], paragraph QG-108:

> "Joining procedures, procedure qualifications, and performance qualifications that were made in accordance with Editions and Addenda of this Section prior to the 1962 Edition may be used in any construction for which the current Edition has been specified, provided the requirements of the 1962 Edition or any later edition have been met."

Please note that ASME Section IX, 1974 edition, has introduced the concept of nonessential variables and supplemental essential variables and other important changes have also been added[27]. Welding Procedure Specifications (WPS) approved between 1962 and 1973 shall be used with precaution, and your WPS shall include all of ASME Section IX[25] latest edition requirements.

ASME Code edition/Weld efficiency	Type 1[a], no RT	Type 1[a], spot RT	Type 1[a], 100% RT	Type 2[b], no RT	Type 2[b], spot RT	Type 2[b], 100% RT
ASME-API, 1943[6] (A7 steel, group C)	74%, without PWHT 78%, with PWHT	74%, without PWHT 78%, with PWHT	74%[e], without PWHT 78%[e], with PWHT	74%, without PWHT 78%, with PWHT	74%, without PWHT 78%, with PWHT	74%[e], without PWHT 78%[e], with PWHT
ASME-API, 1943[6] (A212 steel, group A)	80%, without PWHT 85%, with PWHT	80%, without PWHT 85%, with PWHT	90%, without PWHT 95%, with PWHT	80%, without PWHT 85%, with PWHT	80%, without PWHT 85%, with PWHT	90%, without PWHT 95%, with PWHT
ASME Section VIII, 1950 Edition[7]	80%[c], without PWHT 85%[c], with PWHT	80%, without PWHT 85%, with PWHT	90%, without PWHT 95%, with PWHT	80%[c], without PWHT 85%[c], with PWHT	80%[c], without PWHT 85%[c], with PWHT	90%, without PWHT 95%, with PWHT
ASME Section VIII, 1962 Edition[8]	70%	85%	100 %	65%	80%	90%
ASME Section VIII div. 1, 1971 Edition[9]	70%	85%	100%	65%	80%	90%
ASME Section VIII div. 1, 2013 Edition[17]	70%	85%	100%	65%	80%	90%

Table 2. Weld Efficiencies (E), Weld Types 1 and 2 (reference Table UW-12[17]).

Notes: (a) Type 1 welds are butt joints attained by double-welding or by other means which obtain the same quality of deposited weld metal on the inside and outside weld surfaces to comply with UW-35 requirements according to Table UW-12.[17]
(b) Type 2 welds are single-welded butt joints with a backing strip other than those included under Type 1 weld joints according to Table UW-12.[17]
(c) As an alternative, the mandatory spot examination requirements may be waived provided that a basic unit stress of 80% of the values given in Tables UG-23 and UG-27 (ASME Section VIII 1950 edition) is used in the design of the vessel.
(d) PWHT = Post-Weld Heat Treatment and RT = Radiographic Testing.
(e) According to 1943 ASME-API Code, Table 3 (paragraph W-320), no weld efficiency bonus is authorized when RT is done on group C steel (see list W-318.2).

ASME Code edition/Weld efficiency	Type 3[a], no RT	Type 3[a], spot RT	Type 3[a], 100% RT
ASME-API, 1943[6] (A-7 steel, group C)	64 %, without PWHT 68 %, with PWHT	64%[b], without PWHT 68 %[b], with PWHT	64%[b], without PWHT 68 %[b], with PWHT
ASME-API, 1943[6] (A-212 steel, group A)	70%, without PWHT 74 %, with PWHT	70%[b], without PWHT 74 %[b], with PWHT	70%[b], without PWHT 74 %[b], with PWHT
ASME Section VIII, 1950 Edition[7]	70%[c], without PWHT 75%[c], with PWHT	70%[b](c), without PWHT 75%[b](c), with PWHT	70%[b], without PWHT 75%[b], with PWHT
ASME Section VIII, 1962 Edition[8]	60 %	60 %[b]	60 %[b]
ASME Section VIII div. 1, 1971 Edition[9]	60 %	60 %[b]	60 %[b]
ASME Section VIII div. 1, 2013 Edition[17]	60 %	60 %[b]	60 %[b]

Table 3. Weld Efficiency (E), Weld Type 3 only (reference Table UW-12[17])

Notes:

(a) Type 3 weld are single-welded butt joint without use of backing and limited to circumferential butt joints only, not over 5/8 in. (16 mm) thick and not over 24 in. (600 mm) outside diameter according to Table UW-12.[17]

(b) RT gives no efficiency benefit for type 3 weld joint because no internal access (no internal visual inspection) is possible increasing the potential internal weld defects probability that cannot been detected by the RT method.

(c) As an alternative, the mandatory spot examination requirements may be waived provided a basic unit stress of 80% of the values given in Tables UG-23 and UG-27, ASME Section VIII 1950 edition, is used in the design of the vessel.

(d) PWHT = Post Weld Heat Treatment and RT = Radiographic Testing.

As you can see, before the 1962 edition, Type 1 and 2 weld joints were not as efficient as the same modern butt welds[17]. Also, the rules before 1962 were based on Post-Weld Heat Treatment (PWHT).

The ASME Committee was reluctant to approve the use of welding for fabrication of pressure vessels before 1935[28]. When ASME finally approved it in 1935, they were more restrictive and assigned lower weld efficiencies to welded joints (as shown in ***Tables 2 and 3***) until they collected good operating histories and readjusted the joint efficiency in 1962 accordingly.

These facts show you why it may be an unconservative approach to use the latest edition of the ASME Section VIII, Div. 1[17] for designs done before 1968 (bold line) as recommended by API 510[2] Figure 8-1 and NBIC, Part 3[1] paragraph 3.4.2 (d). These are things to consider and highlight the need for a well-rounded understanding of the specific situation/scenario.

BASED ON IMPACT TEST (BRITTLE FRACTURE) PROPERTIES

Brittle fracture in carbon steel and low-alloy steel is a real concern, particularly on steel dated prior to 1987. Equipment manufactured prior to the December 1987 Addenda of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, were made with limited requirements for notch toughness at cold temperatures. However, this does not mean that all vessels fabricated prior to this date are subject to brittle fracture. Many designers specified supplemental impact tests on equipment that were intended to be in cold service (ref.: API RP 571[3], paragraph 4.2.7.4(a)).

For example, all pressure equipment made from SA-212 coarse-grained plate has a high risk of brittle fracture. SA-212 was removed from Table UCS-23 in ASME Section VIII 1964 edition[26] and replaced by SA-516 which is popular today. An API 579-1/ASME FFS-1, part 3[5] assessment should be performed on each pre-1987 addenda unfired pressure vessel to determine its real Minimum Allowable Temperature (MAT), which is the lowest (coldest) permissible metal temperature for a given material and thickness based on its resistance to brittle fracture.

Note that NBIC, part 3[1], paragraph 4.4.1(a)(4) recommends increasing the metal temperature during any leak test (to at least 60°F) for this kind of coarse-grained plate in order to reduce the risk of brittle fracture. According to UG-99(h)[17], modern plate such as SA-516 Gr. 70 recommends that the metal temperature during hydrostatic testing be maintained at least 30°F (17°C) above the minimum design metal temperature (MDMT).

Another example is the 2 ¼ Cr - 1 Mo materials manufactured prior to the 1972 edition. This material may be particularly susceptible to temper embrittlement[3], especially after long term exposure to temperatures above 650°F (343°C). In order to minimize the possibility of brittle fracture during startups, some plants use procedures to increase the temperature to a calculated value before raising the pressure (see paragraph 4.2.3.6(a)(2) of API RP 571[3]). Strain aging[3] is a type of damage mostly found in older carbon steels (pre-1980 carbon steels with a large grain size) and C-0.5 Mo low alloy steels under the combined effects of deformation and aging at an intermediate temperature. This results in an increase in hardness and strength with a reduction in ductility and toughness, and consequently, is highly susceptible to brittle fracture risks when stressed in cold temperatures.

To conclude, if one date edition needs to be memorized in this section, it is 1987. Equipment manufactured prior to and including the 1986 edition of the ASME Section VIII Div. 1, had impact test exemption rules that were generally limited and not very conservative. In December 1987, ASME Section VIII Div. 1 came with stronger requirements than the 1986 edition. Therefore, pre-1987 edition certified pressure vessels should be subjected to the MAT calculation procedure described in API 579-1/ASME FFS-1, part 3 (see above).

Part 2 of this article, set to be released in an upcoming issue of Inspectioneering Journal, will discuss:

1) The important safety factor changes in the ASME Section VIII, Div. 1, 1998 edition, 1999 addenda, which resulted in the reduction of the minimum required thickness.
2) Considerations for ASME B16.5 standard flanges (mostly used on nozzles) and their importance in any engineering decision associated with integrity assessments.
3) Precautions necessary when hydrostatic tests are planned after major repairs, alterations, etc.

CONCLUSIONS

Owners of unfired pressure vessels built before ASME Section VIII div. 1, 1968 edition, should have a copy of the edition of all their ASME construction code equipment in order to safely perform inspections, repairs, alterations, and FFS assessments. Some of the main reasons have been explained in the previous sections and will continue to be discussed in the follow up article.

First of all, important external loadings such as piping static reaction at nozzles, earthquake, external pressure, etc. were not considered in the original design. Because earthquakes were added around the 1950 edition, assessments on pre-1950 editions should be performed as explained in the external loadings section above to see if it is negligible.
The 1962 edition is also an important transition concerning welding reliability. Weld efficiencies changed after this date and ASME Section IX pre-1962 edition approved WPSs are no longer recognized today.

Also, the December 1987 addenda introduced more conservative impact test rules (UCS-66, etc.). Every piece of pressure equipment built before December 1987 should have an API 579-1/ASME FFS-1 assessment to define its real MAT, as described in the brittle fracture section above.

The National Board[32] and ASME[33] now have a library service designed to assist you with accessing and referencing out-of-print editions and addenda of ASME Section VIII (Div. 1). This service will help you in your day-to-day integrity assessment work.

All of these points are among, in our opinion, the most important ones to consider when it is time to decide which ASME Section VIII (Div. 1) edition shall be used in any inspection, repair, alteration, and/or FFS assessment.

As mentioned in the introduction, if you are doing an inspection, repair, alteration, or a FFS assessment[5] on an ASME Section VIII (Div. 1) unfired pressure vessel built according to different ASME Code editions, you will need the applicable ASME Section VIII (pre-1968 edition) and ASME Section VIII Div. 1 (post-1968 edition) Codes to be able to understand the design limits of each of them and improve your engineering judgment on every calculation.

If you are responsible for an unfired pressure vessel built between 1925 and today (2014), you will need at least the following out-of-print ASME Code documents to be able to comply with the NBIC Part 3[1] paragraph 1.2(a), API RP 572[4] paragraph 4.6, and API 579-1/ASME FFS-1[5] paragraph 1.7.2 recommendations mentioned in introduction of this article:

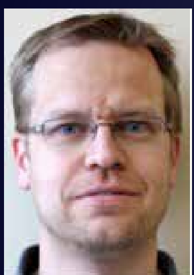
1) API/ASME Code (1934, first edition)
2) API/ASME Code (1956, last edition)
3) ASME Section VIII (1925, first edition)
4) ASME Section VIII (only one dated between 1940 and 1949)
5) ASME Section VIII (only one dated between 1950 and 1959)
6) ASME Section VIII (1962)
7) ASME Section VIII (1967, last addenda)
8) ASME Section VIII Div. 1 (1968, first edition)
9) ASME Section VIII (only one dated between 1970 and 1979)
10) ASME Section VIII div. 1 (1986)
11) ASME Section VIII div. 1 (1987)
12) ASME Section VIII div. 1 (1998)
13) ASME Section VIII div. 1 (1999)
14) ASME Section VIII div. 1 (2013 edition, latest edition currently available)

Endnote [4][27][28]: Prior to the early 1930s, most unfired pressure vessels were built to the design and specifications of the user or manufacturer. Later, most of them were built to conform with either the API/ASME Code for Unfired Pressure Vessels for Petroleum Liquids and Gases (first edition published 1934 and stopped in 1956) or the ASME Section VIII (first edition published in 1925 and became Section VIII, Division 1 in 1968). Welding was only authorized by ASME in 1935 (ASME Section IX first edition was published in 1941). Before 1940, pressure vessels were mainly riveted.

References

1) National Board Inspection Code (NBIC NB-23), Part 3- Repairs and Alterations, 2013 Edition
2) API 510, Pressure Vessel Inspection Code_ In-Service Inspection, Rating, Repair, and Alteration, 9th edition, June 2006
3) API RP 571, Damage Mechanisms Affecting Fixed Equipment in the Refining Industry, 2nd edition
4) API RP 572, Inspection Practices for Pressure Vessels, 3rd edition, November 2009
5) API 579-1/ASME FFS-1, Fitness-For-Service, 2nd edition (June 2007 edition including February 2009 errata)
6) ASME/API Unfired Pressure Vessels for Petroleum Liquids and Gases, 4th edition (1943)
7) ASME Section VIII, Rules for Construction of Unfired Pressure Vessel (1950 edition)
8) ASME Section VIII, Unfired Pressure Vessel (1962 edition)
9) ASME Section VIII div. 1, Rules for Construction of Pressure Vessel (1971 edition)
10) ASME Section VIII div. 1, Rules for Construction of Pressure Vessel (1976 edition, winter addenda)
11) ASME Section VIII div. 1, Appareils à Pression (French version, 1982, summer addenda)
12) ASME Section VIII div. 1, Rules for Construction of Pressure Vessel (1983 edition, summer addenda)
13) ASME Section VIII div. 1, Rules for Construction of Pressure Vessel (1986 edition)
14) ASME Section VIII div. 1, Rules for Construction of Pressure Vessel (1995 edition)
15) ASME Section VIII div. 1, Rules for Construction of Pressure Vessel (2001 edition, 2002 addenda)
16) ASME Section VIII div. 1, Rules for Construction of Pressure Vessel (2004 edition, 2006 addenda)
17) ASME Section VIII div. 1, Rules for Construction of Pressure Vessel (2013 edition)
18) ASME Section II Part D: Properties (Customary) (1995 edition)
19) ASME Section II Part D: Properties (Customary) (2004 edition, 2006 addenda)
20) ASME Section II Part D: Properties (Customary) (2013 edition)
21) USAS B16.5, Steel Pipe Flanges and Flanged Fittings, 150, 300, 400, 600, 900, 1500 and 2500 lb including Reference to Valves, 1968 edition
22) ASME B16.5, Pipe Flanges and Flanged Fittings, NPS 1/2 Through NPS

24, 1996 edition
23) ASME B16.5, Pipe Flanges and Flanged Fittings, NPS 1/2 Through NPS 24 Metric/Inch·Standard, 2013 edition
24) ABSA's Information Bulletin No. IB98-005 (June 18th, 1998), http://www.absa.ca/IBIndex/ib98-005.pdf
25) ASME Section IX, Qualification Standard for Welding, Brazing, and Fusing Procedures; Welders; Brazers; and Welding, Brazing, and Fusing Operators, 2013 edition
26) ASME Code Case 1347, dated November 10th 1964
27) CASTI Guidebook to ASME Section IX – Welding Qualifications, 4th edition
28) CASTI Guidebook to ASME Section VIII Div. 1 — Pressure Vessels, 4th Edition
29) 1995 NBIC Interpretations, http://www.nationalboard.org/SiteDocuments/NBIC/1995Interps.pdf
30) CNB, volume 2, division B, part 4, 2010 edition (National Building Code of Canada)
31) Quebec's Construction Code, chapter B-1.1, r. 2 (Updated to 1st December 2013), http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=3&file=/B_1_1/B1_1R2_A.HTM
32) National Board out-of-print editions and addenda: http://www.nationalboard.org/Index.aspx?pageID=290
33) ASME out-of-print editions and addenda: https://www.asme.org/shop/standards/access-to-out-of-print-codes-standards-and-asme?cm_re=New%20Releases-_-Left%20Navigation-_-Access%20to%20Out-of-Print%20Codes%20Standards



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