ASME BPVC.VIII.2-2025

SECTION VIII

Rules for Construction of Pressure Vessels

2025 ASME Boiler and Pressure Vessel Code

An International Code

Division 2

Alternative Rules

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AN INTERNATIONAL CODE

2025 ASME Boiler & Pressure Vessel Code

2025 Edition July 1, 2025

VIII

RULES FOR CONSTRUCTION OF PRESSURE VESSELS

Division 2

Alternative Rules

ASME Boiler and Pressure Vessel Committee
on Pressure Vessels

The American Society of Mechanical Engineers
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FOREWORD[*]

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In 1911, The American Society of Mechanical Engineers established the Boiler and Pressure Vessel Committee to formulate standard rules for the construction of steam boilers and other pressure vessels. In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees:

(a) Committee on Power Boilers (I)
(b) Committee on Materials (II)
(c) Committee on Construction of Nuclear Facility Components (III)
(d) Committee on Heating Boilers (IV)
(e) Committee on Nondestructive Examination (V)
(f) Committee on Pressure Vessels (VIII)
(g) Committee on Welding, Brazing, and Fusing (IX)
(h) Committee on Fiber-Reinforced Plastic Pressure Vessels (X)
(i) Committee on Nuclear Inservice Inspection (XI)
(j) Committee on Transport Tanks (XII)
(k) Committee on Overpressure Protection (XIII)
(l) Technical Oversight Management Committee (TOMC)

Where reference is made to "the Committee" in this Foreword, each of these committees is included individually and collectively.

The Committee's function is to establish rules of safety relating to pressure integrity. The rules govern the construction[**] of boilers, pressure vessels, transport tanks, and nuclear components, and the inservice inspection of nuclear components and transport tanks. For nuclear items other than pressure-retaining components, the Committee also establishes rules of safety related to structural integrity. The Committee also interprets these rules when questions arise regarding their intent. The technical consistency of the Sections of the Code and coordination of standards development activities of the Committees is supported and guided by the Technical Oversight Management Committee. The Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks, or nuclear components, or the inservice inspection of nuclear components or transport tanks. Users of the Code should refer to the pertinent codes, standards, laws, regulations, or other relevant documents for safety issues other than those relating to pressure integrity and, for nuclear items other than pressure-retaining components, structural integrity. Except for Sections XI and XII, and with a few other exceptions, the rules do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of components addressed by the Code. The objective of the rules is to afford reasonably certain protection of life and property, and to provide a margin for deterioration in service to give a reasonably long, safe period of usefulness. Advancements in design and materials and evidence of experience have been recognized.

The Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities and inservice inspection and testing activities. The Code does not address all aspects of these activities and those aspects that are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase *engineering judgment* refers to technical judgments made by knowledgeable engineers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy, and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code

[*] The information contained in this Foreword is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. Therefore, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Code.

[**] *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and overpressure protection.

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neither requires nor prohibits the use of computers for the design or analysis of components constructed to the requirements of the Code. However, designers and engineers using computer programs for design or analysis are cautioned that they are responsible for all technical assumptions inherent in the programs they use and the application of these programs to their design.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design, or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code cases, and requests for interpretations. Only the Committee has the authority to provide official interpretations of the Code. Requests for revisions, new rules, Code cases, or interpretations shall be addressed to the staff secretary in writing and shall give full particulars in order to receive consideration and action (see the Correspondence With the Committee page). Proposed revisions to the Code resulting from inquiries will be presented to the Committee for appropriate action. The action of the Committee becomes effective only after confirmation by ballot of the Committee and approval by ASME. Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute (ANSI) and published at http://go.asme.org/BPVCPublicReview to invite comments from all interested persons. After public review and final approval by ASME, revisions are published at regular intervals in Editions of the Code.

The Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed to the Committee. ASME is to be notified should questions arise concerning improper use of the ASME Single Certification Mark.

When required by context in the Code, the singular shall be interpreted as the plural, and vice versa.

The words "shall," "should," and "may" are used in the Code as follows:

- *Shall* is used to denote a requirement.
- *Should* is used to denote a recommendation.
- *May* is used to denote permission, neither a requirement nor a recommendation.

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STATEMENT OF POLICY ON THE USE OF THE ASME SINGLE CERTIFICATION MARK AND CODE AUTHORIZATION IN ADVERTISING

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use the ASME Single Certification Mark for marking items or constructions that have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the ASME Single Certification Mark for the benefit of the users, the enforcement jurisdictions, and the holders of the ASME Single Certification Mark who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the ASME Single Certification Mark, Certificates of Authorization, and reference to Code construction. The American Society of Mechanical Engineers does not "approve," "certify," "rate," or "endorse" any item, construction, or activity and there shall be no statements or implications that might so indicate. An organization holding the ASME Single Certification Mark and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities "are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code," or "meet the requirements of the ASME Boiler and Pressure Vessel Code." An ASME corporate logo shall not be used by any organization other than ASME.

The ASME Single Certification Mark shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of the ASME Single Certification Mark who may also use the facsimile in advertising to show that clearly specified items will carry the ASME Single Certification Mark.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the ASME Single Certification Mark described in the governing Section of the Code.

Markings such as "ASME," "ASME Standard," or any other marking including "ASME" or the ASME Single Certification Mark shall not be used on any item that is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME that tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

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January 1, 2025

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CORRESPONDENCE WITH THE COMMITTEE

General

ASME codes and standards are developed and maintained by committees with the intent to represent the consensus of concerned interests. Users of ASME codes and standards may correspond with the committees to propose revisions or cases, report errata, or request interpretations. Correspondence for this Section of the ASME Boiler and Pressure Vessel Code (BPVC) should be sent to the staff secretary noted on the Section's committee web page, accessible at https://go.asme.org/CSCommittees.

NOTE: See ASME BPVC Section II, Part D for guidelines on requesting approval of new materials. See Section II, Part C for guidelines on requesting approval of new welding and brazing materials ("consumables").

Revisions and Errata

The committee processes revisions to this Code on a continuous basis to incorporate changes that appear necessary or desirable as demonstrated by the experience gained from the application of the Code. Approved revisions will be published in the next edition of the Code.

In addition, the committee may post errata and Special Notices at http://go.asme.org/BPVCerrata. Errata and Special Notices become effective on the date posted. Users can register on the committee web page to receive email notifications of posted errata and Special Notices.

This Code is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number, the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Code

(4) to permit use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Code.

(c) The committee will consider proposed cases concerning the following topics only:

(1) equipment to be marked with the ASME Single Certification Mark, or

(2) equipment to be constructed as a repair/replacement activity under the requirements of Section XI

(d) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Code Section and the paragraph, figure, or table number to which the proposed case applies

(4) the editions of the Code to which the proposed case applies

(e) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Cases that have been approved will appear in the next edition or supplement of the Code Cases books, "Boilers and Pressure Vessels" or "Nuclear Components." Each Code Cases book is updated with seven Supplements. Supplements will be sent or made available automatically to the purchasers of the Code Cases books until the next edition of the Code. Annulments of Code Cases become effective six months after the first announcement of the annulment in a Code Case Supplement or Edition of the appropriate Code Case book. The status of any case is available at http://go.asme.org/BPVCCDatabase. An index of the complete list of Boiler and Pressure Vessel Code Cases and Nuclear Code Cases is available at http://go.asme.org/BPVCC.

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Interpretations

(a) Interpretations clarify existing Code requirements and are written as a question and reply. Interpretations do not introduce new requirements. If a revision to resolve conflicting or incorrect wording is required to support the interpretation, the committee will issue an intent interpretation in parallel with a revision to the Code.

(b) Upon request, the committee will render an interpretation of any requirement of the Code. An interpretation can be rendered only in response to a request submitted through the online Inquiry Submittal Form at http://go.asme.org/InterpretationRequest. Upon submitting the form, the inquirer will receive an automatic email confirming receipt.

(c) ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Code requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers may track the status of their requests at http://go.asme.org/Interpretations.

(d) ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

(e) Interpretations are published in the ASME Interpretations Database at http://go.asme.org/Interpretations as they are issued.

Committee Meetings

The ASME BPVC committees regularly hold meetings that are open to the public. Persons wishing to attend any meeting should contact the secretary of the applicable committee. Information on future committee meetings can be found at http://go.asme.org/BCW.

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SUMMARY OF CHANGES

Changes listed below are identified on the pages by a margin note, **(25)**, placed next to the affected area.

Page	*Location*	*Change*
xxviii	List of Sections	Title of Section XI, Division 1 revised
xxix	Foreword	Third, fourth, seventh, tenth, and eleventh paragraphs editorially revised
xxxii	Personnel	Updated
2	1.2.1.3	First paragraph revised
3	1.2.4.2	Second sentence revised
3	1.2.6.1	Subparagraph (c) revised
5	Table 1.1	Updated
7	1-B.2	*(1)* 1-B.2.1 revised *(2)* 1-B.2.10 and 1-B.2.11 deleted and subsequent paragraphs redesignated
15	2.2.1.1	Last sentence revised
15	2.2.3.1	In subpara. (f)(1), first sentence revised
17	2.3.1.2	First sentence revised
18	2.3.3.1	In subpara. (a)(3), cross-reference updated
19	2.3.8.4	First paragraph revised
20	2.4.1	Revised
21	2-A.2.1	Subparagraph (c) revised
22	Table 2-A.1	In first paragraph, reference to “Class” deleted
23	2-B.1	In subpara. (a), first sentence revised
23	2-B.2.1	Subparagraph (c) revised
24	Table 2-B.1	In first paragraph, reference to “Class” deleted
25	2-C.1.1	Subparagraphs (b) and (c)(2) revised
25	2-C.1.3	Subparagraph (a)(4) added
27	2-C.3.2	Last sentence added
28	Table 2-D.1	Instructions for Note Nos. 12 and 41 revised
30	Table 2-D.2	Instructions for Note Letter B revised
31	Form A-1	Line 5, “Certificate of Shop Inspection,” and “Certificate of Field Assembly Inspection” revised
34	Form A-1P	“Certificate of Shop Inspection” and “Certificate of Field Assembly Inspection” revised
36	Form A-2	Line 5 and “Certificate of Shop Inspection” revised
43	2–E.5.3	Added

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Page	Location	Change
44	2-E.15.4	Last sentence revised
45	Annex 2-F	References to vessel class deleted throughout
45	2-F.1	Subparagraph (j) deleted
48	2-F.8	First sentence revised
49	Figure 2-F.1	Revised
50	2-G.6.2	First sentence revised
52	2-J.3.2	Subparagraph (a), (c)(3), and (c)(4) revised
53	2-J.3.3	Subparagraph (c) revised
55	3.2.1.6	Second sentence revised
56	3.2.2.3	Added
56	3.2.4.1	Revised
56	3.2.5	3.2.5.1 through 3.2.5.3 revised
58	3.2.6.1	Subparagraphs (b) and (c) revised
63	3.3.1	Revised
63	3.3.4	In 3.3.4.3 and 3.3.4.4, first sentence revised
76	3.11.2.3	Subparagraph (b) revised
78	3.11.2.5	In subpara. (a), Steps 5(a) and 5(b) revised
79	3.11.2.8	Revised
80	3.11.2.9	Subparagraph (a) revised
80	3.11.3.1	Subparagraphs (b), (c)(1), and (c)(2) revised
82	3.11.4.3	Subparagraph (e) revised
89	3.19	Table 3.1 added and subsequent tables redesignated
90	Table 3.2	*(1)* Formerly Table 3.1; entries for $2\frac{1}{4}$Cr–1Mo revised *(2)* Note (1) deleted and General Note added
91	Table 3.5	Formerly Table 3.4; for Material Specification SA-193, Material Type/Grade B16, Diameter 64 mm ($2\frac{1}{2}$ in.) and under, temperature revised
99	3.20	Figures 3.1 and 3.2 added and subsequent figures redesignated
108	Figure 3.8	Formerly Figure 3.6; in y-axis caption, “mm” corrected to “mils” by errata
120	Figure 3.14	Formerly Figure 3.12; graph and Note (1) revised
121	Figure 3.14M	Formerly Figure 3.12M; graph and Note (1) revised
122	Figure 3.15	Formerly Figure 3.13; graph and Note (1) revised
123	Figure 3.15M	Formerly Figure 3.13M; graph and Note (1) revised
127	3-A.1.2	Revised
128	Table 3-A.1	Note (1) deleted
133	Table 3-A.2	Revised
134	Table 3-A.3	Note (1) deleted and former Note (2) redesignated

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Page	Location	Change
140	Table 3-A.4	Material Specification SB-247 added
142	Table 3-A.6	*(1)* Material Specifications SA-182, SA-213, SA-240, SA-312, SA-403, SA-479, SA-688, and SA-965 added *(2)* Note (1) deleted
144	Table 3-A.7	Note (1) deleted
159	3-F.1	Revised
161	3-F.2	Revised
162	3-F.3	Definitions of C_S and E_A added
162	3-F.4	Tables 3-F.1, 3-F.2, and 3-F.2M revised
164	3-F.5	Titles of Figures 3-F.1 through 3-F.3M and 3-F.4M revised
173	4.1.1	4.1.1.2, 4.1.1.3, and 4.1.1.5 revised
174	4.1.5.1	Revised
174	4.1.5.2	Subparagraph (e) revised
175	4.1.5.3	In subpara. (b), last sentence revised
176	4.1.6.2	Revised
178	4.1.13	*(1)* Definitions of β, β_T, and $\gamma_{St/S}$ revised *(2)* Definition of $\gamma_{\min}$ deleted
179	Table 4.1.2	*(1)* Design Load Combinations revised *(2)* Note (4) deleted
180	Table 4.1.3	Revised in its entirety
181	4.2.5.4	Subparagraph (c)(1) revised
193	Table 4.2.9	For Details 1 through 4, Design Notes revised
207	Figure 4.2.2	Revised
225	Table 4.3.3	In Note (1), "+" added to first line of equation by errata
240	4.4.2	Second and last sentences and eq. (4.4.3) revised
243	4.4.5.2	Subparagraph (f) revised
245	4.4.6.1	Subparagraph (c) revised
247	4.4.12	*(1)* 4.4.12.2(b), 4.4.12.2(c), 4.4.12.2(e), 4.4.12.2(f), 4.4.12.2(h), 4.4.12.2(i), and 4.4.12.3(b) revised *(2)* Equations redesignated and cross-references updated accordingly
253	4.4.15	*(1)* Definition of D_e deleted *(2)* Definitions of D_i, D_L, and D_S revised *(3)* Definition of β added
256	Table 4.4.2	*(1)* Revised *(2)* In General Note (a), definition of MSTS added
265	4.5.4.1	Penultimate sentence revised
269	4.5.7	*(1)* Equations revised, added, and deleted *(2)* Subsequent equations throughout 4.5 redesignated and cross-references updated accordingly

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Page	*Location*	*Change*
270	4.5.9	Equations revised, added, and deleted
282	4.5.18	Definitions of L_{H1}, L_{H2}, L_{H3}, L_{I1}, L_{I2}, L_{I3}, L_{R1}, L_{R2}, and L_{R3} added
290	Figure 4.5.5	Revised
292	Figure 4.5.7	Revised
293	Figure 4.5.8	Revised
302	Table 4.6.1	For Detail 9, Requirements revised
316	4.8	Revised in its entirety
327	4.11.6.1	First sentence revised
328	4.11.7	*(1)* Definitions of S_u and S_{yT} revised *(2)* Definition of t_h added
329	Table 4.11.1	Details 1 and 4 through 7 revised
335	Table 4.11.2	Details 2 and 5 revised
341	Figure 4.11.3	Revised
345	4.12.6	Revised
347	4.12.7.1	*(1)* In Step 4(b), cross-reference updated *(2)* Step 5 revised
349	4.12.11.1	Definitions of E, E_g, and E_m revised
351	4.12.12	Tables 4.12.2 through 4.12.13 revised
374	4.12.13	Figure notes revised throughout
410	4.15.3.5	In eqs. (4.15.24) and (4.15.27), "=" revised to "≥"
419	Figure 4.15.3	Illustration (c) revised
425	4.16.3	Revised
426	4.16.4.3	First sentence corrected by errata
426	4.16.6.1	In Step 3, last sentence revised
427	4.16.7.2	*(1)* In Step 6, second sentence revised *(2)* In eqs. (4.16.14), (4.16.15), (4.16.17), and (4.16.18), "F_s" revised to "F_{sr}"
428	4.16.8	In subparas. (a) and (b), "F_s" revised to "F_{sr}"
429	4.16.11	Last sentence revised
429	4.16.13	*(1)* Definitions of F_s, g_2, t_g, and V_s added *(2)* Former term F_s revised to F_{sr} *(3)* Definition of w revised
431	Table 4.16.1	Column titled "Column in Table 4.16.1" deleted and cross-references in last column updated
433	Table 4.16.3	Revised in its entirety
434	Table 4.16.4	Welded slip-on-type flange added
436	Table 4.16.5	Welded slip-on-type flange added
439	Table 4.16.6	Revised

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Page	Location	Change
439	Table 4.16.7	*(1)* In first equation for I_p, "A_r" corrected to "A_R" by errata *(2)* Welded slip-on-type flange added
440	Table 4.16.8	Welded slip-on-type flange added
440	Table 4.16.9	Welded slip-on-type flange added
441	Table 4.16.10	Welded slip-on-type flange added
443	Figure 4.16.1	Revised, incorporating former Figure 4.16.2 and former Figure 14.6.5, illustration (a)
447	Figure 4.16.5	Former Figure 14.6.6 redesignated
448	Figure 4.16.6	Former Figure 4.16.7 revised and redesignated
449	Figure 4.16.7	Added
461	4.18.3	Subparagraphs (h)(1) through (h)(2)(-b) revised and subpara. (i) added
462	4.18.5.3	In subpara. (a), first sentence revised
462	4.18.5.4	In eq. (4.18.1b), denominator corrected by errata
464	4.18.7.3	Subparagraph (a)(3) revised
464	4.18.7.4	*(1)* Equation (4.18.27) corrected by errata *(2)* Equations (4.18.31) through (4.18.34) and Step 6 revised
468	4.18.7.5.3	Subparagraph (d)(1)(-b) revised
469	4.18.8.3	Subparagraph (a)(3) revised
470	4.18.8.4	*(1)* Equation (4.18.73), eq. (4.18.81), Step 9(b), and Step 10(c) corrected by errata *(2)* Equations (4.18.83) through (4.18.85) and (4.18.97) revised
479	4.18.8.8.3	Subparagraph (d)(2) revised
482	4.18.9.3	Subparagraph (b)(3) revised
483	4.18.9.4	*(1)* Equation (4.18.170), eq. (4.18.171), eq. (4.18.223) [formerly (4.18.224)], eq. (4.18.224) [formerly (4.18.225)], Step 11(b)(1), and Step 11(b)(2) corrected by errata *(2)* Equations (4.18.180) through (4.18.182), eq. (4.18.190), and Step 8(b) revised *(3)* Equation (4.18.214) deleted and subsequent equations redesignated
489	4.18.9.5	Subparagraphs (b)(5) and (c)(3) revised
491	4.18.9.7.3	Subparagraph (d)(2) revised
493	4.18.13	Revised in its entirety
495	4.18.15	Revised in its entirety
504	Table 4.18.4	General Note added
518	Figure 4.18.15	In Note (4), "O.B." corrected to "0.8" by errata
521	Figure 4.18.19	"d" revised to "d_n"
520	4.19.2	Subparagraph (g) revised
554	4.19.14	In Forms 4.19.1 and 4.19.2, "Vessel Class" deleted

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Page	*Location*	*Change*
563	4.21.3.2	Equations (4.21.24) and (4.21.25) revised
565	4.21.4	*(1)* Definition of P_o revised *(2)* In definition of S_w, "(S, S_t)" corrected to "min(S, S_t)" by errata *(3)* Definitions of $S_{y,a}$ and $S_{y,t,a}$ added
572	Annex 4-B	Revised
575	4-D.1	Revised
575	4-D.4.1	Second paragraph revised
588	Part 5	5.1 through 5.16, including all figures and tables, revised in their entirety
670	5-A.4.1.2	First paragraph revised
742	6.1.1.2	In subpara. (a), last sentence revised
747	6.2.2.1	*(1)* Subparagraphs (a), (b), and (c)(4)(-a) [formerly (c)(4)(-b)] revised *(2)* Subparagraph (c)(4)(-a) deleted and subsequent subparagraphs redesignated
749	6.2.4	Revised in its entirety
756	6.4.5.2	Subparagraph (c) revised
757	6.4.6.3	Subparagraph (c)(1) revised
760	6.6.5.2	*(1)* Subparagraph (c) revised *(2)* Former subpara. (c)(2) redesignated as (d) and subsequent subparagraph redesignated *(3)* Subparagraph (f) added
764	6.7.3	Subparagraph (a) revised
765	6.7.7.1	Last sentence added
766	6.7.8.2	Last sentence added
779	Table 6.10	In "Holding Temperature and Time Based on Nominal Thickness" column, holding times revised
780	Table 6.11	In "Holding Temperature and Time Based on Nominal Thickness" column, holding times revised
782	Table 6.12	In "Holding Temperature and Time Based on Nominal Thickness" column, holding times revised
783	Table 6.13	In "Holding Temperature and Time Based on Nominal Thickness" column, holding times revised
786	Table 6.15	In "Holding Temperature and Time Based on Nominal Thickness" column, holding times revised
789	Table 6.17	*(1)* For SA-353 and SA-553, "(Nominal) Thickness ..." entries revised *(2)* Note (1) revised and Note (3) added
799	6-A.4.5	Second sentence revised
800	6-A.5.4	Subparagraph (b) revised
800	6-A.6.5	First paragraph and subparagraph (d) revised
800	6-A.6.6	Subparagraphs (b) and (c) revised

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Page	Location	Change
800	6-A.6.7	Subparagraph (c) revised
801	6-A.6.8	In subpara. (d), first sentence revised
801	6-A.6.11	In first paragraph, last sentence revised
802	6-A.7.3	Subparagraphs (b) and (d) revised
802	6-A.7.4	Second sentence revised
802	6-A.7.5	Subparagraph (b) revised
802	6-A.7.6	Last sentence revised
803	6-A.8.2	First sentence revised
804	6-A.9.1	Revised
810	7.4.10.1	In subpara. (a), first sentence revised
810	7.4.10.3	First sentence revised
811	7.4.11.10	Subparagraph (a) revised
826	Table 7.6	Acceptance Criteria for Nos. 2, 4, 6, and 7 revised
849	7-A.2.1	Subparagraph (b) revised
849	7-A.2.2	Subparagraph (a) revised
849	7-A.3.1	Subparagraph (a) revised
850	7-A.3.2.3	Subparagraph (a) revised
850	7-A.3.2.4	Subparagraphs (a) and (b) revised
850	7-A.3.2.5	First sentence revised
850	7-A.3.2.6	In subparas. (a), (b), and (c), last sentence revised
853	8.1.1	Subparagraph (a) revised
854	8.1.3.1	First sentence revised
854	8.1.3.3	Revised in its entirety
855	8.1.5	Last paragraph revised
856	8.2.1	Subparagraphs (a), (d), and (e) revised
856	8.2.2	Revised in its entirety
857	8.2.4	Revised in its entirety
857	8.2.5	Revised in its entirety
858	8.3.2	In subpara. (c), first sentence revised
859	8.5	Definitions of β_T and $\gamma_{St/S}$ revised
860	9.2	Subparagraphs (a) and (c) revised
860	9.3	Subparagraph (a) revised
861	9.4	Subparagraph (a) revised
862	9.5	*(1)* Subparagraph (b)(3) revised *(2)* Subparagraph (c)(3) deleted *(3)* Subparagraphs (e)(3) and (e)(4) added
863	9.6	Subparagraph (h) revised

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CROSS-REFERENCING IN THE ASME BPVC

Paragraphs within the ASME BPVC may include subparagraph breakdowns, i.e., nested lists. The following is a guide to the designation and cross-referencing of subparagraph breakdowns:

(a) Hierarchy of Subparagraph Breakdowns

(1) First-level breakdowns are designated as (a), (b), (c), etc.

(2) Second-level breakdowns are designated as (1), (2), (3), etc.

(3) Third-level breakdowns are designated as (-a), (-b), (-c), etc.

(4) Fourth-level breakdowns are designated as (-1), (-2), (-3), etc.

(5) Fifth-level breakdowns are designated as (+a), (+b), (+c), etc.

(6) Sixth-level breakdowns are designated as (+1), (+2), etc.

(b) Cross-References to Subparagraph Breakdowns. Cross-references within an alphanumerically designated paragraph (e.g., PG-1, UIG-56.1, NCD-3223) do not include the alphanumerical designator of that paragraph. The cross-references to subparagraph breakdowns follow the hierarchy of the designators under which the breakdown appears. The following examples show the format:

(1) If X.1(c)(1)(-a) is referenced in X.1(c)(1), it will be referenced as (-a).

(2) If X.1(c)(1)(-a) is referenced in X.1(c)(2), it will be referenced as (1)(-a).

(3) If X.1(c)(1)(-a) is referenced in X.1(e)(1), it will be referenced as (c)(1)(-a).

(4) If X.1(c)(1)(-a) is referenced in X.2(c)(2), it will be referenced as X.1(c)(1)(-a).

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PART 1
GENERAL REQUIREMENTS

1.1 GENERAL

1.1.1 INTRODUCTION

1.1.1.1 This Division contains mandatory requirements, specific prohibitions, and nonmandatory guidance for the design, materials, fabrication, examination, inspection, testing, overpressure protection, and certification of pressure vessels.

1.1.1.2 The Code does not address all aspects of these activities. Those aspects that are not specifically addressed should not be considered prohibited and shall be addressed by appropriate engineering judgment. Engineering judgment shall be consistent with the philosophy of this Division, and such judgments shall never be used to overrule mandatory requirements or specific prohibitions of this Division.

1.1.2 ORGANIZATION

1.1.2.1 The requirements of this Division are contained in the nine Parts listed below. Each of these Parts and Annexes is composed of paragraphs that are identified by an alphanumeric numbering system in accordance with the ISO Standard Template for the Preparation of Normative-Type Documents. References to paragraphs are made directly by reference to the paragraph number. For example, the Scope is referenced as 1.2.

(a) Part 1 – General Requirements, provides the scope of this Division and establishes the extent of coverage

(b) Part 2 – Responsibilities and Duties, sets forth the responsibilities of the user and Manufacturer, and the duties of the Inspector

(c) Part 3 – Materials Requirements, provides the permissible materials of construction, applicable material specification and special requirements, physical properties, allowable stresses, and design fatigue curves

(d) Part 4 – Design by Rule Requirements, provides requirements for design of vessels and components using rules

(e) Part 5 – Design by Analysis Requirements, provides requirements for design of vessels and components using analytical methods

(f) Part 6 – Fabrication Requirements, provides requirements governing the fabrication of vessels and parts

(g) Part 7 – Examination and Inspection Requirements, provides requirements governing the examination and inspection of vessels and parts

(h) Part 8 – Pressure Testing Requirements, provides pressure testing requirements

(i) Part 9 – Pressure Vessel Overpressure Protection, provides overpressure protection requirements

1.1.2.2 Mandatory and nonmandatory requirements are provided as normative and informative annexes, respectively, to the specific Part under consideration. The Normative Annexes address specific subjects not covered elsewhere in this Division and their requirements are mandatory when the subject covered is included in construction under this Division. Informative Annexes provide information and suggested good practices.

1.1.2.3 The materials, design, fabrication, examination, inspection, testing, overpressure protection, and certification of pressure vessels shall satisfy all applicable Parts and Normative Annexes shown above in order to qualify the construction in accordance with this Division.

1.1.3 DEFINITIONS

The definitions for the terminology used in this Part are contained in Annex 1-B.

1.2 SCOPE

1.2.1 OVERVIEW

1.2.1.1 In the scope of this Division, pressure vessels are containers for the containment of pressure, either internal or external. This pressure may be obtained from an external source or by the application of heat from a direct or indirect source as a result of a process, or any combination thereof.

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1.2.1.2 Vessels with an internal or external design pressure not exceeding 103 kPa (15 psi) and multichambered vessels of which the design pressure on the common elements does not exceed 103 kPa (15 psi) were not considered when the rules of this Division were developed and are not considered within the scope.

(25) **1.2.1.3** The rules of this Division may be used for the construction of the following pressure vessels:

(a) Vessels to be installed at a fixed (stationary) location for a specific service where operation and maintenance control is retained during the useful life of the vessel by the user and is in conformance with the User's Design Specification required by Part 2.

(b) Pressure vessels installed in ocean-going ships, barges, and other floating craft or used for motor vehicle or rail freight. For these applications it is necessary that prior written agreement with the jurisdictional authority be established covering operation and maintenance control for a specific service. This operation and maintenance control must be retained during the useful life of the pressure vessel by the user in conformance with the User's Design Specification required in Part 2. Such a pressure vessel as described above may be constructed and stamped within the scope of this Division, provided it meets all other requirements as specified with the following additional provisions.

(1) Loading conditions imposed by movement of the pressure vessel during operation and by relocation of the pressure vessel between work sites or due to loading and discharge, as applicable, shall be considered in the design.

(2) The User's Design Specification shall include the agreements that define those aspects of operation and maintenance control unique to the particular pressure vessel.

(c) Pressure vessels or parts subject to direct firing from the combustion of fuel (solid, liquid, or gaseous), that are not within the scope of Section I, III, or IV may be constructed in accordance with the rules of this Division.

(d) Unfired steam boilers shall be constructed in accordance with the rules of Section I or Section VIII, Division 1.

(e) The following pressure vessels in which steam is generated shall be constructed in accordance with the rules of Section VIII, Division 1 or this Division:

(1) Vessels known as evaporators or heat exchangers;

(2) Vessels in which steam is generated by the use of heat resulting from operation of a processing system containing a number of pressure vessels such as used in the manufacture of chemical and petroleum products; and

(3) Vessels in which steam is generated but not withdrawn for external use.

1.2.1.4 The scope of this Division has been established to identify components and parameters considered in formulating the rules given in this Division. Laws or regulations issued by municipality, state, provincial, federal, or other enforcement or regulatory bodies having jurisdiction at the location of an installation establish the mandatory applicability of the Code rules, in whole or in part, within the jurisdiction. Those laws or regulations may require the use of this Division of the Code for vessels or components not considered to be within its scope. These laws or regulations should be reviewed to determine size or service limitations of the coverage which may be different or more restrictive than those given here.

1.2.2 ADDITIONAL REQUIREMENTS FOR VERY HIGH PRESSURE VESSELS

1.2.2.1 The rules of this Division do not specify a limitation on pressure but are not all-inclusive for all types of construction. For very high pressures, some additions to these rules may be necessary to meet the design principles and construction practices essential to vessels for such pressures. However, only in the event that, after application of additional design principles and construction practices, the vessel still complies with all of the requirements of the Code, may it be stamped with the Certification Mark.

1.2.2.2 As an alternative to this Division, Section VIII, Division 3 should be considered for the construction of vessels intended for operating pressures exceeding 68.95 MPa (10,000 psi).

1.2.3 GEOMETRIC SCOPE OF THIS DIVISION

The scope of this Division is intended to include only the vessel and integral communicating chambers, and shall include the following:

(a) Where external piping, other pressure vessels including heat exchangers, or mechanical devices (i.e., pumps, mixers, or compressors) are to be connected to the vessel:

(1) The welding end connection for the first circumferential joint for welded connections (see 4.2.5.9).

(2) The first threaded joint for screwed connections.

(3) The face of the first flange for bolted and flanged connections. Optionally, when the first flange is welded to the nozzle neck, the weld connecting the flange to the nozzle neck may be considered as the first circumferential joint, provided this construction is documented in the User's Design Specification and is properly described on the vessel drawing and the Manufacturer's Data Report Form.

(4) The first sealing surface for proprietary connections or fittings.

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(b) Where non-pressure parts are welded directly to either the internal or external pressure-retaining surface of a pressure vessel, the scope of this Division shall include the design, fabrication, testing, and material requirements established for non-pressure-part attachments by the applicable paragraphs of this Division (see 4.2.5.6).

(c) Pressure-retaining covers and their fasteners (bolts and nuts) for vessel openings, such as manhole and handhole covers.

(d) The first sealing surface for proprietary connections, fittings or components that are designed to rules that are not provided by this Division, such as gages, instruments, and nonmetallic components.

1.2.4 CLASSIFICATIONS OUTSIDE THE SCOPE OF THIS DIVISION

1.2.4.1 The scope of this Division has been established to identify the components and parameters considered in formulating the rules given in this Division. Laws or regulations issued by a Jurisdictional Authority at the location of an installation establish the mandatory applicability of the Code rules, in whole or in part, within that jurisdiction. Those laws or regulations may require the use of this Division of the Code for vessels or components not considered to be within its Scope. These laws or regulations should be reviewed to determine size or service limitations that may be more restrictive than those given here.

1.2.4.2 The following vessels are not included in the scope of this Division. However, any pressure vessel, with the exception of (a) below, that is not excluded from the scope of this Division by 1.2.1.3 and that meets all applicable requirements of this Division may be stamped with the Certification Mark with the U2 Designator. (25)

(a) Vessels within the scope of other Sections.

(b) Fired process tubular heaters as defined in API STD 560.

(c) Pressure containers that are integral parts or components of rotating or reciprocating mechanical devices, such as pumps, compressors, turbines, generators, engines, and hydraulic or pneumatic cylinders where the primary design considerations and/or stresses are derived from the functional requirements of the device.

(d) Structures consisting of piping components, such as pipe, flanges, bolting, gaskets, valves, expansion joints, and fittings whose primary function is the transport of fluids from one location to another within a system of which it is an integral part, that is, piping systems, including the piping system between a pressure relief device and the vessel it protects, see Part 9.

(e) Pressure-containing parts of components, such as strainers and devices that serve such purposes as mixing, separating, snubbing, distributing, and metering or controlling flow, provided that pressure-containing parts of such components are generally recognized as piping components or accessories.

(f) A vessel for containing water under pressure, including those containing air the compression of which serves only as a cushion, when none of the following limitations are exceeded:

(1) A design pressure of 2.07 MPa (300 psi)

(2) A design temperature of 99°C (210°F)

(g) A hot water supply storage tank heated by steam or any other indirect means when none of the following limitations is exceeded:

(1) A heat input of 58.6 kW (200,000 Btu/hr)

(2) A water temperature of 99°C (210°F)

(3) A nominal water containing capacity of 454 L (120 gal)

(h) Vessels with an internal or external design pressure not exceeding 103 kPa (15 psi) with no limitation on size, for multi-chambered vessels, the design pressure on the common elements shall not exceed 103 kPa (15 psi).

(i) Vessels with an inside diameter, width, height, or cross section diagonal not exceeding 150 mm (6 in.), with no limitation on length of vessel or pressure.

(j) Pressure vessels for human occupancy (requirements for pressure vessels for human occupancy are covered in ASME PVHO-1).

1.2.5 COMBINATION UNITS

When a pressure vessel unit consists of more than one pressure chamber, only the chambers that come within the scope of this Division need be constructed in compliance with its provisions (see 4.1.8).

1.2.6 FIELD ASSEMBLY OF VESSELS

1.2.6.1 Field assembly of vessels constructed to this Division may be performed as follows. (25)

(a) The Manufacturer of the vessel completes the vessel in the field, completes the Form A-1 or Form A-1P Manufacturer's Data Report, and stamps the vessel.

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(b) The Manufacturer of parts of a vessel to be completed in the field by some other party stamps these parts in accordance with Code rules and supplies the Form A-2 Manufacturer's Partial Data Report to the other party. The other party, who must hold a valid U2 Certificate of Authorization, makes the final assembly, performs the required NDE, performs the final pressure test, completes the Form A-1 or Form A-1P Manufacturer's Data Report, and stamps the vessel.

(c) The field portion of the work is completed by a holder of a valid U2 Certificate of Authorization other than the vessel Manufacturer. The Certificate holder performing the field work is required to supply a Form A-2 Manufacturer's Partial Data Report covering the organization's portion of the work completed (including data on the pressure test if conducted by the Certificate holder performing the field work) to the Manufacturer responsible for the Code vessel. The vessel Manufacturer applies the Certification Mark with U2 Designator in the presence of a representative from the Inspection Agency and completes the Form A-1 or Form A-1P Manufacturer's Data Report with the Inspector.

1.2.6.2 In all three alternatives, the party completing and signing the Form A-1 or Form A-1P Manufacturer's Data Report assumes full Code responsibility for the vessel. In all three cases, each Manufacturer's Quality Control System shall describe the controls to assure compliance by each Certificate holder.

1.2.7 OVERPRESSURE PROTECTION

The scope of this Division includes provisions for overpressure protection necessary to satisfy the requirements of Part 9.

1.3 STANDARDS REFERENCED BY THIS DIVISION

(a) Throughout this Division, references are made to various standards, such as ASME standards, which describe parts or fittings or which establish dimensional limits for pressure vessel parts. These standards, with the year of the acceptable edition, are listed in Table 1.1.

(b) Rules for the use of these standards are stated elsewhere in this Division.

1.4 UNITS OF MEASUREMENT

(a) Either U.S. Customary, SI, or any local customary units may be used to demonstrate compliance with requirements of this edition related to materials, fabrication, examination, inspection, testing, certification, and overpressure protection.

(b) A single system of units shall be used for all aspects of design except where otherwise permitted by this Division. When components are manufactured at different locations where local customary units are different than those used for the general design, the local units may be used for the design and documentation of that component within the limitations given in (c). Similarly, for proprietary components or those uniquely associated with a system of units different than that used for the general design, the alternate units may be used for the design and documentation of that component within the limitations given in (c).

(c) For any single equation, all variables shall be expressed in a single system of units. Calculations using any material data published in this Division or Section II, Part D (e.g., allowable stresses, physical properties, external pressure design factor B) shall be carried out in one of the standard units given in Table 1.2. When separate equations are provided for U.S. Customary and SI units, those equations shall be executed using variables in the units associated with the specific equation. Data expressed in other units shall be converted to U.S. Customary or SI units for use in these equations. The result obtained from execution of these equations or any other calculations carried out in either U.S. Customary or SI units may be converted to other units.

(d) Production, measurement and test equipment, drawings, welding procedure specifications, welding procedure and performance qualifications, and other fabrication documents may be in U.S. Customary, SI or local customary units in accordance with the fabricator's practice. When values shown in calculations and analysis, fabrication documents or measurement and test equipment are in different units, any conversions necessary for verification of Code compliance and to ensure that dimensional consistency is maintained shall be in accordance with the following:

(1) Conversion factors shall be accurate to at least four significant figures

(2) The results of conversions of units shall be expressed to a minimum of three significant figures

(e) Conversion of units, using the precision specified above shall be performed to assure that dimensional consistency is maintained. Conversion factors between U.S. Customary and SI units may be found in Annex 1-C. Whenever local customary units are used the Manufacturer shall provide the source of the conversion factors which shall be subject to verification and acceptance by the Authorized Inspector or Certified Individual.

(f) Dimensions shown in the text, tables and figures, whether given as a decimal or a fraction, may be taken as a decimal or a fraction and do not imply any manufacturing precision or tolerance on the dimension.

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(g) Material that has been manufactured and certified to either the U.S. Customary or SI material specification (e.g., SA-516 or SA-516M) may be used regardless of the unit system used in design. Standard fittings (e.g., flanges and elbows) that have been certified to either U.S. Customary units or SI units may be used regardless of the units system used in design.

(h) All entries on a Manufacturer's Data Report and data for Code-required nameplate marking shall be in units consistent with the fabrication drawings for the component using U.S. Customary, SI, or local customary units. Units (either primary or alternative) may be shown parenthetically. Users of this Code are cautioned that the receiving Jurisdiction should be contacted to ensure the units are acceptable.

1.5 TOLERANCES

The Code does not fully address tolerances. When dimensions, sizes, or other parameters are not specified with tolerances, the values of these parameters are considered nominal, and allowable tolerances or local variances may be considered acceptable when based on engineering judgment and standard practices as determined by the designer.

1.6 TECHNICAL INQUIRIES

A procedure for submittal of Technical Inquiries to the ASME Boiler and Pressure Vessel Code Committee is contained in the front matter.

1.7 TABLES

Table 1.1
Year of Acceptable Edition of Referenced Standards in This Division (25)

Title	Number	Year
Marking and Labeling Systems	ANSI/UL-969	Latest edition
Fitness-For-Service	API 579-1/ASME FFS-1	2021
Materials and Fabrication of 2¼Cr–1Mo, 2¼Cr–1Mo–¼V, 3Cr–1Mo, and 3Cr–1Mo–¼V Steel Heavy Wall Pressure Vessels for High-Temperature, High-Pressure Hydrogen Service	API RP 934-A	2019
Fired Heaters for General Refinery Service	API Standard 560	Latest edition
Minimum Design Loads and Associated Criteria for Buildings and Other Structures	ASCE/SEI 7	2022
Nuts for General Applications: Machine Screw Nuts, Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)	ASME/ANSI B18.2.2	Latest edition
Unified Inch Screw Threads (UN and UNR Thread Form)	ASME B1.1	Latest edition
Metric Screw Threads — M Profile	ASME B1.13M	Latest edition
Pipe Threads, General Purpose, Inch	ASME B1.20.1	Latest edition
Metric Screw Threads — MJ Profile	ASME B1.21M	Latest edition
Pipe Flanges and Flanged Fittings, NPS ½ Through NPS 24 Metric/Inch Standard	ASME B16.5	2025 [Note (1)]
Factory-Made Wrought Buttwelding Fittings	ASME B16.9	Latest edition
Forged Fittings, Socket-Welding and Threaded	ASME B16.11	Latest edition
Cast Copper Alloy Threaded Fittings, Classes 125 and 250	ASME B16.15	Latest Edition
Metallic Gaskets for Pipe Flanges	ASME B16.20	Latest edition
Cast Copper Alloy Pipe Flanges, Flanged Fittings, and Valves, Classes 150, 300, 600, 900, 1500, and 2500	ASME B16.24	2021
Large Diameter Steel Flanges, NPS 26 Through NPS 60 Metric/Inch Standard	ASME B16.47	2025 [Note (1)]
Metric Heavy Hex Screws	ASME B18.2.3.3M	Latest edition
Metric Fasteners for Use in Structural Applications	ASME B18.2.6M	Latest edition
Conformity Assessment Requirements	ASME CA-1	Latest edition
Pressure Boundary Bolted Flange Joint Assembly	ASME PCC-1	2022
Repair of Pressure Equipment and Piping	ASME PCC-2	2022
Criteria for Shell-and-Tube Heat Exchangers According to Part UHX of ASME Section VIII-Division 1	ASME PTB-7	2014
Qualifications for Authorized Inspection	ASME QAI-1	Latest edition
Standard Practice for Quantitative Measurement and Reporting of Hypoeutectoid Carbon and Low-Alloy Steel Phase Transformations	ASTM A1033	Latest edition
Standard Test Method for Measurement of Fracture Toughness	ASTM E1820	2024

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Table 1.1
Year of Acceptable Edition of Referenced Standards in This Division (Cont'd)

Title	Number	Year
Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings	ASTM E125	1963 (R2023) [Note (2)]
Standard Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks	ASTM E127	2020
Standard Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials	ASTM E139	Latest edition
Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, and Scleroscope Hardness	ASTM E140	Latest edition
Standard Reference Radiographs for Heavy-Walled [2 to 4$^1/_2$ in. (50.8 to 114 mm)] Steel Castings	ASTM E186	2020
Standard Test Method of Conducting Drop Weight Test to Determine Nil Ductility Transition Temperature of Ferritic Steel	ASTM E208	Latest edition
Standard Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Alloy Castings	ASTM E272	2021
Standard Reference Radiographs for Heavy-Walled [4$^1/_2$ to 12 in. (114 to 305 mm)] Steel Castings	ASTM E280	2021
Standard Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness	ASTM E446	2020
Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Austenitic-Ferrite Stainless Steel Weld Metal	AWS A4.2M	2020
Metallic materials — Charpy pendulum impact test — Part 1: Test method	ISO 148-1	Latest edition
Metallic materials — Charpy pendulum impact test — Part 2: Verification of testing machines	ISO 148-2	Latest edition
Metallic materials — Charpy pendulum impact test — Part 3: Preparation and characterization of Charpy V-notch test pieces for indirect verification of pendulum impact machines	ISO 148-3	Latest edition
Petroleum, petrochemical and natural gas industries — Fired heaters for general refinery service	ISO 13705	Latest edition
Standard Practice for Ultrasonic Examination of Steel Forgings	SA-388/SA-388M	Latest edition

NOTES:
(1) The use of a flange or flanged fitting that relies on and meets the requirements of an ASME B16 Case is not permitted.
(2) "R" indicates reaffirmed.

Table 1.2
Standard Units for Use in Equations

Quantity	SI Units	U.S. Customary Units
Linear dimensions (e.g., length, height, thickness, radius, diameter)	millimeters (mm)	inches (in.)
Area	square millimeters (mm^2)	square inches (in.^{2})
Volume	cubic millimeters (mm^3)	cubic inches (in.^{3})
Section modulus	cubic millimeters (mm^3)	cubic inches (in.^{3})
Moment of inertia of section	millimeters^4 (mm^4)	inches^4 (in.^{4})
Mass (weight)	kilograms (kg)	pounds mass (lbm)
Force (load)	newtons (N)	pounds force (lbf)
Bending moment	newton-millimeters (N·mm)	inch-pounds (in.-lb)
Pressure, stress, stress intensity, and modulus of elasticity	megapascals (MPa)	pounds per square inch (psi)
Energy (e.g., Charpy impact values)	joules (J)	foot-pounds (ft-lb)
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)
Absolute temperature	kelvin (K)	Rankine (°R)
Fracture toughness	MPa square root meters (MPa$\sqrt{\text{m}}$)	ksi square root inches (ksi$\sqrt{\text{in.}}$)
Angle	degrees or radians	degrees or radians
Boiler capacity	watts (W)	Btu/hr

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ANNEX 1-B
DEFINITIONS

(Normative)

1-B.1 INTRODUCTION

This Annex contains definitions of terms generally used in this Division. Definitions relating to specific applications may also be found in related Parts of this Division.

1-B.2 DEFINITION OF TERMS (25)

1-B.2.1 Acceptance by the Inspector, accepted by the Inspector - an indication that the Inspector has reviewed a subject in accordance with the Inspector's duties as required by the rules of this Division and after such review is able to sign the Certificate of Inspection for the applicable Manufacturer's Data Report Form.

1-B.2.2 ASME Designated Organization – see ASME CA-1.

1-B.2.3 ASME designee – see ASME CA-1.

1-B.2.4 Certificate of Compliance – a document that states that the material represented has been manufactured, sampled, tested and inspected in accordance with the requirements of the material specification (including year of issue) and any other requirements specified in the purchase order or contract shown on the certificate and has been found to meet such requirements. This document may be combined with the Materials Test Report (see 1-B.2.17) as a single document.

1-B.2.5 Certificate of Authorization – a document issued by the Society that authorizes the use of the ASME Certification Mark and appropriate designator for a specified time and for a specified scope of activity.

1-B.2.6 Certification Mark – an ASME symbol identifying a product as meeting Code requirements.

1-B.2.7 Certification Mark Stamp – a metallic stamp issued by the Society for use in impressing the Certification Mark.

1-B.2.8 Certification Designator (Designator) – the symbol used in conjunction with the Certification Mark for the scope of activity described in a Manufacturer's Certificate of Authorization.

1-B.2.9 Certifying Engineer – an engineer or other technically competent professional duly accredited and qualified to practice engineering as required by this Division.

1-B.2.10 Communicating Chambers – appurtenances to a vessel that intersect the shell or heads of a vessel and form an integral part of the pressure-containing enclosure.

1-B.2.11 Construction – an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and pressure relief.

1-B.2.12 Designer – an individual who is qualified to design pressure vessels in accordance with the rules of this Division by demonstrated knowledge in Code requirements and proficiency in selecting correct design formulas and appropriate values to be used when preparing the design of a pressure vessel.

1-B.2.13 Local Jurisdictional Authority – an agency enforcing laws or regulations applicable to pressure vessels.

1-B.2.14 Manufacturer – the organization responsible for construction of a pressure vessel, vessel component, or part in accordance with the rules of this Division and who holds an ASME Certificate of Authorization to apply the Certification Mark to such an item.

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1-B.2.15 Material – any substance or product form covered by a material specification in Section II Part A, B, or C or any other substance or product form permitted for use in pressure vessel construction by this Division.

1-B.2.16 Material Manufacturer – the organization responsible for the production of products meeting the requirements of the material specification and accepting the responsibility for any statements or data in any required Certificate of Compliance or Material Test Report representing the material.

1-B.2.17 Material Test Report – a document in which the results of tests, examinations, repairs, or treatments required by the material specification to be reported are recorded, including those of any supplementary requirements or other requirements stated in the order for the material. This document may be combined with a Certificate of Compliance (see 1-B.2.4) as a single document.

1-B.2.18 User – the organization that purchases the finished pressure vessel for its own use or as an agent for the owner. The user's designated agent may be either a design agency specifically engaged by the user, the Manufacturer of a system for a specific service which includes a pressure vessel as a part and which is purchased by the user, or an organization which offers pressure vessels for sale or lease for specific services.

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ANNEX 1-C
GUIDANCE FOR THE USE OF U.S. CUSTOMARY AND SI UNITS IN THE ASME BOILER AND PRESSURE VESSEL CODES

(Informative)

1-C.1 USE OF UNITS IN EQUATIONS

The equations in this Division are suitable for use only with either the SI or U.S. Customary units provided in Table 1.2 or with the units provided in the nomenclatures associated with the equations. It is the responsibility of the individual and organization performing the calculations to ensure that appropriate units are used. Either SI or U.S. Customary units may be used as a consistent set. When necessary to convert from one system to another, the units shall be converted to at least four significant figures for use in calculations and other aspects of construction.

1-C.2 GUIDELINES USED TO DEVELOP SI EQUIVALENTS

(a) U.S. Customary units are placed in parenthesis after the SI unit in the text.

(b) In general, both SI and U.S. Customary tables are provided if interpolation is expected. The table designation (e.g., table number) is the same for both the SI and the U.S. Customary tables, with the addition of an M after the table number for the SI Table. In the text, references to a Table use only the primary table number (i.e., without the M). For some small tables, where interpolation is not required, U.S. Customary units are placed in parenthesis after the SI unit.

(c) Separate SI and U.S. Customary versions of graphical information (charts) are provided, except that if both axes are dimensionless a single figure (chart) is used.

(d) In most cases, conversions of units in the text were done using hard SI conversion practices, with some soft conversions on a case-by-case basis as appropriate. This was implemented by rounding the SI values to the number of significant figures of implied precision in the existing U.S. Customary units. For example, 3,000 psi has an implied precision of one significant figure. Therefore, the conversion to SI units would typically be to 20 000 kPa. This is a difference of about 3% from the “exact” or soft conversion of 20 684.27 kPa. However, the precision of the conversion was determined by the Committee on a case-by-case basis. More significant digits were included in the SI equivalent if there was any question. The values of allowable stress in Section II, Part D generally include three significant figures.

(e) Minimum thickness and radius values that are expressed in fractions of an inch were generally converted according to Table 1-C.1.

(f) For nominal sizes that are in even increments of inches, even multiples of 25 mm were generally used. Intermediate values were interpolated rather than converting and rounding to the nearest mm. See examples in Table 1-C.2. Note that this table does not apply to nominal pipe sizes (NPS), which are covered in Table 1-C.4.

(g) For nominal pipe sizes, the relationships shown in Table 1-C.4 were used.

(h) Areas in square inches ($in.^2$) were converted to square millimeters (mm^2), and areas in square feet (ft^2) were converted to square meters (m^2), see examples in Table 1-C.5.

(i) Volumes in cubic inches ($in.^3$) were converted to cubic millimeters (mm^3), and volumes in cubic feet (ft^3) were converted to cubic meters (m^3), see examples in the Table 1-C.6.

(j) Although the pressure should always be in MPa or psi for calculations, there are cases where other units are used in the text. For example, kPa is sometimes used for low pressures and ksi is sometimes used for high pressures and stresses. Also, rounding was to one significant figure (two at the most) in most cases, see examples in Table 1-C.7. Note that 14.7 psi converts to 101 kPa, while 15 psi converts to 100 kPa. While this may seem at first glance to be an anomaly, it is consistent with the rounding philosophy.

(k) Material properties that are expressed in psi or ksi (e.g., allowable stress, yield and tensile strength, elastic modulus) were generally converted to MPa to three significant figures. See example in Table 1-C.8.

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(l) In most cases, temperatures (e.g., for PWHT) were rounded to the nearest 5°C. Depending on the implied precision of the temperature, some were rounded to the nearest 1°C or 10°C or even 25°C. Temperatures colder than 0°F (negative values) were generally rounded to the nearest 1°C. The examples in Table 1-C.9 were created by rounding to the nearest 5°C, with one exception.

1-C.3 SOFT CONVERSION FACTORS

Table 1-C.10 of "soft" conversion factors is provided for convenience. Multiply the U.S. Customary value by the factor given to obtain the SI value. Similarly, divide the SI value by the factor given to obtain the U.S. Customary value. In most cases it is appropriate to round the answer to three significant figures.

1-C.4 TABLES

Table 1-C.1
Typical Size or Thickness Conversions for Fractions

Fraction in U.S. Customary Units, in.	Proposed SI Conversion, mm	Difference, %
1/32	0.8	−0.8
3/64	1.2	−0.8
1/16	1.5	5.5
3/32	2.5	−5.0
1/8	3	5.5
5/32	4	−0.8
3/16	5	−5.0
7/32	5.5	1.0
1/4	6	5.5
5/16	8	−0.8
3/8	10	−5.0
7/16	11	1.0
1/2	13	−2.4
9/16	14	2.0
5/8	16	−0.8
11/16	17	2.6
3/4	19	0.3
7/8	22	1.0
1	25	1.6

Table 1-C.2
Typical Size or Thickness Conversions

Size, in.	Size, mm
1	25
1 1/8	29
1 1/4	32
1 1/2	38
2	50
2 1/4	57
2 1/2	64
3	75
3 1/2	89
4	100
4 1/2	114

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Table 1-C.2
Typical Size or Thickness Conversions (Cont'd)

Size, in.	Size, mm
5	125
6	150
8	200
12	300
18	450
20	500
24	600
36	900
40	1 000
54	1 350
60	1 500
72	1 800

Table 1-C.3
Typical Size or Length Conversions

Size or Length, ft	Size or Length, m
3	1
5	1.5
200	60

Table 1-C.4
Typical Nominal Pipe Size Conversions

U.S. Customary Practice	SI Practice	U.S. Customary Practice	SI Practice
NPS 1/8	DN 6	NPS 20	DN 500
NPS 1/4	DN 8	NPS 22	DN 550
NPS 3/8	DN 10	NPS 24	DN 600
NPS 1/2	DN 15	NPS 26	DN 650
NPS 3/4	DN 20	NPS 28	DN 700
NPS 1	DN 25	NPS 30	DN 750
NPS 1 1/4	DN 32	NPS 32	DN 800
NPS 1 1/2	DN 40	NPS 34	DN 850
NPS 2	DN 50	NPS 36	DN 900
NPS 2 1/2	DN 65	NPS 38	DN 950
NPS 3	DN 80	NPS 40	DN 1 000
NPS 3 1/2	DN 90	NPS 42	DN 1 050
NPS 4	DN 100	NPS 44	DN 1 100
NPS 5	DN 125	NPS 46	DN 1 150
NPS 6	DN 150	NPS 48	DN 1 200
NPS 8	DN 200	NPS 50	DN 1 250
NPS 10	DN 250	NPS 52	DN 1 300
NPS 12	DN 300	NPS 54	DN 1 350
NPS 14	DN 350	NPS 56	DN 1 400
NPS 16	DN 400	NPS 58	DN 1 450
NPS 18	DN 450	NPS 60	DN 1 500

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Table 1-C.5
Typical Area Conversions

Area in U.S. Customary	Area in SI
1 $in.^2$	650 mm^2
6 $in.^2$	4 000 mm^2
10 $in.^2$	6 500 mm^2
5 ft^2	0.5 m^2

Table 1-C.6
Typical Volume Conversions

Volume in U.S. Customary	Volume in SI
1 $in.^3$	16 000 mm^3
6 $in.^3$	100 000 mm^3
10 $in.^3$	160 000 mm^3
5 ft^3	0.14 m^3

Table 1-C.7
Typical Pressure Conversions

Pressure in U.S. Customary	Pressure in SI
0.5 psi	3 kPa
2 psi	15 kPa
3 psi	20 kPa
10 psi	70 kPa
14.7 psi	101 kPa
15 psi	100 kPa
30 psi	200 kPa
50 psi	350 kPa
100 psi	700 kPa
150 psi	1 MPa
200 psi	1.5 MPa
250 psi	1.7 MPa
300 psi	2 MPa
350 psi	2.5 MPa
400 psi	3 MPa
500 psi	3.5 MPa
600 psi	4 MPa
1,200 psi	8 MPa
1,500 psi	10 MPa

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Table 1-C.8
Typical Strength Conversions

Strength in U.S. Customary, psi	Strength in SI, MPa
30,000	205
38,000	260
60,000	415
70,000	480
95,000	655

Table 1-C.9
Typical Temperature Conversions

Temperature, °F	Temperature, °C
70	20
100	38
120	50
150	65
200	95
250	120
300	150
350	175
400	205
450	230
500	260
550	290
600	315
650	345
700	370
750	400
800	425
850	455
900	480
925	495
950	510
1,000	540
1,050	565
1,100	595
1,150	620
1,200	650
1,250	675
1,800	980
1,900	1 040
2,000	1 095
2,050	1 120

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Table 1-C.10
Conversion Factors

U.S. Customary	SI	Conversion Factor	Notes
in.	mm	25.4	...
ft	m	0.3048	...
$in.^2$	mm^2	645.16	...
ft^2	m^2	0.09290304	...
in^3	mm^3	16,387.064	...
ft^3	m^3	0.02831685	...
US Gal.	m^3	0.003785412	...
psi	MPa	0.0068948	Used exclusively in equations
psi	kPa	6.894757	Used only in text and for nameplate
ft-lb	J	1.355818	...
°F	°C	$^5/_9$(°F − 32)	Not for temperature difference
°F	°C	$^5/_9$(°F)	For temperature differences only
R	K	$^5/_9$	Absolute temperature
lbm	kg	0.4535924	...
lbf	N	4.448222	...
in.-lb	N·mm	112.98484	Use exclusively in equations
ft-lb	N·m	1.3558181	Use only in text
$ksi\sqrt{in}$	$MPa\sqrt{m}$	1.0988434	...
Btu/hr	W	0.2930711	Use for Boiler rating and heat transfer
lb/ft^3	kg/m^3	16.018463	...

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PART 2
RESPONSIBILITIES AND DUTIES

2.1 GENERAL

2.1.1 INTRODUCTION

The user, Manufacturer, and Inspector involved in the production and certification of vessels in accordance with this Division have definite responsibilities or duties in meeting the requirements of this Division. The responsibilities and duties set forth in the following relate only to compliance with this Division, and are not to be construed as involving contractual relations or legal liabilities.

2.1.2 DEFINITIONS

The definitions for the terminology used in this Part are contained in Annex 1-B.

2.1.3 CODE REFERENCE

The Code Edition year on the User's Design Specification and Manufacturer's Design Report shall be the same as the Code Edition year on the Manufacturer's Data Report.

2.2 USER RESPONSIBILITIES

2.2.1 GENERAL

2.2.1.1 It is the responsibility of the user or an agent acting on behalf of the user to provide a User's Design Specification for each pressure vessel to be constructed in accordance with this Division. The User's Design Specification shall contain sufficient detail to provide a complete basis for design and construction in accordance with this Division. It is the user's responsibility to specify, or cause to be specified, the effective Code edition to be used for construction. (25)

2.2.1.2 The User's Design Specification shall be certified by a Certifying Engineer meeting the requirements described in Annex 2-A when the user provides the data required by 2.2.3.1(f)(1) and 2.2.3.1(f)(2) to perform a fatigue analysis.

2.2.2 MULTIPLE IDENTICAL VESSELS

A single User's Design Specification may be prepared to support the design of more than one pressure vessel that is to be located in a single, specific jurisdiction provided that the environmental requirements and jurisdictional regulatory authority applied for each installation location are clearly specified and are the same or more conservative than required.

2.2.3 USER'S DESIGN SPECIFICATION

2.2.3.1 The User's Design Specification shall include but not necessarily be limited to the following: (25)

(a) Installation Site
  (1) Location
  (2) Jurisdictional authority if applicable
  (3) Environmental conditions
    (-a) Wind design loads including relevant factors (i.e., design wind speed, exposure, gust factors)
    (-b) Earthquake design loads
    (-c) Snow loads
    (-d) Lowest one day mean temperature for location
(b) Vessel Identification
  (1) Vessel number or identification
  (2) Service fluid for proprietary fluids specific properties needed for design, e.g., gas, liquid, density, etc.
(c) Vessel Configuration and Controlling Dimensions
  (1) Outline drawings

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(2) Vertical or horizontal

(3) Openings, connections, closures including quantity, type and size, and location (i.e., elevation and orientation)

(4) Principal component dimensions in sufficient detail so that volume capacities can be determined

(5) Support method

(d) Design Conditions

(1) Specified design pressure. The specified design pressure is the design pressure, see 4.1.5.2(a), required at the top of the vessel in its operating position. It shall include suitable margins required above the maximum anticipated operating pressure to ensure proper operation of the pressure relief devices. The MAWP of the vessel may be set equal to this specified design pressure. If the actual MAWP of the vessel is calculated, it shall not be less than the specified design pressure.

(2) Design temperature and coincident specified design pressure [see 4.1.5.2(d)].

(3) Minimum Design Metal Temperature (MDMT) and coincident specified design pressure [see 4.1.5.2(e)].

(4) Dead loads, live loads, and other loads required to perform the load case combinations required in Parts 4 and 5.

(e) Operating Conditions

(1) Operating pressure and pressure load factor for occasional load combinations in Tables 4.1.2 and 5.3

(2) Operating temperature

(3) Fluid transients and flow and sufficient properties for determination of steady-state and transient thermal gradients across the vessel sections, if applicable (see 5.5.3)

(4) Dead loads, live loads, and other operating loads required to perform the load case combinations required in Part 5

(f) Design Fatigue Life

(1) Cyclic operating conditions and whether or not a fatigue analysis of the vessel is required shall be determined in accordance with 4.1.1.4. When a fatigue analysis is required, provide information in sufficient detail so that an analysis of the cyclic operation can be carried out in accordance with 5.5.

(2) When a vessel is designed for cyclic conditions, the number of design cycles per year and the required vessel design life in years shall be stated.

(3) When cyclic operating conditions exist and a fatigue analysis is not required based on comparable equipment experience, this shall be stated. The possible harmful effects of the design features listed in 5.5.2(a) through 5.5.2(f) shall be evaluated when contemplating comparable equipment experience.

(4) Corrosion Fatigue

(-a) The design fatigue cycles given by eqs. (3-F.21) and (3-F.22) do not include any allowances for corrosive conditions and may be modified to account for the effects of environment other than ambient air that may cause corrosion or subcritical crack propagation. If corrosion fatigue is anticipated, a factor should be chosen on the basis of experience or testing, by which the calculated design fatigue cycles (fatigue strength) should be reduced to compensate for the corrosion.

(-b) When using eq. (3-F.22) an environmental modification factor shall be specified in the User's Design Specification.

(-c) If due to lack of experience it is not certain that the chosen stresses are low enough, it is advisable that the frequency of inspection be increased until there is sufficient experience to justify the factor used. This need for increased frequency should be stated in the User's Design Specification.

(g) Materials of Construction

(1) Material specification requirements shall be in accordance with one or more of the following criteria.

(-a) Specification of materials of construction in accordance with Part 3.

(-b) Generic material type (i.e., carbon steel or Type 304 Stainless Steel). The user shall specify requirements that provide an adequate basis for selecting materials to be used for the construction of the vessel. The Manufacturer shall select the appropriate material from Part 3, considering information provided by the user per (3).

(2) The user shall specify the corrosion and/or erosion allowance.

(3) The user, when selecting the materials of construction, shall consider the following:

(-a) Damage mechanisms associated with the service fluid at design conditions. Informative and nonmandatory guidance regarding metallurgical phenomena is provided in Section II, Part D, Nonmandatory Appendix A; API RP 571; and WRC Bulletins 488, 489, and 490.

(-b) Minimum Design Metal Temperature and any additional toughness requirements.

(-c) The need for specific weld filler material to meet corrosion resistance requirements, see 6.2.5.8.

(h) Loads and Load Cases

(1) The user shall specify all expected loads and load case combinations as listed in 4.1.5.3.

(2) These loading data may be established by:

(-a) Calculation

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(-b) Experimental methods
(-c) Actual experience measurement from similar units
(-d) Computer analysis
(-e) Published data

(i) Overpressure Protection

(1) The user shall be responsible for the design, construction and installation of the overpressure protection system unless it is delegated to the Manufacturer. This system shall meet the requirements of Part 9.

(2) The type of over pressure protection intended for the vessel shall be documented in the User's Design Specification as follows (see 9.1):

(-a) Type of overpressure protection system (e.g., type of pressure relief valve, rupture disc, etc.)
(-b) System design [see 9.5(e)]

(3) The user shall state if jurisdictional acceptance is required prior to operation of the vessel.

2.2.3.2 Additional Requirements. The user shall state what additional requirements are appropriate for the intended vessel service such as:

(a) Additional requirements such as non-destructive examination, restricted chemistry, or heat treatments
(b) Type of weld joints and the extent of required nondestructive examinations
(c) Nonmandatory or optional provisions of this Division that are considered to be mandatory for the subject vessel
(d) Any special requirements for marking and their location (see 4.1 and Annex 2-F)
(e) Requirements for seals and/or bolting for closures and covers
(f) Additional requirements relating to erection loadings
(g) Any agreements which resolve the problems of operation and maintenance control unique to the particular pressure vessel. See also 2.2.3.1(f)(4)(-c).
(h) Specific additional requirements relating to pressure testing such as:
(1) Fluid properties and test temperature limits
(2) Position of vessel and support/foundation adequacy if field hydrostatic testing is required
(3) Location: Manufacturer's facility or on-site
(4) Cleaning and drying
(5) Selection of pressure test method (see 8.1.1)
(6) Application of paints, coatings and linings [see 8.1.2(e)]

2.3 MANUFACTURER'S RESPONSIBILITIES

2.3.1 CODE COMPLIANCE

2.3.1.1 The Manufacturer is responsible for the structural and pressure-retaining integrity of a vessel or part thereof, as established by conformance with the requirements of the rules of this Division and the requirements in the User's Design Specification.

2.3.1.2 The Manufacturer completing any vessel or part marked with the Certification Mark with the U2 Designator or the Certification Mark with the PRT VIII-2 Designator in accordance with this Division has the responsibility to comply with all the applicable requirements of this Division and, through proper certification, to ensure that any work by others also complies with the requirements of this Division. The Manufacturer shall certify compliance with these requirements by completing a Manufacturer's Data Report (see 2.3.4). (25)

2.3.1.3 The PRT VIII-2 Certificate Holder is not permitted to assume full Code responsibility for the completed vessel. The PRT VIII-2 Certificate Holder shall only assume responsibility for the construction and marking of completed parts.

2.3.1.4 A single Manufacturer's Design Report may be completed and certified to document more than one pressure vessel that is to be located in a single, specific jurisdiction, provided that the details of design and construction demonstrate that the environmental requirements and jurisdictional regulatory authority applied for each installation location are the same or more conservative than required.

2.3.2 MATERIALS SELECTION

2.3.2.1 When generic material types (i.e., carbon steel or Type 304 Stainless Steel) are specified, the Manufacturer shall select the appropriate material from Part 3, considering information provided by the user per 2.2.3.1(g)(3).

2.3.2.2 Any material substitutions by the Manufacturer are subject to approval of the user.

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2.3.3 MANUFACTURER'S DESIGN REPORT

(25) **2.3.3.1 Certification of a Manufacturer's Design Report.**

(a) The Manufacturer's Design Report shall be certified by a Certifying Engineer in accordance with Annex 2-B when any of the following are performed:

(1) fatigue analysis

(2) use of Part 5 to determine thickness of pressure parts when design rules are not provided in Part 4

(3) use of Part 5 to establish design thickness in lieu of Part 4 specified in 4.1.1.5

(4) use of Part 4.8 to design a quick-actuating closure

(5) a dynamic seismic analysis

(b) The Manufacturer's Design Report may be certified by an engineer or a designer in accordance with Annex 2-B when none of the conditions of (a)(1) through (a)(5) apply.

2.3.3.2 Contents of the Manufacturer's Design Report. The Manufacturer shall provide a Manufacturer's Design Report that includes:

(a) Final as-built drawings.

(b) The actual material specifications used for each component.

(c) Design calculations and analysis that establish that the design as shown on the drawings complies with the requirements of this Division for the design conditions that have been specified in the User's Design Specification.

(1) Documentation of design-by-rule calculations in Part 4 shall include the following:

(-a) The name and version of computer software, if applicable

(-b) Loading conditions and boundary conditions used to address the load cases in the User's Design Specification

(-c) Material models utilized for all required physical properties (i.e., stress–strain data, modulus of elasticity, Poisson's ratio, thermal expansion coefficient, thermal conductivity, thermal diffusivity), strength parameters (i.e., yield and tensile strength), and allowable stresses

(-d) Detailed calculations, including results from all of the applicable steps in the calculations, showing the acceptance criteria utilized to meet the requirements of this Division.

(-e) A summary of the calculation results

(2) Documentation of design-by-analysis calculations in Part 5 shall include the following:

(-a) A detailed description of the numerical method used, including the name and version of computer software, if applicable

(-b) Description of model geometry (including element type for finite element analysis)

(-c) Loading conditions and boundary conditions used to address the load cases in the User's Design Specification

(-d) Material models utilized for all required physical properties (i.e., modulus of elasticity, Poisson's ratio, thermal expansion coefficient, thermal conductivity, thermal diffusivity), strength parameters (i.e., yield and tensile strength), strain limits, if applicable, and the design membrane stress intensity per Part 3

(-e) Description of whether material nonlinearity is utilized in the analysis including a description of the material model (i.e., stress–strain curve and cyclic stress–strain curve)

(-f) Description of the numerical analysis procedure (i.e., static analysis, thermal analysis (temperature and stress), buckling analysis, natural frequency analysis, dynamic analysis) and whether a geometrically linear or nonlinear option is invoked

(-g) Graphical display of relevant results (i.e., numerical model, deformed plots, and contour plots of thermal and stress results)

(-h) Method used to validate the numerical model (i.e., mesh sensitivity review and equilibrium check for finite element analysis, e.g., check of hoop stress in a component away from structural discontinuity and a check to ensure that global equilibrium is achieved between applied loads and reactions at specified boundary conditions)

(-i) Description of results processing performed to establish numerical analysis results (i.e., stress linearization method, use of centroidal or nodal values for stress, strain, and temperature results)

(-j) A summary of the numerical analysis results showing the acceptance criteria utilized to meet the requirements of this Division

(-k) Electronic storage of analysis results including input files and output files that contain numerical analysis results utilized to demonstrate compliance with the requirements of this Division

(d) Any methods of design used that are not covered by the rules of this Division.

(e) The results of any fatigue analyses according to 5.5, as applicable.

(f) Any assumptions used by the Manufacturer to perform the vessel design.

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2.3.4 MANUFACTURER'S DATA REPORT

The Manufacturer shall certify compliance to the requirements of this Division by the completion of the appropriate Manufacturer's Data Report as described in Annex 2-C and Annex 2-D.

2.3.5 MANUFACTURER'S CONSTRUCTION RECORDS

The Manufacturer shall prepare, collect and maintain construction records and documentation as fabrication progresses, to show compliance with the Manufacturer's Design Report (e.g., NDE reports, repairs, deviations from drawings, etc.). An index of the construction records files, in accordance with the Manufacturer's Quality Control System, shall be maintained current (see 2-C.3). These construction records shall be maintained by the Manufacturer for the duration as specified in 2-C.3.

2.3.6 QUALITY CONTROL SYSTEM

The Manufacturer shall have and maintain a Quality Control System in accordance with Annex 2-E.

2.3.7 MANUFACTURER'S DESIGN PERSONNEL

2.3.7.1 The Manufacturer has the responsibility of ensuring all personnel performing and/or evaluating design activities are competent in the area of design (see Annexes 2-C and 2-J).

2.3.7.2 The Manufacturer shall maintain a controlled document, referenced in the Quality Control System, identifying the persons who may exercise control of the design work performed by others.

2.3.8 CERTIFICATION OF SUBCONTRACTED SERVICES

2.3.8.1 The Quality Control System shall describe the manner in which the Manufacturer (Certificate Holder) controls and accepts the responsibility for the subcontracting of activities. The Manufacturer shall ensure that all contracted activities meet the requirements of this Division.

2.3.8.2 Work such as forming, nondestructive examination, heat treating, etc., may be performed by others (for welding, see 6.1.4.2). It is the vessel Manufacturer's responsibility to ensure that all work performed complies with all the applicable requirements of this Division. After ensuring compliance, and obtaining concurrence of the Inspector, the vessel may be stamped with the Certification Mark.

2.3.8.3 Subcontracts that involve welding on the pressure boundary components for construction under the rules of this Division, other than as provided in 6.1.4.2 and for repair welds permitted by the ASME material specifications, shall be made only to subcontractors holding a valid U2 Certificate of Authorization. All such subcontracted welding shall be documented on Form A-2 (see Annex 2-D).

2.3.8.4 A Manufacturer may engage individuals by contract for their services as Welders or Welding Operators, at shop or site locations shown on the Certification of Authorization, provided all of the following conditions are met: (**25**)

(a) The work to be done by Welders or Welding Operators is within the scope of the Certificate of Authorization.

(b) The use of such Welders or Welding Operators is described in the Quality Control System of the Manufacturer. The Quality Control System shall include a requirement for direct supervision and direct technical control of the Welders and Welding operators, acceptable to the Manufacturer's accredited Authorized Inspection Agency.

(c) The Welding Procedures have been properly qualified by the Manufacturer, according to Section IX.

(d) The Welders and Welding Operators are qualified by the Manufacturer according to Section IX to perform these procedures.

(e) Code responsibility and control is retained by the Manufacturer.

2.3.9 INSPECTION AND EXAMINATION

The Manufacturer's responsibility for inspection and examination is summarized in Annex 7-A.

2.3.10 APPLICATION OF CERTIFICATION MARK

Vessels or parts shall be stamped in accordance with the requirements in Annex 2-F. The procedure to obtain and use a Certification Mark is described in Annex 2-G.

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2.4 THE INSPECTOR

(25) ### 2.4.1 IDENTIFICATION OF INSPECTOR

All references to Inspectors throughout this Division shall mean the Authorized Inspector. All inspections required by this Division shall be performed by an Authorized Inspector. An Authorized Inspector is an individual qualified and regularly employed by an ASME-accredited Authorized Inspection Agency, in accordance with ASME QAI-1. The Inspector shall not be in the employ of the Manufacturer.

2.4.2 INSPECTOR QUALIFICATION

All Inspectors shall have been qualified in accordance with ASME QAI-1.

2.4.3 INSPECTOR'S DUTIES

2.4.3.1 It is the duty of the Inspector to make all the inspections specified by the rules of this Division. In addition, the Inspector shall make other such inspections as considered necessary in order to ensure that all requirements have been met. Some typical required inspections and verifications that are defined in the applicable rules are included in the Inspector's responsibility for inspection and examination as summarized in Annex 7-A.

2.4.3.2 The Inspector of the completed vessel does not have the duty of establishing the accuracy of the design calculations but has the duty of verifying that the required design calculations have been performed. The Inspector has the duty of verifying that the Manufacturer of the completed vessel has the User's Design Specification on file and that the requirements specified therein have been addressed in the Manufacturer's Design Report. The Inspector shall verify that both the User's Design Specification and the Manufacturer's Design Report are certified in accordance with the requirements of this Division.

2.4.3.3 The Inspector shall verify that the Manufacturer has a valid Certificate of Authorization and is working according to an approved Quality Control System including having a system in place to maintain the documentation for the Manufacturer's construction records current with production, and the reconciliation of any deviations from the Manufacturer's Design Report.

2.4.3.4 The Inspector shall certify the Manufacturer's Data Report. When the Inspector has certified by signing the Manufacturer's Data Report, this indicates acceptance by the Inspector. This acceptance does not imply assumption by the Inspector of any responsibilities of the Manufacturer.

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ANNEX 2-A
GUIDE FOR CERTIFYING A USER'S DESIGN SPECIFICATION

(Normative)

2-A.1 GENERAL

(a) When required in 2.2.1, one or more individuals in responsible charge of the specification of the vessel and the required design conditions shall certify that the User's Design Specification meets the requirements of this Division and any additional requirements needed for adequate design. Such certification requires the signature(s) of one or more Certifying Engineers as described in (b). One or more individuals may sign the documentation based on information they reviewed and the knowledge and belief that the objectives of this Division have been satisfied.

(b) One or more individuals in responsible charge of the specification of the vessel and the required design conditions shall certify that the User's Design Specification meets the requirements in 2.2.3. Such certification requires the signature(s) of one or more Certifying Engineers with the requisite technical stature and, when applicable, jurisdictional authority to sign such a document. One or more individuals shall sign the documentation based on information they reviewed and the knowledge and belief that the objectives of this Division have been satisfied. In addition, these individuals shall prepare a statement to be affixed to the document attesting to compliance with the applicable requirements of the Code (see 2-A.2.3).

2-A.2 CERTIFICATION OF THE USER'S DESIGN SPECIFICATION

2-A.2.1 When required by 2.2.1.2, certification of the User's Design Specification requires the signature(s) of one or more Certifying Engineers with requisite experience and qualifications as defined in Annex 2-J. The Certifying Engineer(s) shall certify that the User's Design Specification meets the requirements of 2.2.3. (25)

(a) The Certifying Engineer(s) shall prepare a statement to be affixed to the document attesting to compliance with the applicable requirements of the Code (see 2-A.2.3).

(b) This Certifying Engineer shall be other than the Certifying Engineer who certifies the Manufacturer's Design Report, although both may be employed by or affiliated with the same organization.

(c) The Certifying Engineer shall identify the location and authority under which the authority to perform engineering work stipulated in the User's Design Specification was granted.

2-A.2.2 When more than one Certifying Engineer certifies and signs the User's Design Specification the area of expertise shall be noted next to their signature under "areas of responsibilities" (e.g., design, metallurgy, pressure relief, fabrication). In addition, one of the Certifying Engineers signing the User's Design Specification shall certify that all elements required by this Division are included in the Specification.

2-A.2.3 An example of a typical User's Design Specification Certification Form is shown in Table 2-A.1.

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2-A.3 TABLES

(25)

Table 2-A.1
Typical Certification of Compliance of the User's Design Specification

CERTIFICATION OF COMPLIANCE OF THE USER'S DESIGN SPECIFICATION

I (We), the undersigned, being experienced and competent in the applicable field of design related to pressure vessel requirements relative to this User's Design Specification, certify that to the best of my knowledge and belief it is correct and complete with respect to the Design and Service Conditions given and provides a complete basis for construction in accordance with Part 2, 2.2.3 and other applicable requirements of the ASME Section VIII, Division 2 Pressure Vessel Code, _____ Edition, and Code Case(s) _____.

This certification is made on behalf of the organization that will operate these vessels (company name)_____.

Certified by: _____

Title and areas of responsibility: _____

Date: _____

Certified by: _____

Title and areas of responsibility: _____

Date: _____

Certifying Engineer Seal: (As required)

_____

Date: _____

Engineer's registration authority: _____

Registration authority location: _____

Engineer's registration number (if applicable): _____

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ANNEX 2-B
GUIDE FOR CERTIFYING A MANUFACTURER'S DESIGN REPORT

(Normative)

2-B.1 GENERAL (25)

(a) As required in 2.3.3, one or more individuals in responsible charge of the design of the vessel(s) shall certify that the Manufacturer's Design Report is complete, accurate, and in accordance with the User's Design Specification, and that all the requirements of this Division and any additional requirements needed for adequate design have been met. Such certification requires the signature(s) of one or more individuals as described in (b). One or more individuals may sign the documentation based on information they reviewed and the knowledge and belief that the requirements of this Division have been satisfied.

(b) One or more individual(s) experienced in pressure vessel design shall certify that the Manufacturer's Design Report meets the requirements in 2.3.3. Such certification requires the signature(s) of one or more individuals with the requisite technical and corporate authority needed for such a document. These responsible individuals shall sign the documentation based on information they have reviewed and the knowledge and belief that the objectives of this Division have been satisfied. In addition, these individuals shall prepare a statement to be affixed to the document attesting to compliance with the applicable requirements of the Code (see 2-B.4).

(c) The Inspector shall review the Manufacturer's Design Report and ensure that the requirements of 2.4.3 have been satisfied.

2-B.2 CERTIFICATION OF MANUFACTURER'S DESIGN REPORT BY A CERTIFYING ENGINEER

2-B.2.1 When required by 2.3.3.1(a), certification of the Manufacturer's Design Report requires the signature(s) of one or more Certifying Engineers with requisite experience and qualifications as defined in Annex 2-J. The Certifying Engineer(s) shall certify that the Manufacturer's Design Report meets the requirements of 2.3.3. (25)

(a) The Certifying Engineer(s) shall prepare a statement to be affixed to the document attesting to compliance with the applicable requirements of the Code (see 2-B.4).

(b) This Certifying Engineer shall be other than the Certifying Engineer who certifies the User's Design Specification, although both may be employed by or affiliated with the same organization.

(c) The Certifying Engineer shall identify the location and authority under which the authority to perform engineering work stipulated in the User's Design Specification was granted.

2-B.2.2 When more than one Certifying Engineer certifies and signs the Manufacturer's Design Report, the area of expertise shall be noted next to their signature under "areas of responsibilities" (e.g., design, metallurgy, pressure relief, fabrication). In addition, one of the Certifying Engineers signing the Manufacturer's Design Report shall certify that all elements required by this Division are included in the Report.

2-B.3 CERTIFICATION OF A MANUFACTURER'S DESIGN REPORT BY AN ENGINEER OR A DESIGNER

When permitted by 2.3.3.1(b), certification of the Manufacturer's Design Report requires the signature(s) of one or more engineers or designers with requisite experience and qualifications as defined in Annex 2-J. The engineer(s) or designer(s) shall certify that the Manufacturer's Design report meets the requirements of 2.3.3. The Inspector shall review the Manufacturer's Design Report and ensure that the requirements of 2.4.3 have been satisfied.

(a) The engineer or designer shall prepare a statement to be affixed to the document attesting to its compliance with the applicable requirements of the Code (see 2-B.4).

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(b) When more than one engineer or designer certifies and signs the Manufacturer's Design Report, the area of expertise shall be noted next to their signature under "areas of responsibilities" (e.g., design, metallurgy, pressure relief, fabrication). In addition, one of the engineers or designers signing the Manufacturer's Design Report shall certify that all elements required by this Division are included in the report.

2-B.4 MANUFACTURER'S DESIGN REPORT CERTIFICATION FORM

An example of a typical Manufacturer's Design Report Certification Form is shown in Table 2-B.1.

2-B.5 TABLES

(25)

Table 2-B.1
Typical Certification of Compliance of the Manufacturer's Design Report

CERTIFICATION OF COMPLIANCE OF THE MANUFACTURER'S DESIGN REPORT

I (We), the undersigned, being experienced and competent in the applicable field of design related to pressure vessel construction relative to the certified User's Design Specification, certify that to the best of my knowledge and belief the Manufacturer's Design Report is complete, accurate and complies with the User's Design Specification and with all the other applicable construction requirements of the ASME Section VIII, Division 2 Pressure Vessel Code, _____ Edition, and Code Case(s) _____

This certification is made on behalf of the Manufacturer (company name) _____.

Certified by: _____

Title and areas of responsibility: _____

Date: _____

Certified by: _____

Title and areas of responsibility: _____

Date: _____

Certifying Engineer Seal: (As required)

_____

Date: _____

Engineer's registration authority: _____

Registration authority location: _____

Engineer's registration number (if applicable): _____

Authorized Inspector Review: _____

Date: _____

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ANNEX 2-C
REPORT FORMS AND MAINTENANCE OF RECORDS

(Normative)

2-C.1 MANUFACTURER'S DATA REPORTS

2-C.1.1 A Manufacturer's Data Report shall be completed by the Manufacturer for each pressure vessel to be stamped with the Certification Mark. (25)

(a) For sample report forms and guidance in preparing Manufacturer's Data Reports, see Annex 2-D.

(b) A Manufacturer's Data Report shall be filled out on Form A-1 or Form A-1P by the Manufacturer and shall be signed by the Manufacturer and the Inspector for each pressure vessel stamped with the Certification Mark with the U2 Designator.

(c) A Manufacturer's Data Report shall be filled out on Form A-2 by the Manufacturer and shall be signed by the Manufacturer and the Inspector for each part stamped with the Certification Mark with the U2 or PRT VIII-2 Designator, as applicable. Same-day production of vessel parts may be reported on a single parts-documenting Form A-2, provided all of the following requirements are met:

(1) Vessel parts are identical.

(2) Vessel parts are manufactured for stock or for the same user or the user's designated agent.

(3) Serial numbers are in uninterrupted sequence.

(4) The Manufacturer's written Quality Control System includes procedures to control the development, distribution, and retention of the Manufacturer's Data Reports.

(d) Horizontal spacing for information on each page may be altered as necessary. All information must be addressed; however, footnotes described in the "Remarks" block are acceptable, e.g., for multiple cases of "none" or "not applicable."

(e) The method of completing the Manufacturer's Data Report shall be consistent. The report shall be typed or handwritten using legible printing. Handwritten additions or corrections shall be initialed and dated by the Manufacturer's representative and Inspector.

(f) Forms shall not contain advertising slogans, logos, or other commercial matter.

(g) Manufacturer's Data Report Forms may be preprinted or computer generated. Forms shall be identical in size, arrangement, and content, as shown in this Appendix, except that additional lines may be added or Form A-3 or Form A-4 may be used.

When using forms that result in multiple pages, each page shall be marked to be traceable to the first page of the form. For Forms A-1 and A-2, each page shall contain, at the top of the page, as a minimum, the Manufacturer's name, Manufacturer's serial number, CRN (as applicable), and National Board number (as applicable), as shown on the first page of the form.

Additionally, on all forms, each sheet shall contain the page number and total number of pages that compose the complete form. These requirements do not apply to Forms A-3 and A-4, which are intended to be single-page forms attached to another form.

2-C.1.2 Special Requirements for Layered Vessels. A description of the layered shell and/or layered heads shall be given on the Manufacturer's Data Report, describing the number of layers, their thickness or thicknesses, and type of construction (see Table 2-D.2 for the use of Form A-3, Manufacturer's Data Report Supplementary Sheet). An example of the use of Form A-3 illustrating the minimum required data for layered construction is given in Form A-3L.

2-C.1.3 Special Requirements for Combination Units. (25)

(a) Those chambers included within the scope of this Division shall be described on the same Manufacturer's Data Report. This includes the following, as applicable:

(1) for differential pressure design, the maximum differential design pressure for each common element and the name of the higher pressure chamber

(2) for mean metal temperature design, the maximum mean metal design temperature for each common element

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(3) for a common element adjacent to a chamber not included within the scope of this Division, the common element design conditions from that chamber

(4) for limiting pressure tests, the common element subject to collapse due to external pressure and its limiting test pressure

(b) It is recommended that those chambers not included within the scope of this Division be described in the "Remarks" section of the Manufacturer's Data Report.

(c) For fixed tubesheet heat exchangers, Form A-4 shall be completed in conjunction with Form A-1.

2-C.1.4 The Manufacturer shall distribute the Manufacturer's Data Report as indicated below.

(a) Furnish a copy of the Manufacturer's Data Report to the user and, upon request, to the Inspector;

(b) Submit a copy of the Manufacturer's Data Report to the appropriate enforcement authority in the jurisdiction in which the vessel is to be installed where required by law;

(c) Keep a copy of the Manufacturer's Data Report on file in a safe repository for at least 3 yr;

(d) In lieu of (b) or (c) above, the vessel may be registered and the Manufacturer's Data Reports filed with the National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Ave., Columbus, Ohio 43229, USA, where permitted by the jurisdiction in which the vessel is to be installed.

2-C.2 MANUFACTURER'S PARTIAL DATA REPORTS

2-C.2.1 The parts Manufacturer shall indicate under "Remarks" the extent the Manufacturer has performed any or all of the design functions. For guidance in preparing Manufacturer's Partial Data Reports, see Annex 2-D.

2-C.2.2 Manufacturer's Partial Data Reports for pressure vessel parts requiring examination under this Division, which are furnished to the Manufacturer responsible for the completed vessel, shall be executed by the parts Manufacturer's Inspector in accordance with this Division (see 2.3.1.2). All Manufacturer's Partial Data Reports, Form A-2, shall be attached to the Manufacturer's Data Report, Form A-1 or Form A-1P.

2-C.2.3 A Manufacturer with multiple locations, each holding its own Certificate of Authorization, may transfer pressure vessel parts from one of its locations to another without Manufacturer's Partial Data Reports, provided the Quality Control System describes the method of identification, transfer, and receipt of the parts. For cases in which a Manufacturer has multiple locations that include both shop and field locations, and the field assembly of the vessel is completed by one Manufacturer's location that is different from the part Manufacturer's location(s), the name of the Manufacturer responsible for field assembly shall be shown on Line 1 of the Manufacturer's Data Report. The Manufacturer responsible for field assembly shall complete and sign both the Shop and Field portions of the Manufacturer's Data Report.

2-C.3 MAINTENANCE OF RECORDS

2-C.3.1 The Manufacturer shall maintain a file for three years after stamping of the vessel, and furnish to the user and, upon request, to the Inspector, the reports and records shown below. It is noted that items that are included in the Manufacturer's Quality Control System meet the requirements of these subparagraphs.

(a) User's Design Specification (see 2.2.3)

(b) Manufacturer's Design Report (see 2.3.3)

(c) Manufacturer's Data Report (see 2.3.4)

(d) Manufacturer's Construction Records and Manufacturer's Partial Data Reports (see 2.3.5)

(1) Tabulated list of all material used for fabrication with Materials Certifications and Material Test Reports, and a record of any repairs to pressure-retaining material that require a radiographic examination by the rules of this Division. The record of the repairs shall include the location of the repair, examination results, and the repair procedures.

(2) Fabrication information including all heat treatment requirements, forming and rolling procedure when prepared, an inspection and test plan identifying all inspection points required by the user, and signed inspection reports

(3) List of any subcontracted services or parts, if applicable

(4) Welding Procedure Specifications (WPS), Procedure Qualification Records (PQR), weld map and Welder/Welding Operator Performance Qualification Records for each welder who welded on the vessel

(5) Pressure parts documentation and certifications

(6) Record of all heat treatments including post weld heat treatment (these records may be either the actual heat treatment charts or a certified summary description of heat treatment time and temperature)

(7) Results of production test plates, if applicable

(8) NDE procedures, records of procedure demonstrations, and records of personnel certifications

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(9) All reports stating the results of inspection, nondestructive examinations, and testing, including radiographic examination, ultrasonic examination, magnetic particle examination, liquid dye penetrant examination, and hardness tests; and documentation of the Manufacturer's acceptance of the examination results

(10) All nonconformance reports including resolution and a detailed description of any repairs including repair procedures, a sketch, photo, or drawing indicating the location and size of the repaired area

(11) Charts or other records of required hydrostatic, pneumatic, or other tests. Test logs shall include the test date, testing fluid, duration of the test, temperature of the test fluid, and test pressure

(12) Dimensional drawings of the as-built condition

(13) Continuity records showing that the qualifications of welders, brazers, welding operators, and brazing operators have been maintained

2-C.3.2 The Manufacturer shall maintain a complete set of radiographs until the signing of the Manufacturer's Data Report, and furnish upon request to the user and, upon request, to the Inspector [see 7.5.3.1(a)]. Deterioration of radiographic film is not a violation of the requirement for the maintenance of the records. (**25**)

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ANNEX 2-D
GUIDE FOR PREPARING MANUFACTURER'S DATA REPORTS

(Informative)

2-D.1 INTRODUCTION

2-D.1.1 The instructions in this Annex provide general guidance to the Manufacturer in preparing the Manufacturer's Data Reports as required in 2.3.4.

2-D.1.2 Manufacturer's Data Reports required by this Division are not intended for pressure vessels that do not meet the provisions of this Division, including those of special design or construction that require and receive approval by jurisdictional authorities under, laws, rules, and regulations of the respective state or municipality in which the vessel is to be installed.

2-D.1.3 The instructions for completing the Manufacturer's Data Reports are identified by numbers corresponding to numbers on the sample forms in this Annex (see Forms A-1, A-1P, A-2, A-3, and A-4).

2-D.1.4 Where more space is needed than has been provided on the form for any item, indicate in the space "See Remarks," "See attached Form A-3," or "See attached Form A-4," as appropriate.

2-D.1.5 For fixed tubesheet heat exchangers, Form A-4 shall be completed.

2-D.1.6 It is not intended that these Manufacturer's Data Reports replace in any way the required Manufacturer's Design Report (see 2.3.3) or the Manufacturer's Construction Records (see 2.3.5). It is intended that the Manufacturer's Data Reports be used for identifying the vessel, retrieval of records, and certification of compliance with this Division and with the User's Design Specification, by the Manufacturer and by the Inspector.

2-D.2 TABLES

(25)

Table 2-D.1
Instructions for the Preparation of Manufacturer's Data Reports

Applies to Form					Note	
A-1	A-1P	A-2	A-3	A-4	No.	Instructions
X	X	X	X	X	1	Name, street address, city, state or province (as applicable), and country of Manufacturer.
X	X	...	X	X	2	Name and address of purchaser.
X	X	...	X	X	3	Name of user, and address where vessel is to be installed.
...	...	X	...	...	4	Name and address of Manufacturer who will use the vessel part in making the complete vessel
X	X	X	...	X	5	Type of vessel, such as horizontal or vertical, tank, separator, heat exchanger, reactor.
...	...	X	...	...	6	Brief description of vessel part (i.e., shell, two-piece head, tube, bundle).
X	X	X	X	X	7	An identifying Manufacturer's serial number marked on the vessel (or vessel part) (see Annex 2-F).
X	X	X	X	X	8	Applicable Jurisdiction Registration No.
X	X	X	...	X	9	Indicate drawing numbers, including revision numbers, which cover general assembly and list materials. For Canadian registration, the number of the drawing approved by the applicable jurisdictional authority.
...	...	X	...	...	10	Organization that prepared drawing.
X	X	X	X	X	11	Where applicable, National Board Number from Manufacturer's Series of National Board Numbers.
X	X	X	...	...	12	Issue date of Section VIII, Division 2 under which vessel was manufactured.
X	X	X	...	...	13	All Code Case numbers when the vessel is manufactured to any Code Cases.

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Table 2-D.1
Instructions for the Preparation of Manufacturer's Data Reports (Cont'd)

Applies to Form					Note	
A-1	A-1P	A-2	A-3	A-4	No.	Instructions
X	...	...	...	...	14	To be completed when one or more parts of the vessel are furnished by others and certified on Manufacturer's Data Report Form A-2 as required by Annex 2-F. The part manufacturer's name and serial number should be indicated.
X	X	X	...	...	15	Show the complete ASME Specification number and grade of the actual material used in the vessel part. Material is to be as designated in Section VIII, Division 2 (e.g., "SA-285 C"). Exceptions: A specification number for a material not identical to an ASME Specification may be shown only if such material meets the criteria in the Foreword of this Section. When material is accepted through a Code Case, the applicable Case Number shall be shown.
X	X	X	...	...	16	Thickness is the nominal thickness of the material used in the fabrication of the vessel. It includes corrosion allowance.
X	X	X	...	...	17	State corrosion allowance on thickness.
X	...	X	...	...	18	Indicate whether the diameter is inside diameter or outside diameter.
X	...	X	...	...	19	The shell length shall be shown as the overall length between closure or transition section welds, for a shell of a single diameter. In other cases, define length, as appropriate.
X	...	X	...	...	20	Type of longitudinal joint in cylindrical section, or any joint in a sphere (e.g., Type No.1 butt, or seamless) per 4.2.
X	X	X	...	...	21	State the temperature and time if heat treatment is performed by the Manufacturer (i.e., postweld heat treatment, annealing, or normalizing). Explain any special cooling procedure under "Remarks."
X	...	X	...	...	22	Indicate examination applied to longitudinal seams. Any additional examinations should be included under "Remarks."
X	...	X	...	...	23	Type of welding used in girth joints of the cylindrical section (see 20).
X	...	X	...	...	24	Indicate examination applied to girth joints (see 22).
X	...	X	...	...	25	Number of cylindrical courses or belts, required to make one shell.
X	...	X	...	...	26	Show specified minimum thickness of head after forming. State dimensions that define the head shape.
X	X	X	...	...	27	Bolts used to secure removable head or heads of vessel and vessel sections.
X	...	X	...	...	28	For jacketed vessels, explain the type of jacket closures used.
X	X	X	...	X	29	Show the internal maximum allowable working pressure and the external maximum allowable working pressure.
X	X	X	...	X	30	Show the coincident temperatures that correspond to the internal maximum allowable working pressure and the external maximum allowable working pressure, as applicable.
X	X	X	...	...	31	Show minimum Charpy V-notch impact value required and impact test temperature. If exempted, indicate under "Remarks" paragraph under which exemption was taken.
X	X	X	...	...	32	Show minimum design metal temperature.
X	X	X	...	...	33	Show hydrostatic or other tests made with specified test pressure at top of vessel in the test position. Cross out words (pneumatic, hydrostatic, or combination test pressure) that do not apply. Indicate under "Remarks" if vessel was tested in the vertical position. See Part 8 for special requirements for combination units.
X	X	X	...	...	34	Indicate nozzle or other opening that is designated for pressure relief.
X	X	X	...	...	35	Show other nozzles and openings by size and type (see 50).
X	X	X	...	...	36	Show opening designated for inspection. Show location.
X	X	X	...	...	37	Indicate provisions for support of the vessel and any attachments for superimposed equipment.
X	X	X	...	...	38	Indicate whether fatigue analysis is required per Part 4.
X	X	X	...	...	39	Describe contents or service of the vessel.
X	X	X	...	...	40	Space for additional comments, including any Code restrictions on the vessel or any unusual Code requirements that have been met, such as those noted in 21, 22, 24, 31, and 33, or in 1.2.1 and 1.2.2; 2-C.1.3; or 5.11. Indicate stiffening rings, if used.
X	X	X	...	...	41	Certificate of Compliance block is to show the name of the Manufacturer as shown on the ASME Code Certificate of Authorization. This should be signed in accordance with organizational authority defined in the Quality Control System (see Annex 2-E).
X	X	X	...	...	42	This certificate is to be completed by the Manufacturer to show the disposition of the User's Design Specification and the Manufacturer's Design Report, and to identify the individuals who certify them per 2.2.3 and 2.3.3, respectively (see 49).

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Table 2-D.1
Instructions for the Preparation of Manufacturer's Data Reports (Cont'd)

Applies to Form					Note	
A-1	A-1P	A-2	A-3	A-4	No.	Instructions
X	X	X	X	X	43	This certificate is to be completed by the Manufacturer and signed by the Authorized Inspector who performs the shop inspection.
X	X	X	X	X	44	This National Board Authorized Inspector Commission number must be shown.
X	X	...	...	...	45	This certificate is for the Authorized Inspector to sign for any field construction or assembly work (see 44 for National Board Authorized Inspector Commission number requirements). Indicate the method used to pressure test the vessel.
...	...	...	X	X	46	Fill in information identical to that shown on the Data Report to which this sheet is supplementary.
...	...	...	X	X	47	Fill in information for which there was insufficient space for a specific item on the Data Report Form as identified by the notation "See attached Form A-3" or "See attached Form A-4" on the Data Report. Identify the information by the applicable Data Report Item Number.
...	...	X	...	...	48	Indicate data, if known.
X	X	X	...	...	49	Registration locale (as required per 2.2.3 and 2.3.3).
X	X	X	...	...	50	Data entries with descriptions acceptable to Inspector. Abbreviations, coded identification, or reference to Code Figure and sketch number may be used to define any generic name. For ASME B16.5 flanges, the class should be identified. Flange facing and attachment to neck is not required. Some typical abbreviations are shown below. • Flanged fabricated nozzle: Cl. 300 flg • Long weld neck flange: Cl. 300 lwn • Weld end fabricated nozzle: w.e.
X	X	X	...	...	51	Material for nozzle neck. Flange material not necessary.
X	X	X	...	...	52	Nominal nozzle neck thickness. For ASME B16.11 and similar parts, class designation may be substituted for thickness.
...	...	...	...	X	53	Fill in data required by 4.18.14.3(b).
...	X	...	...	...	54	Indicate whether the heat transfer plates are gasketed, semiwelded, or brazed.
...	X	...	...	...	55	Indicate the endplate width and length dimensions.
...	X	...	...	...	56	Describe *(a)* heat transfer plate model name *(b)* heat transfer plate nominal thickness *(c)* minimum and maximum number of heat transfer plates for the given frame configuration *(d)* quantity of heat transfer plates installed at time of pressure test *(e)* minimum and maximum tightening dimension of installed heat transfer plates at the time of pressure test

(25)

Table 2-D.2
Supplementary Instructions for the Preparation of Manufacturer's Data Reports for Layered Vessels

Note Letter	Instructions
A	Letter symbols indicate instructions that supplement the instructions of Table 2-D.1.
B	The Form A-3L is not available preprinted as shown. It is intended as an example of suggested use of Form A-3 for reporting data for a vessel of layered construction. It is intended that the Manufacturer develop an acceptable arrangement to provide supplementary data that describes the vessel.
C	Note the NDE performed (RT, PT, MT, UT).
D	Applies only when heads are of layered construction.
E	Indicates if seamless or welded.
F	When more than one layer thickness is used, add lines as needed.
G	Indicate diameter of vent holes in the layers.
H	Indicate whether vent holes are in random locations in each layer, or are drilled through all layers.
I	Indicate locations of nozzles and openings; layered shell; layered head.
J	Indicate method of attachment and reinforcement of nozzles and openings in layered shells and layered heads. Refer to figure number if applicable.

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(25)

FORM A-1 MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS

Page____ of ____

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 2

1. Manufactured and certified by ① (Name and address of manufacturer)
2. Manufactured for ② (Name and address of purchaser)
3. Location of installation ③ (Name and address)
4. Type ⑤ (Horiz. or vert. tank) ⑦ (Mfr.'s serial no.) ⑧ (CRN) ⑨ (Drawing no.) ⑪ (Nat'l. Bd. no.) (Year built)
5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to ASME Code, Section VIII, Division 2.
   ⑫ (Year) ⑬ (Code case no.)

Items 6 to 11 incl. to be completed for single wall vessels, jackets of jacketed vessels, or shells of heat exchangers

6. Shell ⑮ (Material (spec. no., grade)) ⑯ (Nom. thk.) ⑰ (Corr. allow.) ⑱ (Diameter) ⑲ (Length (overall))
7. Seams ⑳ (Longitudinal) ㉑ (Heat treatment) ㉒ (Nondestructive examination)
   ㉓ (Girth) ㉑ (Heat treatment) ㉔ (Nondestructive examination) ㉕ (No. of courses)
8. Heads: (a) Matl. ⑮ ⑳ ㉑ ㉒ (Spec. no., grade) (b) Matl. ⑮ ⑳ ㉑ ㉒ (Spec. no., grade)

	Location (Top, Bottom, End)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)		㉖	⑰							
(b)										

9. If removable, bolts used (describe other fastenings): ㉗ (Matl. spec. no., grade, size, number)
10. Jacket closure ㉘ (Describe as ogee and weld, bar, etc.) If bar, give dimensions _____. If bolted, describe or sketch.
11. MAXP ㉙ (Internal) ㉙ (External) at max. temp. ㉚ (Internal) ㉚ (External) Min. design metal temp. ㉜ at ㉜
    Impact test ㉛ At test temperature of ㉛
    Hydro., pneu., or comb test pressure ㉝

Items 12 and 13 to be completed for tube sections

12. Tubesheets ⑮ (Stationary matl. (spec. no., grade)) (Diam. (subject to pressure)) ⑯ (Nom. thk.) ⑰ (Corr. allow.) (Attach. (wld., bolted))
    ⑮ (Floating matl. (spec. no., grade)) (Diam.) ⑯ (Nom. thk.) ⑰ (Corr. allow.) (Attach. (wld., bolted))
13. Tubes ⑮ (Matl. (spec. no., grade)) (O.D.) (Nom. thk.) (Number) (Type (straight or "U"))

Items 14 to 18 incl. to be completed for inner chambers of jacketed vessels, or channels of heat exchangers

14. Shell ⑮ (Material (spec. no., grade)) ⑯ (Nom. thk.) ⑰ (Corr. allow.) (Diameter) ⑲ (Length (overall))
15. Seams ⑳ (Longitudinal) ㉑ (Heat treatment) ㉒ (Nondestructive examination)
    ㉓ (Girth) ㉑ (Heat treatment) ㉔ (Nondestructive examination) (No. of courses)
16. Heads: (a) Matl. (Spec. no., grade) (b) Matl. (Spec. no., grade)

	Location (Top, Bottom, End)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)										
(b)										

17. If removable, bolts used (describe other fastenings): (Matl. spec. no., grade, size, number)
18. MAXP ㉙ (Internal) ㉙ (External) at max. temp. ㉚ (Internal) ㉚ (External) Min. design metal temp. ㉜ at ㉜
    Impact test ㉛ At test temperature of ㉛
    Hydro., pneu., or comb test pressure ㉝

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Page _____ of _____

Manufactured by (41) _____

Manufacturer's Serial No. (7) _____ CRN (8) _____ National Board No. (11) _____

Items below to be completed for all vessels where applicable.

19. Nozzles inspection and pressure relief device openings

Purpose (Inlet, Outlet, Drain, etc.)	No.	Diam. or Size	Type	Material	Nom. Thk.	Reinforcement Material	How Attached	Location
(34) (35) (36)		(35)	(35) (50)	(15) (51)	(16) (52)			(36)

20. Body Flanges

Body Flanges on Shells

No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
						(15)			(27)	(15)		(15)

Body Flanges on Heads

No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
						(15)			(27)	(16)		(15)

21. Support Skirt (37) _____ Lugs _____ Legs _____ Other _____ Attached _____
Yes or no; No.; No.; Describe; Where and how

22. Service: Fatigue analysis required (38) _____ and (39) _____
Yes or no; Describe contents or service

Remarks: (21) (22) (24) (31) (33) (37) (40) (47)

(42) **CERTIFICATION OF DESIGN**

User's Design Specification on file at _____
Manufacturer's Design Report on file at _____
User's Design Specification certified by _____ PE State (42) (49) _____ Reg. No. _____
Manufacturer's Design Report certified by _____ PE State (42) (49) _____ Reg. No. _____

(41) **CERTIFICATE OF SHOP COMPLIANCE**

We certify that the statements in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME Code for Pressure Vessels, Section VIII, Division 2.

"U2" Certificate of Authorization No. (41) _____ expires _____

Date _____ Co. name (41) _____ Signed (41) _____
Manufacturer; Representative

(43) **CERTIFICATE OF SHOP INSPECTION**

Vessel made by _____ at _____

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by _____ of _____, have inspected the pressure vessel described in this Manufacturer's Data Report on _____, and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME Code, Section VIII, Division 2. By signing this certificate neither the Inspector nor the Inspector's employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's' Data Report. Furthermore, neither the Inspector nor the Inspector's employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date _____ Signed (43) _____ Commissions (44) _____
Authorized Inspector; National Board Authorized Inspector Commission number

(07/25)

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FORM A-1

Page _____ of _____

Manufactured by (41) _____

Manufacturer's Serial No. (7) _____ CRN (8) _____ National Board No. (11) _____

(41) **CERTIFICATE OF FIELD ASSEMBLY COMPLIANCE**

We certify that the field assembly construction of all parts of this vessel conforms with the requirements of Section VIII, Division 2 of the ASME BOILER AND PRESSURE VESSEL CODE.

"U2" Certificate of Authorization No. _____ expires _____

Date _____ Co. name _____ Signed _____

Assembler that certified and constructed field assembly — Representative

(45) **CERTIFICATE OF FIELD ASSEMBLY INSPECTION**

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by _____ of _____

have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data items _____

not included in the certificate of shop inspection, have been inspected by me and that, to the best of my knowledge and belief, the Manufacturer has constructed and assembled this pressure vessel in accordance with the ASME Code, Section VIII, Division 2.

The described vessel was inspected and subjected to a hydrostatic test of _____.

By signing this certificate neither the Inspector nor the Inspector's employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor the Inspector's employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date _____ Signed (43) _____ Commissions (44) _____

Authorized Inspector — National Board Authorized Inspector Commission number

(07/25)

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(25)

FORM A-1P MANUFACTURER'S DATA REPORT FOR PLATE HEAT EXCHANGERS

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 2

Page ____ of ____

1. Manufactured and certified by (1)
(Name and address of Manufacturer)

2. Manufactured for (2)
(Name and address of Purchaser)

3. Location of installation (3)
(Name and address)

4. Type (5) (Horizontal or vertical) (54) (Gasketed, semiweld, brazed) (7) (Manufacturer's serial no.) (8) (CRN) (9) (Drawing no.)
(National Board no.) Year built

5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to ASME Code, Section VIII, Division 2.
(12) [Edition (Year)] (13) Code case no.

6. Endplates: (a) (15) (Fixed material) (b) (15) (Movable material) (c) (15) (Other material)

No.	Quantity	Width	Length	Thickness	Corr. Allow.	Heat Treat	Temp.	Time
		(55)	(55)	(16)	(17)	(21)	(21)	(21)

7. Frame compression bolts and nuts (37)
(Quantity, diameter, material specification, and grade)

8. Impact test (31)
[Indicate YES and the component(s) impact tested, or NO]

9. Heat transfer plates (56) (Plate model) (15) (Material specification and grade) (56) (Thickness) (56) (Minimum/maximum quantity of plates for frame)
(56) (Quantity of plates pressure tested) (56) (Minimum tightening dimension) (56) (Maximum tightening dimension)

10. Chamber 1, MAWP (29) at max. temp (30) , (32) MDMT at (29) Hydro/pneu. test press. (33)

11. Chamber 2, MAWP (29) at max. temp (30) , (32) MDMT at (29) Hydro/pneu. test press. (33)

12. Nozzles, connections, inspections, and pressure relief device openings:

Purpose (Inlet, Outlet, Drain, etc.)	Qty.	Dia. or Size	Type	Material		Flange Rating	Nozzle Thickness		How Attached		Location (Insp./Open.)
				Nozzle	Flange		Nom.	C.A.	Nozzle	Flange	
(34) (35) (36)		(35)	(35) (50)	(15) (51)	(15)	(50)	(16) (52)	(17)			(36)

13. Supports: Lugs (37) (Quantity) Legs Feet (37) (Quantity) Others (37) (Describe) Attached (37) (Where and how)

14. Service: Fatigue analysis required (38) (Yes or No) (39) (Describe contents or service)

15. Remarks: (21) (31) (40) (47)

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FORM A-1P

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Manufactured by (41) _____

Manufacturer's Serial No. (7) _____ CRN (8) _____ National Board No. (11) _____

(42) **CERTIFICATION OF DESIGN**

User's Design Specification on file at _____

Manufacturer's Design Report on file at _____

User's Design Specification certified by _____ PE State (42) (49) _____ Reg. No. _____

Manufacturer's Design Report certified by _____ PE State (42) (49) _____ Reg. No. _____

(41) **CERTIFICATE OF SHOP COMPLIANCE**

We certify that the statements in this report are correct and that all details of design, material, construction, and workmanship of this plate heat exchanger conform to the ASME Code for Pressure Vessels, Section VIII, Division 2.

"U2" Certificate of Authorization No. (41) _____ expires _____

Date _____ Name (41) _____ Signed (41) _____

Manufacturer Representative

(43) **CERTIFICATE OF SHOP INSPECTION**

Plate heat exchanger made by _____ at _____

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by _____ of _____, have inspected the plate heat exchanger described in this Manufacturer's Data Report on _____ and state that, to the best of my knowledge and belief, the Manufacturer has constructed this plate heat exchanger in accordance with ASME Code, Section VIII, Division 2. By signing this certificate neither the Inspector nor the Inspector's employer makes any warranty, expressed or implied, concerning the plate heat exchanger described in this Manufacturer's' Data Report. Furthermore, neither the Inspector nor the Inspector's employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date _____ Signed (43) _____ Commissions (44) _____

Authorized Inspector National Board Authorized Inspector Commission number

(41) **CERTIFICATE OF FIELD ASSEMBLY COMPLIANCE**

We certify that the field assembly construction of all parts of this plate heat exchanger conforms with the requirements of Section VIII, Division 2 of the ASME BOILER AND PRESSURE VESSEL CODE.

"U2" Certificate of Authorization No. _____ expires _____

Date _____ Name _____ Signed _____

Assembler Representative

(45) **CERTIFICATE OF FIELD ASSEMBLY INSPECTION**

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by _____ of _____ have compared the statements in this Manufacturer's Data Report with the described plate heat exchanger and state that parts referred to as data items _____, not included in the certificate of shop inspection, have been inspected by me and that, to the best of my knowledge and belief, the Manufacturer has constructed and assembled this pressure vessel in accordance with the ASME Code, Section VIII, Division 2.

The described plate heat exchanger was inspected and subjected to a hydrostatic test of _____.

By signing this certificate neither the Inspector nor the Inspector's employer makes any warranty, expressed or implied, concerning the plate heat exchanger described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor the Inspector's employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date _____ Signed (43) _____ Commissions (44) _____

Authorized Inspector National Board Authorized Inspector Commission number

(07/25)

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(25)

FORM A-2 MANUFACTURER'S PARTIAL DATA REPORT

Page ____ of ____

A PART OF A pressure Vessel Fabricated by One Manufacturer for Another Manufacturer
As Required by the Provisions of the ASME Code Rules, Section VIII, Division 2

1. Manufactured and certified by (1) (Name and address of manufacturer)
2. Manufactured for (4) (Name and address of purchaser)
3. Location of installation (3) (Name and address)
4. Type (5) Horiz. or vert. tank; (7) Mfr's. Serial No.; (8) CRN; (9) Drawing No.; (11) Nat'l Board No.; Year built
5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to ASME Code, Section VIII, Division 2.
   (12) Year; (13) Code case No.
6. Constructed to: Drawing No.; Drawing Prepared by; (6) Description of part inspected

Items 7 to 12 incl. to be completed for single wall vessels, jackets of jacketed vessels, or shells of heat exchangers

7. Shell (15) Material (Spec. No., Grade); (16) Nom. thk.; (17) Corr. allow.; (18) diameter; (19) Length (overall)
8. Seams (20) Longitudinal; (21) Heat treatment; (22) Nondestructive Examination
   (23) Girth; (21) Heat treatment; (24) Nondestructive Examination; (25) No. of Courses
9. Heads: (a) Matl. (15) (20) (21) (22) Spec., No., Grade (b) Matl. (15) (20) (21) (22) Spec., No., Grade

	Location (Top, Bottom, End)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)		(26)	(17)							
(b)										

10. If removable, bolts used (describe other fastenings): (27) Matl. Spec. No. Grade Size Number
11. Jacket closure (28) Describe as ogee and weld, bar. etc If bar, give dimensions If bolted, describe or sketch.
12. MAWP (29) (internal) (29) (external) at max. temp. (30) (internal) (30) (external) Min. design metal temp. (32) at (32)
    Impact test (31) At test temperature of (31)
    Hydro., pneu., or comb test pressure (33)

Items 13 and 14 to be completed for tube sections.

13. Tubesheets (15) Stationary matl. (Spec. No., Grade); (18) Diam. (Subject to pressure); (16) Nom. thk.; (17) Corr. Allow.; Attach. (wld., bolted)
    (15) Floating matl. (Spec. No., Grade); (Diam.); (16) Nom. thk.; (17) Corr. Allow.; Attach. (wld., bolted)
14. Tubes (15) Matl. (Spec. No.. Grade); O.D.; Nom. thk.; Number; Type (straight or "U")

Items 15 to 18 incl. to be completed for inner chambers of jacketed vessels, or channels of heat exchangers

15. Shell (15) Material (Spec. No., Grade); (16) Nom. thk.; (17) Corr. allow.; (18) diameter; (19) Length (overall)
16. Seams (20) Longitudinal; (21) Heat treatment; (22) Nondestructive Examination
    (23) Girth; (21) Heat treatment; (24) Nondestructive Examination; No. of Courses
17. Heads: (a) Matl. Spec., No., Grade (b) Matl. Spec., No., Grade

	Location (Top, Bottom, End)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)										
(b)										

18. If removable, bolts used (describe other fastenings): Matl. Spec. No. Grade Size Number
19. Design press. (29) at max. temp. (30). Charpy impact (31)
    at test temp. of (31). Min. design metal temp. (32) at
    Pneu., hydro., or comb. pressure test (33)

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Page _____ of _____

Manufactured by (41) _____

Manufacturer's Serial No. (7) _____ CRN (8) _____ National Board No. (11) _____

Items below to be completed for all vessels where applicable

20. Nozzles inspection and pressure relief device openings

Purpose (Inlet, Outlet, Drain, etc)	No.	Diam. or Size	Type	Material	Nom. Thk.	Reinforcement Material	How Attached	Location
(34)		(35)	(35)	(15)	(16)			(36)
(35)			(50)	(51)	(52)			
(36)								
(48)								

21. Body Flanges

Body Flanges on Shells

No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
						(15)			(27)	(15)		(15)

Body Flanges on Heads

No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
						(15)			(27)	(15)		(15)

22. Support Skirt (37) _____ Lugs _____ Legs _____ Other _____ Attached _____

Yes or No — No. — No — Describe — Where and how

Remarks: (21) (22) (24) (31) (33) (37) (40) (47)

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Page _____ of _____

Manufactured by _____ (41)

Manufacturer's Serial No. _____ (7) CRN _____ (8) National Board No. _____ (11)

(42) **CERTIFICATION OF DESIGN**

User's Design Specification on file at _____

Manufacturer's Design Report on file at _____

User's Design Specification certified by _____ PE State _____ (42) (49) Reg. No. _____

Manufacturer's Design Report certified by _____ PE State _____ (42) (49) Reg. No. _____

(41) **CERTIFICATE OF SHOP COMPLIANCE**

We certify that the statements in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME Code for Pressure Vessels, Section VIII, Division 2.

"U2" or "PRT VIII-2" Certificate of Authorization No _____ (41) expires _____

Date _____ Co. name _____ (41) Manufacturer Signed _____ (41) Representative

(43) **CERTIFICATE OF SHOP INSPECTION**

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by _____ of _____, have inspected the part of a pressure vessel described in this Manufacturer's Data Report on _____, and state that, to the best of my knowledge and belief, the Manufacturer has constructed this part in accordance with ASME Code, Section VIII, Division 2. By signing this certificate neither the Inspector nor the Inspector's employer makes any warranty, expressed or implied, concerning the part described in this Manufacturer's' Data Report. Furthermore, neither the Inspector nor the Inspector's employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date _____ Signed _____ (43) Authorized Inspector Commissions _____ (44) National Board Authorized Inspector Commission number

(07/25)

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FORM A-3 MANUFACTURER'S DATA REPORT SUPPLEMENTARY SHEET
As Required by the Provisions of the ASME Code Rules, Section VIII, Division 2

1. Manufactured and certified by _____ (1) (Name and address of manufacturer)
2. Manufactured for _____ (2) (Name and address of purchaser)
3. Location of installation _____ (3) (Name and address)
4. Type _____ (5) Horiz. or vert. tank _____ (7) Mfr's. Serial No. _____ (8) CRN _____ (9) Drawing No. _____ (11) Nat'l Board No. _____ Year built

Data Report Item Number (46)	Remarks (47)

Date _____ Co. name _____ (43) (46) Manufacturer Signed _____ (43) (46) Representative

Date _____ Signed _____ (43) (46) Authorized Inspector Commissions _____ (44) National Board Authorized Inspector Commission number

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FORM A-3L MANUFACTURER'S DATA REPORT SUPPLEMENTARY SHEET
As Required by the Provisions of the ASME Code Rules, Section VIII, Division 2

1. Manufactured and certified by ① (Name and address of manufacturer)
2. Manufactured for ② (Name and address of purchaser)
3. Location of installation ③ (Name and address)
4. Type ⑤ (Horiz. or vert. tank) ⑦ (Mfr's. Serial No.) ⑧ (CRN) ⑨ (Drawing No.) ⑪ (Nat'l Board No.) (Year built)

Data Report Item Number ㊻						
	Remarks Ⓐ Ⓑ 47					
Item 6 or 7 (Shell)	(a) layered construction type: (Concentric, wrapped, spiral, coil wound, shrink fit, etc.) Nom. Layer					
	Location	Mat'l.	Layer Thk.	Nom. Thk.Tot.	No. Courses	NDE
	(b) Inner Shell					
	(c) Dummy Layer	⑮	Ⓕ	⑯	㉙	Ⓒ
	(d) Layers:					
	(e) Overwraps:					
Item 8 (Heads)	(a) Layered Construction Type: *(Formed, Machined, Segmental, etc.)*					
	(b) Inner Head					
	(c) Dummy Layer	⑮	Ⓕ	⑯	Ⓔ ⑳	Ⓒ
	(d) Layers:					
	(a) Layered Construction Type:					
	(1) Inner Head					
	(2) Dummy Layer					
	(3) Layers:					
Item 21 (Vent holes in layers)		Diam Hole	Staggered Layers or Radial Through			
	(a) Layered Shell		Ⓗ			
	(b) Layered Head	Ⓖ				
Item 24 (Remarks)	Gaps Have Been Controlled According to the Provisions of Paragraph: (See 4.13.12.1, 14.13.12.2, and 14.13.12.3)					
	Ⓘ Ⓙ					
	Ⓑ					

Date _____ Co. name _____ (Manufacturer) Signed _____ (Representative)

Date _____ Signed _____ (Authorized Inspector) Commissions ㊹ (National Board Authorized Inspector Commission number)

(07/17)

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FORM A-4 MANUFACTURER'S DATA REPORT SUPPLEMENTARY SHEET SHELL-AND-TUBE HEAT EXCHANGERS

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 2

1. Manufactured and certified by ① (Name and address of manufacturer)
2. Manufactured for ② (Name and address of purchaser)
3. Location of installation ③ (Name and address)
4. Type ⑤ (Horizontal, vertical, or sloped) ⑦ (Mfr's. Serial No.) ⑧ (CRN) ⑨ (Drawing No.) ⑪ (Nat'l Board No.) (Year built)

FIXED TUBESHEET HEAT EXCHANGERS

	Design/Operating Pressure Ranges				Design/Operating Metal Temperatures				Allowable Axial Differential Thermal Expansion Range	
	Shell Side		Tube Side							
	Min.	Max.	Min.	Max.	Shell	Channel	Tubes	Tubesheet	Min.	Max.
Name of Condition	(units)	(units)	(units)	(units)	(units)	(units)	(units)	(units)	(units)	(units)
Design	㉙	㉙	㉙	㉙	㉚	㉚	㉚	㉚	㉚	㉚
㊸	㊸	㊸	㊸	㊸	㊸	㊸	㊸	㊸	㊸	㊸

Data Report Item Number	Remarks
㊻	㊼

Date _____ Co. Name ㊸ ㊻ (Manufacturer) Signed ㊸ ㊻ (Representative)

Date _____ Signed ㊸ ㊻ (Authorized Inspector) Commissions ㊸ ㊹ ㊻ (National Board Authorized Inspector Commission number)

(07/19)

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ANNEX 2-E
QUALITY CONTROL SYSTEM

(Normative)

2-E.1 GENERAL

2-E.1.1 The Manufacturer shall have and maintain a Quality Control System that will establish that all Code requirements, including material, design, fabrication, examination (by the Manufacturer), and inspection of vessels and vessel parts (by the Inspector), will be met. Provided that Code requirements are suitably identified, the system may include provisions for satisfying any requirements by the Manufacturer or user that exceed minimum Code requirements and may include provisions for quality control of non-Code work. In such systems, the Manufacturer of vessels and vessel parts may make changes in parts of the system that do not affect the Code requirements without securing acceptance by the Inspector (see 2.1.1).

2-E.1.2 The system that the Manufacturer uses to meet the requirements of this Division shall be one suitable for the Manufacturer's circumstances. The necessary scope and detail of the system shall depend on the complexity of the work performed and on the size and complexity of the Manufacturer's organization. A written description of the system the Manufacturer will use to produce a Code item shall be available for review. Depending upon the circumstances, the description may be brief or extensive.

2-E.1.3 The written description may contain information of a proprietary nature relating to the Manufacturer's processes. Therefore, the Code does not require any distribution of this information except for the Inspector's or ASME designee's copy as covered by 2-E.15.3. It is intended that information learned about the system in connection with the evaluation will be treated as confidential and that all loaned descriptions will be returned to the Manufacturer upon completion of the evaluation.

2-E.2 OUTLINE OF FEATURES INCLUDED IN THE QUALITY CONTROL SYSTEM

The following is a guide to some of the features which should be covered in the written description of the Quality Control System and is equally applicable to both shop and field work.

(a) The information associated with 2.3 and Annex 7-A.

(b) The complexity of the work includes factors such as design simplicity versus complexity, the types of materials and welding procedures used, the thickness of materials, the types of nondestructive examinations applied, and whether heat treatments are applied.

(c) The size and complexity of the Manufacturer's organization includes factors such as the number of employees, the experience level of employees, the number of vessels produced, and whether the factors defining the complexity of the work cover a wide or narrow range.

2-E.3 AUTHORITY AND RESPONSIBILITY

The authority and responsibility of those in charge of the Quality Control System shall be clearly established. Persons performing quality control functions shall have sufficient and well-defined responsibility, the authority, and the organizational freedom to identify quality control problems and to initiate, recommend, and provide solutions.

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2-E.4 ORGANIZATION

An organization chart showing the relationship between management and engineering, purchasing, manufacturing, field construction, inspection, and quality control is required to reflect the actual organization. The purpose of this chart is to identify and associate the various organizational groups with the particular function for which they are responsible. The Code does not intend to encroach on the Manufacturer's right to establish, and from time to time to alter, whatever form of organization the Manufacturer considers appropriate for its Code work.

2-E.5 DRAWINGS, DESIGN CALCULATIONS, AND SPECIFICATION CONTROL

2-E.5.1 The Manufacturer's Quality Control System shall provide procedures which will ensure that the latest applicable drawings, design calculations, specifications, and instructions, required by the Code, as well as authorized changes, are used for manufacture, assembly, examination, inspection, and testing. The system shall ensure that authorized changes are included, when appropriate, in the User's Design Specification and/or in the Manufacturer's Design Report.

2-E.5.2 The Manufacturer's or Assembler's Quality Control System shall provide procedures that will ensure Certifying Engineers and Designers performing design activities are competent for each activity they perform (see Annex 2-J).

2-E.5.3 The Manufacturer's or Assembler's Quality Control System shall provide procedures that will ensure that (**25**) any computer program used for preparing calculations or conducting analysis meets the requirements of the Code. The procedures shall ensure that prepared calculations or analysis are verified as follows:

(a) The computer program calculations or analysis shall be verified to show that it produces correct solutions for the mathematical model within defined limits for each parameter of the model that is used.

(1) A mathematical model may include mathematical equations, boundary conditions, initial conditions, and the geometry, physical, and material property data.

(2) Verification is the process of determining that a computational model accurately represents the underlying mathematical model and its solution.

(b) The mathematical model shall be verified to show if it produces correct solutions to the physical characteristics associated with the application.

NOTE: For (a) and (b), verification against examples found in ASME PTB-3 may be sufficient to show verification is met. In lieu of (a) and (b), the computer programs may be verified by the results confirmed by design analysis for each application.

2-E.6 MATERIAL CONTROL

The Manufacturer shall include a system of receiving control that will ensure that the material received is properly identified and has documentation including required material certifications or material test reports to satisfy Code requirements as ordered. The system material control shall ensure that only the intended material is used in Code construction.

2-E.7 EXAMINATION AND INSPECTION PROGRAM

The Manufacturer's Quality Control System shall describe the fabrication operations, including examination, sufficiently to permit the Inspector or ASME designee to determine at what stages specific inspections are to be performed.

2-E.8 CORRECTION OF NONCONFORMITIES

There shall be a system agreed upon with the Inspector for correction of nonconformities. A nonconformity is any condition which does not comply with the applicable rules of this Division. Nonconformities must be corrected or eliminated in some way before the completed component can be considered to comply with this Division.

2-E.9 WELDING

The Quality Control System shall include provisions for indicating that welding conforms to requirements of Section IX as supplemented by this Division.

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2-E.10 NONDESTRUCTIVE EXAMINATION

The Quality Control System shall include provisions for identifying nondestructive examination procedures the Manufacturer or Assembler will apply to conform to the requirements of this Division.

2-E.11 HEAT TREATMENT

The Quality Control System shall provide controls to ensure that heat treatments as required by the rules of this Division are applied. Means shall be indicated by which the Inspector or ASME designee will be ensured that these Code heat treatment requirements are met. This may be by review of furnace time-temperature records or by other methods as appropriate.

2-E.12 CALIBRATION OF MEASUREMENT AND TEST EQUIPMENT

The Manufacturer shall have a system for the calibration of examination, measuring, and test equipment used in fulfillment of requirements of this Division.

2-E.13 RECORDS RETENTION

The Manufacturer shall have a system for the maintenance of Data Reports and records as required by this Division. Requirements for maintenance of records are given in 2-C.3. Additionally, retained records as required by this Division and the Quality Control System shall be made available to the Authorized Inspector Supervisors or to review teams designated by ASME.

2-E.14 SAMPLE FORMS

The forms used in this Quality Control System and any detailed procedures for their use shall be available for review. The written description shall make necessary references to these forms.

2-E.15 INSPECTION OF VESSELS AND VESSEL PARTS

2-E.15.1 Inspection of vessels and vessel parts shall be by the Inspector as defined in 2.4.

2-E.15.2 The written description of the Quality Control System shall include reference to the Inspector.

2-E.15.3 The Manufacturer shall make available to the Inspector, at the Manufacturer's plant or construction site, a current copy of the written description of the Quality Control System.

(25) **2-E.15.4** The Manufacturer's Quality Control System shall provide for the Inspector at the Manufacturer's plant to have access to the User's Design Specification, the Manufacturer's Design Report, and all drawings, calculations, specifications, procedures, process sheets, repair procedures, records, test results, and other documents as necessary for the Inspector to perform his duties in accordance with this Division. The Manufacturer may provide either access to such documents or copies to the Inspector.

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ANNEX 2-F
CONTENTS AND METHOD OF STAMPING (25)

(Normative)

2-F.1 REQUIRED MARKING FOR VESSELS (25)

Each pressure vessel to which the Certification Mark with the U2 Designator is applied shall be marked with the following:

(a) The official Certification Mark with the U2 Designator, as shown in Figure 2-F.1, sketch (a), which shall be stamped on vessels certified in accordance with this Division.

(b) The name of the Manufacturer of the pressure vessel as it is shown on the Certificate of Authorization or an abbreviation accepted by ASME, preceded by "Certified by." A trademark is not considered to be sufficient identification for vessels or parts constructed to this Division.

(c) The Manufacturer's serial number (MFG SER).

(d) The MAWP (Maximum Allowable Working Pressure), internal or external, at the coincident maximum design metal temperature. When a vessel is specified to operate at more than one pressure and temperature condition, such values of coincident pressure and design temperature shall be added to the required markings. The maximum allowable working pressure (external) is required only when specified as a design condition.

(e) The MDMT (minimum design metal temperature) at coincident MAWP in accordance with Part 3.

(f) The year built.

(g) Code Edition (see 2.1.3).

(h) The construction type, i.e., all of the applicable construction types shall be marked under the Certification Mark and U2 Designator or, if marking is by a fabricator of pressure vessel parts only, under the Certification Mark and PRT VIII-2 Designator. WL (welded layered) is the only construction type that is required to be marked on the vessel.

(i) Heat treatment markings shall be as follows:

(1) The letters HT shall be applied under the Certification Mark and U2 Designator and under the Certification Mark and PRT VIII-2 Designator, as applicable, when the complete vessel has been postweld heat treated in accordance with Part 3.

(2) The letters PHT shall be applied under the Certification Mark and U2 Designator or under the Certification Mark and PRT VIII-2 Designator, as applicable, when only part of the complete vessel has been postweld heat treated in accordance with Part 3.

2-F.2 REQUIRED MARKING FOR COMBINATION UNITS

(a) Those chambers included within the scope of this Division shall be marked. The marking shall include the name of each chamber (e.g., process chamber, jacket, tubes, channel) and its corresponding data. The markings shall be grouped in one location on the combination unit or applied to each individual chamber. Each detachable chamber shall be marked to identify it with the combination unit. When required, the marking shall include the following:

(1) for differential pressure design, the maximum differential design pressure for each common element and the name of the higher pressure chamber

(2) for mean metal temperature design, the maximum mean metal design temperature for each common element

(3) for a common element adjacent to a chamber not included within the scope of this Division, the common element design conditions from that chamber

(b) It is recommended that the design conditions for those chambers not included within the scope of this Division be marked on the combination unit. The markings may be on the applicable chamber or grouped as described in 2-F.2(a), provided they are not included in the markings covered by the Certification Mark.

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2-F.3 APPLICATION OF STAMP

The Certification Mark with the U2 Designator or the Certification Mark with the PRT VIII-2 Designator shall be applied by the Manufacturer only with the approval of the Inspector, and after the hydrostatic test and all other required inspection and testing has been satisfactorily completed. Such application of the Certification Mark with the U2 Designator or the Certification Mark with the PRT VIII-2 Designator, together with final certification in accordance with the rules of this Division, shall confirm that all applicable requirements of this Division and the User's Design Specification have been satisfied.

2-F.4 PART MARKING

2-F.4.1 Parts of pressure vessels for which Partial Data Reports are required shall be marked by the parts Manufacturer with the following:

(a) the official Certification Mark with, as applicable, the

(1) U2 Designator, as shown in Figure 2-F.1, above the word "PART," or

(2) PRT VIII-2 Designator, as shown in Figure 2-F.1

(b) the name of the Manufacturer of the part, preceded by the words "Certified by"

(c) the Manufacturer's serial number assigned to the part

(d) the MAWP and coincident maximum design metal temperature (see Part 2)

(e) the MDMT (minimum design metal temperature) at the MAWP (see Part 3)

When stamping with the Certification Mark with the PRT VIII-2 Designator, the word "PART" may be eliminated from the stamping.

2-F.4.2 The requirements for part marking in accordance with 2-F.4.1(d) and 2-F.4.1(e) do not apply for the following:

(a) parts for which the parts Manufacturer does not prepare a Manufacturer's Design Report

(b) overpressure relief devices that are covered in Part 9

2-F.5 APPLICATION OF MARKINGS

Markings required in 2-F.1 through 2-F.4 shall be applied by one of the following methods:

(a) Nameplate – A separate metal nameplate, of a metal suitable for the intended service, at least 0.5 mm (0.02 in.) thick, shall be permanently attached to the vessel or to a bracket that is permanently attached to the vessel. The nameplate and attachment shall be such that removal shall require willful destruction of the nameplate or its attachment system. The attachment weld to the vessel shall not adversely affect the integrity of the vessel. Attachment by welding shall not be permitted on materials enhanced by heat treatment or on vessels that have been pre-stressed.

(1) Only the Certification Mark need be stamped on the nameplate.

(2) All other data may be stamped, etched, or engraved on the nameplate (see 2-F.7).

(3) The nameplate or a bracket to which the nameplate is affixed may be attached to a component other than the pressure-retaining shell under the following conditions:

(-a) The User's Design Specification shall state the need for not directly attaching the nameplate on the vessel shell.

(-b) The nameplate or a bracket to which the nameplate is affixed shall be located in a clearly visible and accessible location and welded to the vessel skirt or other component that is permanently attached to the vessel.

(-c) The nameplate location shall be indicated in the remarks on the Manufacturer's Data Report.

(b) Directly on Vessel Shell

(1) Markings shall be stamped, with low stress type stamps, directly on the vessel, located on an area designated as a low stress area by the Manufacturer in the Manufacturer's Design Report (see 2.3.3).

(2) Markings, including the Certification Mark, may be electrochemically etched on the external surfaces on the vessel under the following conditions:

(-a) The markings are acceptable to the user as indicated in the User's Design Specification.

(-b) The data shall be in characters not less than 8 mm ($^{5}/_{16}$ in.) high.

(-c) The materials shall be limited to high alloy steels and nonferrous materials.

(-d) The process controls for electrochemical etching shall be described in the Quality Control System and shall be acceptable to the Authorized Inspector. The process controls shall be established so that it can be demonstrated that the characters will be at least 0.1 mm (0.004 in.) deep.

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(-e) The external vessel surface condition where electrochemical etching is acceptable shall be clean, uncoated, and unpainted.

(-f) The electrochemical etching shall not result in any detrimental effect to the materials of the vessel.

(c) Adhesive Attachment – Nameplates may be attached with pressure-sensitive acrylic adhesive systems in accordance with the following requirements:

(1) Adhesive systems for the attachment of nameplates are permitted under the following conditions:

(-a) The adhesive used is a pressure-sensitive acrylic adhesive that has been preapplied by the nameplate manufacturer to a nominal thickness of at least 0.13 mm (0.005 in.).

(-b) The adhesive is protected with a moisture-stable liner.

(-c) The vessel(s) to which the nameplate is being attached has a design temperature within the range of −40°C to 150°C (−40°F to 300°F), inclusive.

(-d) The nameplate is applied to a clean, bare metal surface with attention being given to removal of anti-weld-spatter compound that may contain silicone.

(-e) The nameplate application procedure is qualified as outlined in (2).

(-f) The preapplied adhesive is used within 2 yr after initial adhesive application.

(2) Nameplate Application Procedure Qualification

(-a) The Manufacturer's Quality Control System (see Annex 2-E) shall define that written procedures, acceptable to the Inspector, for the application of adhesive-backed nameplates shall be prepared and qualified.

(-b) The application procedure qualification shall include the following essential variables, using the adhesive and nameplate manufacturers' recommendations where applicable:

(-1) Description of the pressure-sensitive acrylic adhesive system employed, including generic composition

(-2) The qualified temperature range, the cold box test temperature shall be −40°C (−40°F) for all applications

(-3) Materials of nameplate and substrate when the mean coefficient of expansion at design temperature of one material is less than 85% of that for the other material

(-4) Finish of the nameplate and substrate surfaces

(-5) The nominal thickness and modulus of elasticity at application temperature of the nameplate when nameplate preforming is employed — a change of more than 25% in the quantity: [(nameplate nominal thickness)^2 × nameplate modulus of elasticity at application temperature] will require requalification

(-6) The qualified range of preformed nameplate and companion substrate contour combinations when preforming is employed

(-7) Cleaning requirements for the substrate

(-8) Application temperature range and application pressure technique

(-9) Application steps and safeguards

(-c) Each procedure used for nameplate attachment by pressure-sensitive acrylic adhesive systems shall be qualified for outdoor exposure in accordance with Standard UL-969, Marking and Labeling Systems, with the following additional requirements.

(-1) Width of nameplate test strip shall not be less than 25 mm (1 in.).

(-2) Nameplates shall have an average adhesion of not less than 1.4 N/mm (8 lb/in.) of width after all exposure conditions, including low temperature.

(-3) Any change in (-b) shall require requalification.

(-4) Each lot or package of nameplates shall be identified with the adhesive application date.

2-F.6 DUPLICATE NAMEPLATE

A duplicate nameplate may be attached on the support, jacket, or other permanent attachment to the vessel. All data on the duplicate nameplate, including the Certification Mark with U2 Designator, shall be cast, etched, engraved, or stamped. The Inspector need not witness this marking. The duplicate nameplate shall be marked "DUPLICATE." The use of duplicate nameplates, and the stamping of the Certification Mark on the duplicate nameplate, shall be controlled as described in the Manufacturer's Quality Control System.

2-F.7 SIZE AND ARRANGEMENTS OF CHARACTERS FOR NAMEPLATE AND DIRECT STAMPING OF VESSELS

2-F.7.1 The data shall be arranged substantially as shown in Figure 2-F.1. The characters for direct stamping of the vessel shall be not less than 8 mm ($^5/_{16}$ in.) high. The characters for nameplate stamping shall be not less than 4 mm ($^5/_{32}$ in.) high. The characters shall be either indented or raised at least 0.10 mm (0.004 in.) and shall be legible and readable.

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2-F.7.2 Where space limitations do not permit the requirements of 2-F.7.1 to be met, such as for parts with outside diameters of 89 mm (3.5 in.) or smaller, the required character size to be stamped directly on the vessel may be 3 mm ($\frac{1}{8}$ in.).

(25) ## 2-F.8 ATTACHMENT OF NAMEPLATE OR TAG

If all or part of the data is marked on the nameplate or tag before it is attached to the vessel, the Manufacturer shall ensure that the nameplate with the correct marking has been attached to the vessel to which it applies as described in the Manufacturer's Quality Control System. The Inspector shall verify that this has been done.

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2-F.9 FIGURES

Figure 2-F.1
Form of Stamping

(25)

U2

Letters Denoting the Construction Type
[see 2-F.1(h), 2-F.1(i), and 2-F.4.1(a)]

(a) [Note (1)]

PRT VIII-2

Letters Denoting the Construction Type
[see 2-F.1(h), 2-F.1(i), and 2-F.4.1(a)]

(b) [Note (1)]

Certified by

_____
(Name of Manufacturer)

_____ at _____
Maximum Allowable Working Pressure (Internal)

_____ at _____
Maximum Allowable Working Pressure (External) [Note (2)]

_____ at _____
Minimum Design Metal Temperature

_____
Manufacturer's Serial Number

_____
Year Built

_____
Code Edition

GENERAL NOTES:

(a) For cases where the MAWP (internal) and MAWP (external) have the same designated coincident temperature, the values may be combined on a single line as follows:

$$P_{int}/FV\ (psi)\ at\ Temp\ (°F)$$

(b) The letters "FV" may be used to designate a full vacuum condition, e.g., 150 psi/FV at 300°F.

NOTES:

(1) Information within parentheses or brackets is not part of the required marking. Phrases identifying data may be abbreviated; minimum abbreviations shall be MAWP, MDMT, S/N, and year, respectively.

(2) The maximum allowable working pressure (external) required only when specified as a design condition.

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ANNEX 2-G
OBTAINING AND USING CERTIFICATION MARK STAMPS

(Normative)

2-G.1 CERTIFICATION MARK

A Certificate of Authorization to use the Certification Mark with the U2 or PRT VIII-2 Designator (see https://www.asme.org/shop/certification-accreditation) shown in Annex 2-F will be granted by ASME pursuant to the provisions of the following paragraphs. Stamps for applying the Certification Mark shall be obtained from ASME.

2-G.2 APPLICATION FOR CERTIFICATE OF AUTHORIZATION

Any organization desiring a Certificate of Authorization shall apply to ASME in accordance with the certification process of ASME CA-1. Authorization to use Certification Marks may be granted, renewed, suspended, or withdrawn as specified in ASME CA-1.

2-G.3 ISSUANCE OF AUTHORIZATION

A Certificate of Authorization shall be issued in accordance with ASME CA-1.

2-G.4 DESIGNATED OVERSIGHT

The Manufacturer shall comply with the requirements of ASME CA-1 for designated oversight by use of an Authorized Inspection Agency.

2-G.5 QUALITY CONTROL SYSTEM

Any Manufacturer holding or applying for a Certificate of Authorization shall demonstrate a Quality Control System that meets the requirements of ASME CA-1 and Annex 2-E.

2-G.6 EVALUATION OF THE QUALITY CONTROL SYSTEM

2-G.6.1 The issuance or renewal of a Certificate of Authorization is based upon ASME's evaluation and approval of the Quality Control System, and shall be in accordance with ASME CA-1.

(25) **2-G.6.2** Before issuance or renewal of a Certificate of Authorization for use of the Certification Mark with the U2 Designator or the Certification Mark with the PRT VIII-2 Designator, the Manufacturer's facilities and organization are subject to a joint review by a representative of the Authorized Inspection Agency and an individual certified as an ASME designee who is selected by the concerned legal jurisdiction. For those areas where there is no jurisdiction or where a jurisdiction does not choose to select an ASME designee to review a Manufacturer's facility, an ASME designee selected by ASME shall perform that function. Where the jurisdiction is the Manufacturer's Inspection Agency, the jurisdiction and the ASME designee shall make the joint review and joint report.

2-G.7 CODE CONSTRUCTION BEFORE RECEIPT OF CERTIFICATE OF AUTHORIZATION

A Manufacturer may start fabricating Code items before receipt of a Certificate of Authorization to use a Certification Mark and Designator under the conditions specified in ASME CA-1.

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ANNEX 2-I
ESTABLISHING GOVERNING CODE EDITIONS AND CASES FOR PRESSURE VESSELS AND PARTS

(Normative)

2-I.1 GENERAL

(a) After Code revisions are approved by ASME, they may be used beginning with the date of issuance shown on the Code. Except as noted below, revisions become mandatory six months after the date of issuance. Code Cases are permissible and may be used beginning with the date of approval by ASME. Only Code Cases that are specifically identified as being applicable to this Section may be used. At the time a Code Case is applied, only the latest revision may be used. Code Cases that have been incorporated into this Section or have been annulled shall not be used.

(b) Changes in the Code and Code Cases that have been published prior to completion of the pressure vessel or part may include details critical to the intended service conditions of the pressure vessel, which should be considered by the Manufacturer. Application of such changes shall be a matter of agreement between the Manufacturer and the user. Specific incorporated Code provisions from later editions that have been applied to construction shall be noted in the "Remarks" section of the Manufacturer's Data Report.

2-I.2 CONSTRUCTION

(a) The Manufacturer of any complete vessel or part that is to be stamped with the ASME Certification Mark required by this Section (see Annex 2-C) has the responsibility of ensuring through proper Code certification that all work performed complies with the effective Code Edition as follows:

(1) Vessels. The Code Edition used for construction of a pressure vessel shall be either the Edition that is mandatory on the date the pressure vessel is contracted for by the Manufacturer, or a published Edition issued by ASME prior to the contract date that is not yet mandatory [see 2-I.1(a)].

(2) Subcontracted Parts. When a vessel Manufacturer subcontracts some of the construction to another Certificate Holder, the part Manufacturer shall construct the part to the Code Edition established for the entire pressure vessel.

(3) Parts Built for Stock. Parts built for stock shall be constructed to either the Edition that is mandatory at the time of Code certification or a published Edition issued by ASME prior to Code certification that is not yet mandatory [see 2-I.1(a)].

(4) Parts Used From Stock. When a vessel Manufacturer uses a part from stock, the vessel Manufacturer shall ensure that the part fully satisfies all applicable Code requirements for the Code Edition used for construction of the complete vessel.

(b) It is permitted to use overpressure protection requirements from the Edition in effect when the vessel is placed in service.

2-I.3 MATERIALS

For parts subject to stress due to pressure, the Manufacturer shall use material conforming to one of the specifications listed as approved for use in the Edition specified for construction, or listed as approved for use in the Guideline for Acceptable ASTM Editions or in the Guideline for Acceptable Non-ASTM Editions in Section II, Part A or Part B.

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ANNEX 2-J
QUALIFICATIONS AND REQUIREMENTS FOR CERTIFYING ENGINEERS AND DESIGNERS

(Normative)

2-J.1 INTRODUCTION

(a) Persons engaged in design activity shall be competent in the topic of each design activity performed and shall be able to show evidence of this competency as described in 2-J.2.

(b) When a Certifying Engineer is required by 2.3.3.1 to certify the Manufacturer's Design Report, it is permissible for an engineer or designer to perform the design activity, provided all the following requirements are met:

(1) The individual has evidence of competence in the topic of design under consideration.

(2) The individual is working under the responsible charge[1] of a Certifying Engineer.

2-J.2 COMPETENCY REQUIREMENTS

(a) The engineer or designer may engage in any activity required by this Division or any supplemental requirements from the User's Design Specification except for Code activities listed in Table 2-J.1, unless the requirements of 2-J.1(b) are met.

(b) The Certifying Engineer may engage in any design activity required by this Division or any supplemental requirements from the User's Design Specification.

2-J.3 QUALIFICATION REQUIREMENTS

2-J.3.1 GENERAL

(a) One or more persons within the Manufacturer's organization shall be qualified to perform design work in accordance with the requirements of this Annex for any design activity listed in the Manufacturer's Quality Control System (see 2-E.5).

(b) The qualifications of 2-J.3.2 and 2-J.3.3 shall also apply to Certifying Engineers, engineers, and designers that are engaged by the Manufacturer by contract or agreement for their services.

(25) 2-J.3.2 CERTIFYING ENGINEERS

(a) The Certifying Engineer shall attest in writing to understanding and meeting the requirements of the ASME Code of Ethics and shall meet the requirements of (b) and (c).

(b) The Certifying Engineer may perform any design activity required by this Division for which the engineer has a minimum of 4 yr of experience in the design of pressure vessels.

(1) For Certifying Engineers who certify the Manufacturer's Design Report, this experience shall be demonstrated through documentation certified by a Manufacturer.

(2) For Certifying Engineers who certify the User's Design Specification, this experience shall be demonstrated through documentation maintained by the Certifying Engineer.

(c) The Certifying Engineer shall be chartered, registered, or licensed in accordance with one or more of the following:

(1) a registered Professional Engineer in at least one state of the United States or province of Canada

(2) the International Register of Professional Engineers by an authorized member of the International Professional Engineers Agreement (IPEA)

[1] For further information regarding responsible charge, see the National Society of Professional Engineers Position Statement No. 1778.

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Table 2-J.1
Design Activities Requiring a Certifying Engineer

Design Activities	Code Location
Performance of numerical analysis	5.1.2
Fatigue assessments	
Elastic stress analysis	5.5.3
Elastic–plastic stress analysis	5.5.4
Elastic analysis and structural stress	5.5.5
Design due to seismic reactions	
Linear response history procedure	5.1.3
Nonlinear response history procedure	5.1.3
Quick-actuating closures	4.8

(3) an authorized member of the Asia Pacific Economic Cooperation (APEC) Engineer Agreement

(4) an authorized member of Engineers Europe

2-J.3.3 ENGINEERS AND DESIGNERS (25)

(a) Education

(1) The engineer shall have a degree from an accredited university or college in engineering, science, or technology requiring an equivalent of 4 yr of full-time study of higher education.

(2) The designer shall have completed an accredited engineering technician or associates degree, requiring the equivalent of at least 2 yr of study.

(b) Personnel Experience

(1) An engineer engaged in and/or having responsible oversight for pressure vessel design shall as a minimum hold the qualification described in (c)(1)(-b).

(2) A designer meeting the education requirements of (a)(2) engaged in and/or having responsible oversight for pressure vessel design shall as a minimum hold the qualification described in (c)(1)(-c).

(3) A designer that does not meet the minimum education requirements of (a)(2) engaged in and/or having responsible oversight for pressure vessel design shall as a minimum hold the qualification described in (c)(1)(-d).

(4) The engineer or designer may also hold any of the additional qualifications described in (c)(2) through (c)(4).

(c) Practical Experience

(1) General Pressure Vessel Design

(-a) This qualification includes all design activity required for this Division that the individual engages in, or as listed in the Manufacturer's Quality Control System, except as provided for in (2) through (4).

(-b) The engineer shall be able to demonstrate through documentation a minimum of 4 yr of experience in pressure vessel design.

(-c) A designer meeting the education requirements of (a)(2) shall be able to demonstrate through documentation a minimum of 6 yr of experience in pressure vessel design.

(-d) A designer that does not meet the minimum education requirements of (a)(2) shall be able to demonstrate a minimum of 10 yr of experience in pressure vessel design.

(2) Heat Exchanger Design. The engineer or designer shall be able to demonstrate through documentation a minimum of 2 yr of experience in each of the following design Code activities for heat exchangers that the engineer or designer practice:

(-a) tubesheets (see 4.18)

(-b) bellows expansion joints (see 4.19)

(-c) flexible shell element expansion joints (see 4.20)

(3) Numerical Analysis

(-a) The engineer or designer shall be able to demonstrate through documentation a minimum of 2 yr of experience performing design calculations not specifically addressed in this Division, including numerical analysis.

(-b) An engineer or designer engaged in the performance of numerical analysis shall be able to demonstrate through documentation the receipt of instruction in the use and understanding of any numerical analysis computer program(s). This documentation shall be provided to the engineer or designer by one of the following:

(-1) the developer of the computer program (e.g., the software vendor)

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(-2) a training course acceptable to or licensed by the developer

(-3) a Certifying Engineer with requisite knowledge of the computer program and qualifications to train others on its use

(4) Quick-Actuating Closures. The engineer or designer shall be able to demonstrate through documentation a minimum of 2 yr of experience in design activity for quick-actuating closures (see 4.8).

(5) The experience requirements of (2) through (4) may be acquired concurrently.

(6) The engineer or designer's qualification(s) remain valid if the individual can demonstrate through documentation design activity completed within a continuous period of 36 months for each of their qualifications in (1), (2), (3), or (4).

2-J.4 CERTIFICATION REQUIREMENTS

2-J.4.1 CERTIFYING ENGINEERS

(a) The Manufacturer who employs (directly or by contract) the engineer who certifies the Manufacturer's Design Report shall prepare a statement, in conjunction with 2-J.3.2(b)(1), that the Certifying Engineer is qualified to perform the design activities used.

(b) Certifying Engineers who certify the User's Design Specification shall indicate their qualification as shown in 2-J.3.2(b)(2).

(c) Unless otherwise modified by the Manufacturer as stated in their Quality Control Manual, certification of pressure vessel design competence qualification expires for all design activities when no single design activity has occurred within a continuous period of 36 months.

2-J.4.2 ENGINEERS AND DESIGNERS

(a) The Manufacturer who employs (directly or by contract) the engineer or designer who certifies the Manufacturer's Design Report shall prepare a statement that the individual is qualified to perform the design activities used.

(b) Unless otherwise modified by the Manufacturer as stated in their Quality Control Manual, certification of pressure vessel design competence qualification expires for all Code activities when no single design activity has occurred within a continuous period of 36 months.

2-J.4.3 REACTIVATION

Certification may be reactivated by either of the following methods:

(a) continuity of the design activity for a 6-month period

(b) completion of eight or more professional development hours (PDHs) consisting of one or more of the following activities:

(1) taught or attended an appropriate course, training program, or seminar covering the design topic

(2) attended a technical society meeting related to the topic

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PART 3
MATERIALS REQUIREMENTS

3.1 GENERAL REQUIREMENTS

The requirements for materials used in the construction of pressure vessel parts according to the rules of this Division are defined in this Part. General rules and supplemental requirements are defined for different material types and product forms. In cases of conflicts, the requirements stipulated in the paragraphs containing “Supplemental Requirements” shall govern.

3.2 MATERIALS PERMITTED FOR CONSTRUCTION OF VESSEL PARTS

3.2.1 MATERIALS FOR PRESSURE PARTS

3.2.1.1 Materials used for the construction of pressure parts shall conform to one of the specifications given in Section II, and shall be limited to those material specifications shown in the allowable design stress tables in Annex 3-A unless specifically allowed by other rules of this Division.

3.2.1.2 Materials outside the limits of size, thickness, or weight limits stipulated in the title or scope clause of the material specification given in Section II and permitted by 3.2.1.1 may be used if the material is in compliance with the other requirements of the specification and a size, thickness, or weight limitation is not given in the allowable design stress table (see Annex 3-A) or in Table 7.2. For specifications in which chemical composition or mechanical properties vary with size or thickness, materials outside the range shall be required to conform to the composition and mechanical properties shown for the nearest specified range.

3.2.1.3 Materials shall be proven of weldable quality. Satisfactory qualification of the welding procedure under Section IX is considered as proof.

3.2.1.4 Materials for which fatigue curves are provided (see 3.15) shall be used in construction of vessels or vessel parts subject to fatigue unless the fatigue analysis exemption criteria of 5.5.3 are satisfied.

3.2.1.5 Materials other than those allowed by this Division shall not be used unless data therein are submitted to and approved by the Boiler and Pressure Vessel Committee in accordance with Section II, Part D, Mandatory Appendix 5.

3.2.1.6 The rules in this Division do not provide detailed requirements for selection of an alloy suitable for the intended service or the amount of corrosion allowance to be provided. It is required that the user or the user's designated agent assure the materials used for the construction of vessels or vessel parts are suitable for the intended service conditions with respect to mechanical properties, resistance to corrosion, erosion, oxidation, and other damage mechanisms anticipated during service life. Informative and nonmandatory guidance regarding metallurgical phenomena that occur in material subject to certain process environments is provided in Section II, Part D, Nonmandatory Appendix A. (25)

3.2.1.7 The material specifications listed in Annex 3-A of this Division include a column of UNS (Unified Numbering System) numbers assigned to identify the various alloy compositions. These numbers are used in the rules of this Division whenever reference is made to materials of approximately the same chemical composition that are furnished under more than one approved specification or in more than one product form.

3.2.2 MATERIALS FOR ATTACHMENTS TO PRESSURE PARTS

3.2.2.1 Except as permitted in 3.2.2.2, materials for non-pressure parts which are welded to pressure parts shall meet all the requirements of 3.2.1 and all supplemental requirements stipulated in this Part [see 2.2.3.1(g)].

3.2.2.2 Except as limited in 3.5 for quenched and tempered steels, or by 6.7 for forged vessel construction where welding is not permitted, minor attachments may be of a non-ASME material and may be welded directly to the pressure part, provided the criteria listed below are satisfied. In this context, minor attachments are parts of small size [i.e., not over 10 mm ($^3/_8$ in.) thick or 80 cm^3 (5 in.^{3}) volume] that support no load or insignificant loads (i.e., stress calculations are not required in the Manufacturer’s judgment), such as name plates, insulation supports, and locating lugs.

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(a) The material is identified and is suitable for welding. Satisfactory qualification of welding procedure under Section IX is considered as proof.

(b) The material is compatible insofar as welding is concerned with that to which the attachment is to be made.

(c) The welds are postweld heat treated when required by 6.4.2 of this Division.

(25) **3.2.2.3** For UNS S17400, no welding is permitted, except non-pressure parts may be welded to the pressure vessel provided the following requirements are met:

(a) All material shall be heat treated prior to welding to the solution-annealed condition or to a yield strength of 724 MPa (105 ksi) or less, in accordance with the heat treatment requirements of the applicable materials specification.

(b) The weld metal shall be the same nominal composition as UNS S17400.

(c) After welding, the welded component shall be fully solution annealed and aged to the H1075, H1100, or H1150 condition, as applicable.

(d) The weldment shall be liquid penetrant examined per 7.5.7 after the final heat treatment.

(e) Separate welding procedure and performance qualification in accordance with Section IX shall be conducted.

(f) Temporary welds and repair welds shall be considered the same as all other welds insofar as requirements for qualified operators and procedures and for heat treatment are concerned.

3.2.3 WELDING MATERIALS

3.2.3.1 Welding materials used for the construction of pressure parts shall comply with the requirements of this Division, those of Section IX, and the applicable qualified welding procedure specification.

3.2.3.2 When the welding materials comply with one of the specifications in Section II, Part C, the marking or tagging of the material, containers, or packages as required by the applicable Section II specification may be adopted for identification in lieu of a Test Report or a Certificate of Compliance. When the welding materials do not comply with one of the specifications of Section II, the marking or tagging shall be identifiable with the welding materials set forth in the welding procedure specification, and may be acceptable in lieu of a Test Report or a Certificate of Compliance.

3.2.4 DISSIMILAR MATERIALS

(25) **3.2.4.1** The user or the user's designated agent shall ensure that the coupling of dissimilar materials will not have a detrimental effect on the corrosion rate or service life of the vessel (see Section II, Part D, Nonmandatory Appendix A).

3.2.4.2 The requirements for the base metals, heat-affected zones (HAZ), and weld metals of weldments between metals having different impact testing requirements and acceptance criteria shall be applied in accordance with the rules of this Division.

(25) 3.2.5 PRODUCT SPECIFICATIONS

3.2.5.1 Plates. The term “plate” as used in this Division also includes sheet and strip.

3.2.5.2 Bars.

(a) General

(1) A bar is defined as a solid section whose axial length is greater than its maximum cross-sectional dimension, with a nominally constant cross section throughout its length.

(2) A rod is defined as a bar with other than a square or rectangular cross section; the general term “bar” is used in this paragraph.

(3) Bar that is forged, independent of the material specification to which it is certified, may be used only within the limitations of 3.2.5.2.

(b) Bars Used in Tension or Longitudinal Bending. Bars may be used in pressure vessel construction for pressure parts whose primary stresses are parallel to the axis of the bar, such as flange rings [see 4.16.4.3(a)], stiffening rings, frames for reinforced openings, stays and staybolts, and similar parts.

(c) Other Parts Machined From Bar. Pressure parts other than those in (b), such as hollow, cylindrically shaped parts, heads, caps, tubesheets, flanges, elbows, return bends, tees, and header tees, may be machined directly from bar as provided below. (See Table 3.1.)

(1) Using a Reduction in Design Stresses. Parts may be machined from bar provided all the following requirements are met:

(-a) The minimum required thickness of the component is calculated using 50% of the following values, as appropriate:

(-1) the specified allowable stress

(-2) the “B” value for external pressure or compressive stress design

(-3) the yield and tensile strengths for rules using such values

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(-b) The following surfaces shall be examined by the magnetic particle or liquid penetrant method in accordance with the requirements of Part 7 (see Figure 3.1):

(-1) any surface that has a slope greater than 1:3 from the axis of the bar following final machining, except where accessibility prevents meaningful interpretation and characterization of imperfections

(-2) the cut surfaces of the weld preparations prior to welding

(-c) Bar having a minimum cross-sectional dimension greater than 205 mm (8.00 in.) shall also conform to the ultrasonic requirements of (2)(-b) and (2)(-c).

(2) Using Transverse Tension Testing and Ultrasonic Examination. As an alternative to (1), parts may be machined from bar without a reduction in design stresses provided all the following requirements are met:

(-a) Transverse Test Specimens

(-1) In addition to the tension test specimens required by the material specification, tension test specimens shall meet the following requirements:

(+a) They shall be taken transverse to the axis of the bar per the requirements of (-2).

(+b) They shall be sampled from each lot (as defined in the material specification) of bar material.

(+c) In addition to the per-lot requirement of (+b), bars in the same lot shall be sampled from each diameter in the lot.

(-2) Specimens shall be removed from the bar as shown in Figure 3.2.

(+a) Hollow Parts, Such as Hollow, Cylindrically Shaped Parts, and Ring, Slip-On, or Weld Neck Flanges. The axis of the two outer tension test specimens shall be located, as nearly as practicable, midway between the minimum inner and maximum outer surfaces of the finished part, as measured from the bar axis , and 90 deg around the perimeter from each other.

(+b) Solid Parts, Such as Heads, Caps, Tubesheets, Blind Flanges, Elbows, Return Bends, Tees, and Header Tees

(+1) The axis of the two outer tension test specimens shall be located as nearly as practicable to the outer surface of the finished part, as measured from the bar axis, and 90 deg around the perimeter from each other.

(+2) The axis and mid-gage length of the third specimen shall be located approximately at the centerline of the bar; its orientation need not be aligned with either of the two other specimens.

(-3) All specimens shall meet all the mechanical tension test property requirements of the material specification.

(-b) Radial Ultrasonic Examination. Each bar, before machining, shall be 100% ultrasonically examined perpendicular to the longitudinal axis by the straight beam technique in accordance with Section V, SA-388 or SA-745, as applicable. The bar shall be unacceptable if either of the following occurs:

(-1) The examination results show one or more indications accompanied by loss of back reflection larger than 60% of the reference back reflection.

(-2) The examination results show indications larger than 40% of the reference back reflection when accompanied by a 40% loss of back reflection.

(-c) Longitudinal Ultrasonic Examination. For machined features of components for which it is practicable, such as heads, tubesheets and the flat portion of caps, the ultrasonic examination perpendicular to the longitudinal axis of (-b) shall also be performed in the axial direction. If the axial ultrasonic examination is qualified for the bar prior to machining, this ultrasonic examination may be done in lieu of the examination perpendicular to the longitudinal axis per (-b).

(-d) Surface Examination. Each part shall be surface examined per (1)(-b).

(3) Exemption for ASME Standard Parts. The requirements of (1) and (2) do not apply to parts conforming to an ASME standard per 3.2.8.3.

3.2.5.3 When a material specification is not listed in this Division covering a particular wrought or hot isostatically pressed material product of a grade (i.e., desired material), but there is an approved specification listed in this Division covering some other wrought or hot isostatically pressed material product of that grade (i.e., approved material), the desired material may be used, provided the following conditions are met:

(a) The chemical, mechanical, heat treating, deoxidation, and grain size requirements conform to the approved material.

(b) Hot isostatically pressed material shall also meet the requirements of Section II, Part D, Mandatory Appendix 5, Tables 5-100 and 5-600 and shall be limited to the classes of material itemized in the title of Section II, Part D, Mandatory Appendix 5, Table 5-100.

(c) The desired material is covered in a Section II specification.

(d) The stress values for the approved material given in the tables referenced in Annex 3-A shall be used.

(e) For the case of welded product forms without the addition of filler metal, the allowable stresses of the desired material shall be the appropriate approved material stress values multiplied by a factor of 0.85.

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(f) The product is not pipe or tube fabricated by fusion welding with the addition of filler metal unless it is constructed as a pressure part in accordance with the rules of this Division.

(g) The material test reports reference the specifications used in producing the material and reference this paragraph.

3.2.5.4 Forgings certified to SA-105, SA-181, SA-182, SA-350, SA-403, and SA-420 may be used as tubesheets and hollow cylindrical forgings for pressure vessel shells that otherwise meet all the rules of this Division, provided that the following additional requirements are met:

(a) Forgings certified to SA-105 or SA-181 shall be subject to one of the austenitizing heat treatments permitted by these specifications.

(b) One tension test specimen shall be taken from each forging weighing more than 2 250 kg (5,000 lb). The largest obtainable tension test specimen as specified by the test methods referenced in the applicable specification shall be used. Except for upset-disk forgings, the longitudinal axis of the test specimen shall be taken parallel to the direction of major working of the forging. For upset-disk forgings, the longitudinal axis of the test specimen shall be taken in the tangential direction. When agreed to by the Manufacturer, and when not prohibited by the material specification, test specimens may be machined from specially forged test blocks meeting the provisions for such as provided in SA-266 or other similar specifications for large forgings.

(c) For quenched and tempered forgings weighing more than 4 500 kg (10,000 lb) at the time of heat treatment, two tension test specimens shall be taken from each forging. These shall be offset 180 deg from each other, except if the length of the forging, excluding test prolongations, exceeds 3.7 m (12 ft); then one specimen shall be taken from each end of the forging.

3.2.6 CERTIFICATION

(25)

3.2.6.1 Certificate of Compliance and Material Test Report.

(a) The Manufacturer shall ensure all requirements of the material specification, and all special requirements of Part 3 of this Division, that are to be fulfilled by the materials manufacturer have been complied with. The Manufacturer shall accomplish this by obtaining Certificates of Compliance or Material Test Reports. These documents shall include results of all required tests and examinations, evidence of compliance with the material specifications and additional requirements as applicable. When the specification permits certain specific requirements to be completed later, those incomplete items shall be noted on the material documentation. When these specific requirements have been completed by someone other than the material manufacturer, this completion shall be documented and attached to the material documentation.

(b) For plates, the Manufacturer shall receive a copy of the test report or reports as prepared by the material manufacturer or by the material manufacturer and subsequent processors, if any, responsible for the data, and shall maintain the reports as part of the construction records.

(c) For all other product forms, the Manufacturer shall receive a copy of the test report as prepared by the material manufacturer. When preparing a test report, a material manufacturer may transcribe data produced by other organizations, provided the material manufacturer accepts responsibility for the accuracy and authenticity of the data.

(d) All conflicts between the material specification and the supplemental requirements stipulated in this Part shall be noted, and compliance with the supplemental requirements shall be certified.

3.2.6.2 Certificate of Compliance and Material Test Reports by Other Than Materials Manufacturer.

(a) Except as otherwise provided in 3.2.5.3 and 3.2.7, if the requirements in a material specification listed in Annex 3-A have been completed by other than the materials manufacturer, then the vessel Manufacturer shall obtain supplementary material test reports and the Inspector shall examine these documents and determine that they represent the material and meet the requirements of the material specification.

(b) The vessel Manufacturer shall certify compliance with all the supplemental requirements stipulated in this Part for any of the treatments or examinations specified herein. The certification shall include certified reports of results of all tests and examinations performed on the materials by the vessel Manufacturer.

3.2.7 PRODUCT IDENTIFICATION AND TRACEABILITY

3.2.7.1 General Requirements.

(a) Material for pressure parts shall be organized so that when the vessel is completed, one complete set of the original identification markings required in the specifications for all materials of construction will be clearly visible. In case the original identification markings are unavoidably cut out or the material is divided into two or more parts, the vessel Manufacturer shall assure identification of each piece of material during fabrication and subsequent identification of the markings on the completed vessel by using the methods listed below.

(1) Accurate transfer of the original identification markings to a location where the markings will be visible on the completed vessel.

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(2) Identification by coded marking, described in the Quality System Manual, acceptable to the Inspector and traceable to the original required marking.

(b) An as-built sketch or tabulation of materials shall be made, identifying each piece of material with a test report or, where permitted by this Part, with a Certificate of Compliance and the coded marking that ensure identification of each piece of material during fabrication and subsequent identification in the completed vessel.

(c) When plate specification heat treatments are not performed by the material manufacturer, they shall be performed by, or under the control of, the vessel Manufacturer who shall then place the letters "MT" (denoting material treatment) following the letter "G" denoting green) in the Mill plate marking (see SA-20) to indicate that the heat treatments required by the material specification have been performed. The fabricator shall also document in accordance with 3.2.6.2(b) that the specified heat treatments have been performed in accordance with the material manufacturer's recommendation.

3.2.7.2 Method of Transferring Markings by the Manufacturer.

(a) Transfer of markings shall be made prior to cutting except that the Manufacturer may transfer markings immediately after cutting, provided the control of these transfers is described in the Manufacturer's written Quality Control System. The Inspector need not witness the transfer of the marks but shall be satisfied that it has been done correctly.

(b) The material may be marked by any method acceptable to the Inspector; however, all steel stamping shall be done with commercially available "low stress" dies.

(c) Where the service conditions prohibit die-stamping for material identification, and when so specified by the user, the material manufacturer and the vessel Manufacturer shall mark the required data on the plates in a manner which will allow positive identification upon delivery. The markings must be recorded so that each plate will be positively identified in its position in the completed vessel to the satisfaction of the Inspector.

3.2.7.3 Transfer of Markings by Other Than the Manufacturer.

(a) When material is to be formed into shapes by anyone other than the Manufacturer of the completed pressure vessel and the original markings as required by the applicable material specification are unavoidably cut out, or the material is divided into two or more parts, the manufacturer of the shape shall either:

(1) Transfer the original identification markings to another location on the shape.

(2) Provide for identification by the use of a coded marking traceable to the original required marking, using a marking method agreed upon and described in the Quality Control System of the Manufacturer of the completed pressure vessel.

(b) The mill certification of the mechanical and chemical properties requirements of the material formed into shapes, in conjunction with the above modified marking requirements, shall be considered sufficient to identify these shapes. Manufacturer's Partial Data Reports and parts stamping are not required unless there has been fabrication of the shapes that include welding, except as exempted by 3.2.8.2.

3.2.7.4 Marking of Plates. The material manufacturer's identification marking required by the material specification shall not be stamped on plate material less than 6 mm ($^1/_4$ in.) in thickness unless the following requirements are met.

(a) The materials shall be limited to P-No. 1 Group Nos. 1 and 2.

(b) The minimum nominal plate thickness shall be 5 mm ($^3/_{16}$ in.) or the minimum nominal pipe wall thickness shall be 4 mm (0.154 in.).

(c) The MDMT shall be no colder than −29°C (−20°F).

3.2.8 PREFABRICATED OR PREFORMED PRESSURE PARTS FURNISHED WITHOUT A CODE STAMP

3.2.8.1 General Requirements.

(a) Prefabricated or preformed pressure parts for pressure vessels that are subject to stresses due to pressure and that are furnished by others or by the Manufacturer of the completed vessel shall conform to all applicable requirements of this Division except as permitted in 3.2.8.2, 3.2.8.3, 3.2.8.4, and 3.2.8.5.

(b) When the prefabricated or preformed parts are furnished with a nameplate that contains product identifying marks and the nameplate interferes with further fabrication or service, and where stamping on the material is prohibited, the Manufacturer of the completed vessel, with the concurrence of the Authorized Inspector, may remove the nameplate. The removal of the nameplate shall be noted in the "Remarks" section of the vessel Manufacturer's Data Report. The nameplate shall be destroyed.

(c) The rules of 3.2.8.2, 3.2.8.3, 3.2.8.4, and 3.2.8.5 below shall not be applied to welded shells or heads or to quick-actuating closures (see 4.8).

(d) Parts furnished under the provisions of 3.2.8.2, 3.2.8.3, or 3.2.8.4 need not be manufactured by a Certificate of Authorization Holder.

(e) Prefabricated or preformed pressure parts may be supplied as follows:

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(1) cast, forged, rolled, or die-formed nonstandard pressure parts

(2) cast, forged, rolled, or die-formed standard pressure parts, either welded or nonwelded, that comply with an ASME product standard

(3) cast, forged, rolled, or die-formed standard pressure parts, either welded or nonwelded, that comply with a standard other than an ASME product standard

3.2.8.2 Cast, Forged, Rolled, or Die-Formed Nonstandard Pressure Parts.

(a) Pressure parts such as shells, heads, removable doors, and pipe coils that are wholly formed by casting, forging, rolling, or die forming may be supplied basically as materials. All such parts shall be made of materials permitted under this Division, and the Manufacturer of the part shall furnish identification in accordance with 3.2.6.1.

Such parts shall be marked with the name or trademark of the parts manufacturer and with such other markings as will serve to identify the particular parts with accompanying material identification.

(b) The Manufacturer of the completed vessel shall be satisfied that the part is suitable for the design conditions specified for the completed vessel in accordance with the rules of this Division.

3.2.8.3 Cast, Forged, Rolled, or Die-Formed Standard Pressure Parts, Either Welded or Nonwelded, That Comply With an ASME Product Standard.

(a) Pressure parts that comply with an ASME product standard accepted by reference in 4.1.11. The ASME product standard establishes the basis for the pressure–temperature rating and marking unless modified in 4.1.11.

(b) Flanges and flanged fittings may be used at the pressure–temperature ratings specified in the appropriate standard listed in this Division.

(c) Materials for standard pressure parts shall be as follows:

(1) as permitted by this Division or

(2) as specifically listed in the ASME product standard

(d) When welding is performed it shall meet the following:

(1) the requirements of 6.2.2.1(a) and 6.2.2.2 through 6.2.2.5, or;

(2) the welding requirements of SA-234

(e) Pressure parts, such as welded standard pipe fittings, welding caps, and flanges that are fabricated by one of the welding processes recognized by this Division do not require inspection, material certification in accordance with 3.2.6, or Partial Data Reports, provided the requirements of 3.2.8.3 are met.

(f) If postweld heat treatment is required by the rules of this Division, it may be performed either in the location of the parts manufacturer or in the location of the Manufacturer of the vessel to be marked with the Certification Mark.

(g) If radiography or other volumetric examination is required by the rules of this Division, it may be performed at one of the following locations:

(1) the location of the Manufacturer of the completed vessel

(2) the location of the pressure parts manufacturer

(h) Parts made to an ASME product standard shall be marked as required by the ASME product standard.

(i) The Manufacturer of the completed vessels shall have the following responsibilities when using standard pressure parts that comply with an ASME product standard:

(1) Ensure that all standard pressure parts comply with applicable rules of this Division.

(2) Ensure that all standard pressure parts are suitable for the design conditions of the completed vessel.

(3) When volumetric examination is required by the rules of this Division, obtain the completed radiographs, properly identified, with a radiographic inspection report, and any other applicable volumetric examination report.

(j) The Manufacturer shall fulfill these responsibilities by obtaining when necessary, documentation as provided below, provide for retention of this documentation, and have such documentation available for examination by the Inspector when requested. The documentation shall contain at a minimum:

(1) material used

(2) the pressure–temperature rating of the part

(3) The basis for establishing the pressure–temperature rating

3.2.8.4 Cast, Forged, Rolled, or Die-Formed Standard Pressure Parts, Either Welded or Nonwelded, That Comply With a Standard Other Than an ASME Product Standard.

(a) Standard pressure parts that are either welded or nonwelded and comply with a manufacturer's proprietary standard or a standard other than an ASME product standard may be supplied by

(1) a Certificate of Authorization holder

(2) a pressure parts manufacturer

(b) Parts of small size falling within this category for which it is impossible to obtain identified material or that may be stocked and for which material certification in accordance with 3.2.6 cannot be obtained and are not customarily furnished, may be used for parts as described in 3.2.2.2.

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(c) Materials for these parts shall be as permitted by this Division only.

(d) When welding is performed, it shall meet the requirements of 6.2.2.1(a) and 6.2.2.2 through 6.2.2.5.

(e) Pressure parts, such as welded standard pipe fittings, welding caps, and flanges that are fabricated by one of the welding processes recognized by this Division do not require inspection, material certification in accordance with 3.2.6, or Partial Data Reports provided the requirements of 3.2.8.4 are met.

(f) If postweld heat treatment is required by the rules of this Division, it may be performed either in the location of the parts manufacturer or in the location of the Manufacturer of the completed vessel.

(g) If radiography or other volumetric examination is required by the rules of this Division, it may be performed at one of the following locations:

(1) The location of the Manufacturer of the completed vessel

(2) The location of the parts Manufacturer

(3) The location of the pressure parts manufacturer

(h) Marking for these parts shall be as follows:

(1) with the name or trademark of the Certificate Holder or the pressure part manufacturer and any other markings as required by the proprietary standard or other standard used for the pressure part.

(2) with a permanent or temporary marking that will serve to identify the part with the Certificate Holder or the pressure parts manufacturer's written documentation of the particular items, and that defines the pressure–temperature rating of the part.

(i) The Manufacturer of the completed vessels shall have the following responsibilities when using standard pressure parts:

(1) Ensure that all standard pressure parts comply with applicable rules of this Division

(2) Ensure that all standard pressure parts are suitable for the design conditions of the completed vessel.

(3) When volumetric examination is required by the rules of this Division, obtain the completed radiographs, properly identified, with a radiographic inspection report, and any other applicable volumetric examination report.

(j) The Manufacturer of the completed vessel shall fulfill the responsibilities of (i) by one of the following methods:

(1) Obtain when necessary, documentation as provided below, provide for retention of this documentation, and have such documentation available for examination by the Inspector when requested or

(2) Perform an analysis of the pressure part in accordance with the rules of this Division. This analysis shall be included in the documentation and shall be made available for examination by the Inspector when requested.

(k) The documentation shall contain at a minimum the following:

(1) material used

(2) the pressure–temperature rating of the part

(3) the basis for establishing the pressure–temperature rating

(4) a written certification by the pressure parts manufacturer that all welding complies with Code requirements

3.2.8.5 The Code recognizes that a Certificate of Authorization Holder may fabricate parts in accordance with 3.2.8.4, and that are marked in accordance with 3.2.8.4(h). In lieu of the requirement in 3.2.8.4(d), the Certificate of Authorization Holder may subcontract to an individual or organization not holding an ASME Certificate of Authorization standard pressure parts that are fabricated to a standard other than an ASME product standard, provided all the following conditions are met:

(a) The activities to be performed by the subcontractor are included within the Certificate Holder's Quality Control System.

(b) The Certificate Holder's Quality Control System provides for the following activities associated with subcontracting of welding operations, and these provisions shall be acceptable to the Manufacturer's Authorized Inspection Agency.

(1) The welding processes permitted by this Division that are permitted to be subcontracted.

(2) Welding operations

(3) Authorized Inspection activities

(4) Placement of the Certificate of Authorization Holders marking in accordance with (d).

(c) The Certificate Holder's Quality Control System provides for the requirements of 7.2.2 to be met at the subcontractor's facility.

(d) The Certificate Holder shall be responsible for reviewing and accepting the Quality Control Programs of the subcontractor.

(e) The Certificate Holder shall ensure that the subcontractor uses written procedures and welding operations that have been qualified as required by this Division.

(f) The Certificate Holder shall ensure that the subcontractor uses personnel that have been qualified as required by this Division.

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(g) The Certificate Holder and the subcontractor shall describe in their Quality Control Systems the operational control of procedure and personnel qualifications of the subcontracted welding operations.

(h) The Certificate Holder shall be responsible for controlling the quality and ensuring that all materials and parts that are welded by subcontractors and submitted to the Inspector for acceptance, conform to all applicable requirements of this Division.

(i) The Certificate Holder shall describe in their Quality Control Systems the operational control for maintaining traceability of materials received from the subcontractor.

(j) The Certificate Holder shall receive approval for subcontracting from the Authorized Inspection Agency prior to commencing of activities.

3.2.9 DEFINITION OF PRODUCT FORM THICKNESS

3.2.9.1 The requirements in this Division make reference to thickness. When the material specification does not specify thickness, the following definitions of nominal thickness apply.

(a) Plate – the thickness is the dimension of the short transverse dimension.

(b) Forgings – the thickness is the dimension defined as follows:

(1) Hollow Forgings – the nominal thickness is measured between the inside and the outside surfaces (radial thickness).

(2) Disk Forgings– the nominal thickness is the axial length (axial length ≤ outside the diameter).

(3) Flat Ring Forgings – for axial length less than or equal to 50 mm (2 in.), the axial length is the nominal thickness; for axial length greater than 50 mm (2 in.), the radial thickness is the nominal thickness (axial length less than the radial thickness).

(4) Rectangular Solid Forgings – the least rectangular dimension is the nominal thickness.

(5) Round, Hexagonal and Octagonal Solid Forgings - the nominal thickness is the diameter or distance across the flats (axial length > diameter or distance across the flats).

(c) Castings – for castings of the general shapes described for forgings, the same definitions apply. For other castings, the maximum thickness between two cast coincidental surfaces is the nominal thickness.

3.2.9.2 The definition of nominal thickness for postweld heat treat requirements is covered in 6.4.2.7.

3.2.10 PRODUCT FORM TOLERANCES

3.2.10.1 Plate. Plate material shall be ordered not thinner than the design thickness. Vessels made of plate furnished with an undertolerance of not more than the smaller value of 0.3 mm (0.01 in.) or 6% of the ordered thickness may be used at the full design pressure for the thickness ordered if the material specification permits such an undertolerance. If the specification to which the plate is ordered allows a greater undertolerance, the ordered thickness of the material shall be sufficiently greater than the design thickness so that the thickness of the material furnished is not more than the smaller of 0.3 mm (0.01 in.) or 6% under the design thickness.

3.2.10.2 Pipe and Tube. If pipe or tube is ordered by its nominal wall thickness, the manufacturing undertolerance on wall thickness shall be taken into account. After the minimum required wall thickness is determined, it shall be increased by an amount sufficient to provide the manufacturing undertolerance allowed in the pipe or tube specification.

3.2.11 PURCHASE REQUIREMENTS

3.2.11.1 A summary of the pertinent requirements in 3.2 through 3.8 is provided in Annex 3-B.

3.2.11.2 Special chemical compositions, heat treatment procedures, fabrication requirements, and supplementary tests may be required to assure that the vessel will be in the most favorable condition for the intended service.

3.2.12 MATERIAL IDENTIFIED WITH OR PRODUCED TO A SPECIFICATION NOT PERMITTED BY THIS DIVISION

3.2.12.1 Identified Material With Complete Certification From the Material Manufacturer. Material identified with a specification not permitted by this Division and identified to a single production lot as required by a permitted specification may be accepted as satisfying the requirements of a specification permitted by this Division, provided the following conditions are satisfied:

(a) Documentation is provided to the Certificate Holder demonstrating that all applicable requirements (including, but not limited to, melting method, melting practice, deoxidation, chemical analysis, mechanical properties, quality, and heat treatment) of the specification permitted by this Division to which the material is to be recertified, including the requirements of this Division (see 3.2.6), have been met.

(b) The material has marking, acceptable to the Inspector, for identification to the documentation.

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(c) When the conformance of the material with the permitted specification has been established, the material shall be marked as required by the permitted specification.

3.2.12.2 Identified Material Recertification. Only the vessel or Part Manufacturer is permitted to recertify material per 3.2.12.1.

3.3 SUPPLEMENTAL REQUIREMENTS FOR FERROUS MATERIALS

3.3.1 GENERAL (25)

All forms of ferrous products listed in Tables 3-A.1 through 3-A.3 shall meet the supplemental requirements of 3.3. Cr-Mo materials listed in Table 3.2 shall also meet the supplemental requirements of 3.4. Additionally, the high-strength quenched and tempered steels listed in Table 3-A.2 shall also meet the supplemental requirements of 3.5.

3.3.2 CHEMISTRY REQUIREMENTS

Carbon and low alloy steel having carbon content of more than 0.35% by heat analysis shall not be used in welded construction or be shaped by oxygen cutting (except as provided elsewhere in this Division).

3.3.3 ULTRASONIC EXAMINATION OF PLATES

3.3.3.1 Except as permitted in 3.3.3.2, all plate 50 mm (2 in.) and over in nominal thickness shall be ultrasonically examined in accordance with the requirements of SA-578. The acceptance standard shall be Level B of SA-578.

3.3.3.2 When the design rules permit credit for thickness of cladding on plate conforming to SA-263, SA-264, and SA-265, ultrasonic examination shall be made of the base plate and the bond between the cladding and the base plate in accordance with the requirements of SA-578. The acceptance standard shall be at least Level B of SA-578. Alternatively, the acceptance standard of Level C may be used to satisfy this requirement.

3.3.4 ULTRASONIC EXAMINATION OF FORGINGS (25)

3.3.4.1 All forgings 50 mm (2 in.) and over in nominal thickness shall be examined ultrasonically as follows:

(a) Rings, flanges, and other hollow forgings shall be examined using the angle beam technique. For other forgings, the straight beam technique shall be used.

(b) Reference specimens shall have the same nominal thickness, composition, and P-number grouping as the forgings to be examined in order to have substantially the same structure.

(c) Tables 3.2, 3-A.1, and 3-A.2 steels shall be examined in accordance with Section V, SA-388.

(d) Table 3-A.3 steels shall be examined in accordance with Section V, SA-388 or Section V, SA-745, as applicable.

3.3.4.2 Forgings are unacceptable if:

(a) The straight beam examination results show one or more discontinuities which produce indications accompanied by a complete loss of back reflection not associated with or attributable to the geometric configuration.

(b) Angle beam examination results show one or more discontinuities which produce indications exceeding in amplitude the indication from the calibration notch.

3.3.4.3 In the case of straight beam examination, the following conditions shall be reported to the purchaser for consideration and approval prior to shipment of the forging:

(a) Forgings containing one or more indications with amplitudes exceeding adjacent back reflections.

(b) Forgings containing one or more discontinuities which produce traveling indications accompanied by reduced back reflections. A traveling indication is defined as an indication that displays sweep movement of the oscilloscope screen at constant amplitudes as the transducer is moved.

3.3.4.4 In the case of angle beam examination, the following conditions shall be reported to the purchaser for consideration and approval prior to shipment of the forging:

(a) Indications having an amplitude exceeding 50% of the calibration block amplitude.

(b) Clusters of indications located in a small area of the forging with amplitudes less than 50% of the calibration notch amplitude. A cluster of indications is defined as three or more indications exceeding 10% of the standard calibration notch amplitude and located in any volume approximately a 50 mm (2 in.) or smaller cube.

3.3.4.5 Additional nondestructive examination procedures or trepanning may be employed to resolve questions of interpretation of ultrasonic indications.

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3.3.5 MAGNETIC PARTICLE AND LIQUID PENETRANT EXAMINATION OF FORGINGS

3.3.5.1 Following final machining by the manufacturer, all accessible surfaces of forgings having a nominal thickness greater than 100 mm (4 in.), such as contour and variable-thickness nozzles, integrally hubbed tubesheets, standard or custom flanges, and other forgings that are contour shaped or machined to essentially the finished product configuration prior to heat treatment, shall be examined by the magnetic particle method in accordance with ASTM A275/A275M or by the liquid penetrant method in accordance with ASTM E165. The evaluation of indications detected by the magnetic particle method or by the liquid penetrant method and the acceptance standards shall be in accordance with Part 7 of this Division.

3.3.5.2 Unacceptable imperfections shall be removed and the areas shall be reexamined to ensure complete removal of the unacceptable imperfection. Unless prohibited by the material specification, the forgings may be repair welded with the approval of the vessel Manufacturer. Repairs shall be made utilizing welding procedures that have been qualified in accordance with Section IX. The repaired forging shall meet all requirements of this Division.

3.3.6 INTEGRAL AND WELD METAL OVERLAY CLAD BASE METAL

3.3.6.1 Applied Linings. Material used for applied corrosion resistant lining may be any metallic material of weldable quality, provided all applicable requirements of this Division are satisfied.

3.3.6.2 Design Calculations Based on Total Thickness.

(a) Base material with corrosion resistant integral or weld metal overlay cladding used in construction in which the design calculations are based on total thickness including cladding (see 4.1.9) shall consist of base plate listed in one of the material tables in Part 3 and shall conform to one of the following specifications or utilize weld metal overlay cladding meeting the requirements of this Division.

(1) SA-263, Specification for Corrosion-Resisting Chromium-Steel Clad Plate, Sheet and Strip;

(2) SA-264, Specification for Corrosion-Resisting Chromium-Nickel Steel Clad Plate, Sheet and Strip; or

(3) SA-265, Specification for Nickel and Nickel-Base Alloy Clad Steel Plate.

(b) Base material with corrosion resistant integral cladding in which any part of the cladding is included in the design calculations, as permitted in (a), that is constructed of multiple cladding plates welded together prior being bonded to the base material shall have the cladding-alloy-to-cladding-alloy welding that is performed prior to bonding to the base material:

(1) performed by a Manufacturer holding a Certificate of Authorization.

(2) radiographically examined for their full length in the manner prescribed in 7.5.3. In place of radiographic examination, welds may be ultrasonically examined for their full length (see 7.5.5).

(3) be supplied with a Partial Data Report if that welding is not performed by the vessel Manufacturer.

3.3.6.3 Design Calculations Based on Base-Plate Thickness. Clad plate used in constructions in which the design calculations are based on the base-plate thickness, exclusive of the thickness of the cladding material, may consist of any base-plate material satisfying the requirements of Part 3 and any metallic integral or weld metal overlay cladding material of weldable quality that meets the requirements of 6.5 of this Division.

3.3.6.4 Shear Strength of Bond of Integrally Clad Plates. Integrally clad plates in which any part of the cladding is included in the design calculations, as permitted in 4.1.9, shall show a minimum shear strength of 140 MPa (20 ksi) when tested in the manner described in the plate specification. One shear test shall be made on each such clad plate and the results shall be reported on the test report. A shear or bond strength test is not required for weld metal overlay cladding.

3.3.6.5 Removal of Cladding for Mill Tension Tests. When any part of the cladding thickness is specified an allowance for corrosion, such added thickness shall be removed before mill tension tests.

3.3.6.6 Low-Temperature Operations.

(a) When an applied corrosion-resistant lining is used (see 4.1.10), the impact test exemption temperature of the component shall consider the base material only.

(b) When a corrosion-resistant integral cladding is used in accordance with 3.3.6.2 or 3.3.6.3, the impact test exemption temperature of the component shall be the warmer of the two values determined for the base material and the integral cladding material. The impact test exemption temperature for the integral cladding material shall be determined in accordance with 3.11.4.3 or 3.11.5, as applicable.

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3.3.7 CLAD TUBESHEETS

3.3.7.1 Tube-to-tubesheet welds in the cladding of either integral or weld metal overlay clad tubesheets may be considered strength welds (full or partial), provided the welds meet the design requirements of 4.2.1. In addition, when the strength welds are to be made in the clad material of integral clad tubesheets, the integral clad material to be used for tubesheets shall meet the requirements in (a) and (b) for any combination of clad and base materials. The shear strength test and ultrasonic examination specified in (a) and (b) are not required for weld metal overlay clad tubesheets.

(a) Integral clad material shall be shear strength tested in accordance with SA-263. One shear test shall be made on each integral clad plate or forging, and the results shall be reported on the material test report.

(b) Integral clad material shall be ultrasonically examined for bond integrity in accordance with SA-578, including Supplementary Requirement S1, and shall meet the acceptance criteria given in SA-263 for Quality Level Class 1.

3.3.7.2 When the design calculations for clad tubesheets are based on the total thickness including the cladding, the clad material shall meet any additional requirements specified in 3.3.6.

3.3.7.3 When tubesheets are constructed using linings or integral cladding that does not meet the requirements of 3.3.7.1(a) and 3.3.7.1(b), the strength of the tube-to-tubesheet joint shall not be dependent upon the connection between the tubes and the lining or integral cladding, as applicable.

3.3.7.4 When the tubes are strength welded (full or partial) to integral or weld metal overlay clad tubesheets, S_t shall be the allowable stress value of the integral cladding or the wrought material whose chemistry most closely approximates that of the weld metal overlay cladding. The thickness of the integral or weld metal clad overlay material shall be sufficient to prevent any of the strength weld from extending into the base material.

3.4 SUPPLEMENTAL REQUIREMENTS FOR Cr–Mo STEELS

3.4.1 GENERAL

3.4.1.1 The rules in 3.4 include supplemental requirements for fabrication and testing for Cr-Mo steels. The materials and appropriate specifications covered by this paragraph are listed in Table 3.2.

3.4.1.2 Certification that the requirements of 3.4 have been satisfied shall be shown on the Manufacturer's Data Report Form.

3.4.2 POSTWELD HEAT TREATMENT

The final postweld heat treatment shall be in accordance with the requirements of 6.4.2 of this Division.

3.4.3 TEST SPECIMEN HEAT TREATMENT

3.4.3.1 Two sets of tension specimens and one set of Charpy impact specimens shall be tested. One set each of the tension specimens shall be exposed to heat treatment Condition A. The second set of tension specimens and the set of Charpy specimens shall be exposed to heat treatment Condition B.

(a) Condition A – Temperature shall be no lower than the actual maximum vessel-portion temperature, less 14°C (25°F). Time at temperature shall be no less than 80% of the actual holding time of the vessel portion exposed to the maximum vessel-portion temperature.

(b) Condition B – Temperature shall be no higher than the actual minimum vessel-portion temperature, plus 14°C (25°F). Time at temperature shall be no more than 120% of the actual hold time of the vessel portion exposed to the minimum vessel-portion temperature.

3.4.3.2 The suggested procedure for establishing the test specimen heat treatment parameters are shown below.

(a) Establish maximum and minimum temperatures and hold times for the vessel/component heat treatment based on experience/equipment;

(b) Determine Conditions A and B for the test specimen heat treatments;

(c) Vessel heat treatment temperature and hold time limitations, and test specimen Conditions A and B, are shown in Figure 3.3.

3.4.4 WELDING PROCEDURE QUALIFICATIONS AND WELDING CONSUMABLES TESTING

3.4.4.1 Welding procedure qualifications using welding consumables of the same classification or trade designation as those to be used in production shall be made for material welded to itself or to other materials. The qualifications shall conform to the requirements of Section IX, and the maximum tensile strength at room temperature shall be 760 MPa (110 ksi) (for heat treatment Conditions A and B).

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3.4.4.2 Weld metal from each heat or lot of electrodes and filler-wire–flux combination shall be tested, unless specific heat- or lot-traceable test reports meeting the additional requirements of 3.4 related to welding consumables testing have been provided by the welding consumables manufacturer. The minimum and maximum tensile properties shall be met in postweld heat treated (PWHT) Conditions A and B. The minimum Charpy V-notch impact properties shall be met in PWHT Condition B. Testing shall be in general conformance with SFA-5.5 for covered electrodes and SFA-5.23 for filler wire-flux combinations.

3.4.4.3 Duplicate testing in PWHT Condition A and PWHT Condition B (see 3.4.3) is required. The minimum tensile strength and Charpy impact properties for the base metal shall be met. Charpy impact testing is only required for Condition B.

3.4.4.4 For 2¼Cr–1Mo–¼V material, the weld metal shall meet the compositional requirements listed in Table 3.3. For all other materials, the minimum carbon content of the weld metal shall be 0.05%.

3.4.4.5 In addition for 2¼Cr–1Mo and 2¼Cr–1Mo–¼V material, Category A welds intended for design temperatures above 440°C (825°F), each heat of filler wire and flux combination used in production shall also be qualified by a weld metal stress-rupture test performed in accordance with ASTM E139 or other equivalent national or international test standard on specimens machined parallel (all weld metal specimens) and transverse to the weld axis (one specimen each), applying the following testing parameters and acceptance criteria:

(a) The specimen diameter within the gage length shall be 13 mm (½ in.) or greater. The specimen centerline shall be located at the 0.25-t thickness location (or closer to the center) for material 19 mm (¾ in.) and greater in thickness.

(b) The gage length for the transverse specimen shall include the weld and at least 19 mm (¾ in.) of base metal adjacent to the fusion line.

(c) The test material shall be postweld heat treated to Condition A.

(d) For 2¼Cr–1Mo material, the condition of the stress-rupture test shall be 210 MPa (30 ksi) at 510°C (950°F). The time of failure shall exceed 650 hr.

(e) For 2¼Cr–1Mo–¼V material, the condition of the stress-rupture test shall be 210 MPa (30 ksi) at 540°C (1000°F). The time of failure shall exceed 900 hr.

3.4.5 TOUGHNESS REQUIREMENTS

The minimum toughness requirements for base metal, weld metal, and heat-affected zone, after exposure to the simulated postweld heat treatment Condition B, are shown in Table 3.4. If the material specification or other parts of this Division have more demanding toughness requirements, they shall be met.

3.5 SUPPLEMENTAL REQUIREMENTS FOR Q&T STEELS WITH ENHANCED TENSILE PROPERTIES

3.5.1 GENERAL

3.5.1.1 The supplemental requirements in 3.5 apply to ferritic steels with tensile properties enhanced by quenching and tempering and shall be used in conjunction with the other requirements of this Division. The material specifications for these steels are shown in Table 3-A.2.

3.5.1.2 The requirements of this paragraph are not intended to apply to steels listed in Table 3-A.1 that are furnished in such thicknesses that heat treatment, involving the use of accelerated cooling, including liquid quenching, is used to obtain structures comparable to those attained by normalizing thinner sections.

3.5.2 PARTS FOR WHICH Q&T STEELS MAY BE USED

High strength quenched and tempered steels shown in Table 3-A.2, may be used for the entire vessel or for individual components of vessels that are joined to other grades of quenched and tempered steels, or to other steels conforming to specifications listed in Tables 3-A.1, 3-A.3, and 3-A.6, subject to the requirements and limitations of this Division.

3.5.3 STRUCTURAL ATTACHMENTS

3.5.3.1 Except as permitted in 3.5.3.2 below, all permanent structural attachments other than minor attachments specified in 3.5.3.3 and stiffening rings that are welded directly to pressure parts shall be made of material whose specified minimum yield strength is within ±20% of that of the material to which they are attached.

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3.5.3.2 All permanent structural attachments welded directly to a shell or head constructed of a material conforming to SA-333, Grade 8, SA-334, Grade 8, SA-353, SA-522, SA-553, and SA-645 Grade A shall be made from a material covered by these same specifications, or nickel alloys UNS N06625 or N10276, or from wrought non-hardenable austenitic stainless steels. If an austenitic stainless steel is used, consideration should be given to the additional weld stresses resulting from the difference in thermal expansion between the attachment and the shell.

3.5.3.3 If the following conditions are met, the material of minor attachments given in 4.2.5.6(c) may be used. The definition of minor attachments is given in 4.2.5.1(h).

(a) The specified minimum tensile strength of quenched and tempered steel for pressure parts shall be less than 690 MPa (100 ksi).

(b) The specified minimum yield strength of minor attachments shall be within +20% and −60% of that of the material to which they are attached.

(c) If the minor attachment is welded in the area less than $2.5\sqrt{R_m t}$ from any gross structural discontinuity, where R_m is the mean radius of the shell, and t is the thickness of the shell, the stress evaluation in accordance with Part 5 shall be performed.

(d) If the continuous fillet weld is used, the leg dimension of fillet weld shall not be less than $0.25t$, where t is the thickness of the minor attachment.

(e) The effect of differential thermal expansion shall be considered when the thermal expansion coefficient of the minor attachment differs from that of the pressure part to which it is attached.

(f) Welding materials with room-temperature tensile strength equivalent to that of quenched and tempered steels shall be used.

(g) The welds shall be postweld heat treated when required by Part 6.

3.6 SUPPLEMENTAL REQUIREMENTS FOR NONFERROUS MATERIALS

3.6.1 GENERAL

Nonferrous materials covered by 3.6 shall conform to one of the specifications listed in Tables 3-A.4, 3-A.5, 3-A.6, and 3-A.7, and shall be used in conjunction with the other requirements of this Division.

3.6.2 ULTRASONIC EXAMINATION OF PLATES

All plates 50 mm (2 in.) and over in nominal thickness shall be ultrasonically examined in accordance with the applicable requirements of the ASTM standards and ASME specifications listed below:

(a) SE-114, Ultrasonic Testing by Reflection Method Using Pulsed Longitudinal Waves Induced by Direct Contact;

(b) E214, Immersed Ultrasonic Testing by the Reflection Method Using Pulsed Longitudinal Waves;

(c) E127, Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks;

(d) SB-548, Ultrasonic Testing of Aluminum Plate.

3.6.3 ULTRASONIC EXAMINATION OF FORGINGS

3.6.3.1 Insofar as practicable, all solid rectangular forgings shall be examined by the straight beam technique from two directions at approximately right angles. Hollow forgings including flanges and rings 50 mm (2 in.) and over in nominal thickness shall be examined using the angle beam technique by either the contact method or the immersion method. Reference specimens and acceptance criteria shall be examined from one face or surface normal to the axis in the circumferential direction unless the wall thickness or geometric configuration makes angle beam examination impracticable. Disk forgings shall be examined from one flat side and from the circumferential surface.

3.6.3.2 The entire volume of metal shall be ultrasonically examined at some state of manufacture. For heat-treated material, examination after final heat treatment is preferred, but if the contour of the forging precludes complete examination at this stage, the maximum possible volume of the forging shall be reexamined after the final heat treatment.

3.6.3.3 The method used in the examination of forgings shall conform to the following requirements.

(a) In straight beam examination, the transducers shall be 19 mm to 29 mm ($^3/_4$ in. to $1^1/_8$ in.) in diameter or 25 mm (1 in.) square. The nominal frequency shall be appropriate for the material being examined. The instrument shall be set so that the first back reflection is 75% ± 5% of the screen height when the transducer is placed on the indication-free area of the forging.

(b) In angle beam examination by the contact method, a 25 mm × 25 mm (1 in. × 1 in.) or 25 mm × 38 mm (1 in. × $1^1/_2$ in.), 45 deg. transducer shall be used at an appropriate frequency.

(c) In angle beam examination by the immersion method, a 19 mm ($^3/_4$ in.) diameter transducer oriented at an approximate angle of inclination shall be used at an appropriate frequency.

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(d) Angle beam examination shall be calibrated with a notch of a depth equal to the smaller of 10 mm ($^{3}/_{8}$ in.) or 3% of the nominal section thickness, a length of approximately 25 mm (1 in.) and width not greater than two times the depth.

3.6.3.4 The material shall be unacceptable (unless repaired in accordance with the rules of this Division) if straight beam examination shows one or more discontinuities which produce indications accompanied by a complete loss of back reflection not associated with or attributable to the geometric configuration, or if angle beam examination results show one or more discontinuities which produce indications exceeding that of the calibration notch.

3.6.4 LIQUID PENETRANT EXAMINATION OF FORGINGS

3.6.4.1 Following final machining by the manufacturer all accessible surfaces of thick and complex forgings, such as contour nozzles, thick tubesheets, flanges, and other complex forgings that are contour shaped or machined to essentially the finished product configuration prior to heat treatment, shall be examined by the liquid penetrant method in accordance with Practice E165.

3.6.4.2 The evaluation of indications detected by the liquid penetrant method and the acceptance standards shall be in accordance with Part 7 of this Division.

3.6.4.3 Unacceptable imperfections shall be removed and the areas shall be reexamined to ensure complete removal of the unacceptable imperfection. Unless prohibited by the material specification, the forgings may be repair welded with the approval of the vessel Manufacturer. Repairs shall be made utilizing welding procedures that have been qualified in accordance with Section IX. The repaired forging shall meet all requirements of this Division.

3.6.5 CLAD PLATE AND PRODUCTS

Clad plate or products used in construction for which the design calculations are based on total thickness, including cladding, shall consist of base plate listed in one of the material tables in this Division and shall conform to one of the following specifications:

(a) SB-209, Specification for Aluminum Alloy Sheet and Plate.

(b) SB-211, Specification for Aluminum Alloy Extruded Bars, Rods, Shapes, and Tubes.

3.6.6 CLAD TUBESHEETS

Clad tubesheets that will contain strength welded tube-to-tubesheet joints in the cladding shall meet the requirements of 3.3.7 and any applicable requirements specified in 3.6.5.

3.7 SUPPLEMENTAL REQUIREMENTS FOR BOLTING

3.7.1 GENERAL

The supplemental requirements in 3.7 are required for all bolts, studs, and nuts supplied with vessels constructed to this Division.

3.7.2 EXAMINATION OF BOLTS, STUDS, AND NUTS

Bolts, studs, and nuts covered by the material specifications listed in Annex 3-A shall be subjected to the following examinations:

(a) All areas of threads, shanks, and heads of final machined parts shall be visually examined. Discontinuities, such as laps, seams, cracks are unacceptable.

(b) All bolts, studs, and nuts over 25 mm (1 in.) nominal bolt size shall be examined by the magnetic particle method or by the liquid penetrant method in accordance with Part 7 of this Division. This examination shall be performed on the finished component after threading or on the material stock at approximately the finished diameter before threading and after heading (if involved). Linear non-axial indications are unacceptable. Linear indications greater than 25 mm (1 in.) in length are unacceptable.

(c) All bolts, studs, and nuts greater than 50 mm (2 in.) nominal bolt size shall be ultrasonically examined over the entire surface prior to threading in accordance with the following requirements:

(1) Examination shall be carried out by the straight beam, radial scan method.

(2) Examination shall be performed at a nominal frequency of 2.25 MHz with the search unit not to exceed 645 mm^2 (1 in.^{2}) in area.

(3) Calibration sensitivity shall be established by adjustment of the instrument so that the first back screen reflection is 75% to 90% of full screen height.

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(4) Any discontinuity which causes an indication in excess of 20% of the height of the first back reflection or any discontinuity which prevents the production of the first back reflection of 50% of the calibration amplitude is not acceptable.

(d) All bolts, studs, and nuts greater than 100 mm (4 in.) nominal bolt size shall be ultrasonically examined over an entire end surface before or after threading in accordance with the following requirements:

(1) Examination shall be carried out by the straight beam, longitudinal scan method.

(2) Examination shall be performed at a nominal frequency of 2.25 MHz with the search unit not to exceed 320 mm^2 (0.5 $in.^2$) in area.

(3) Calibration shall be established on a test bar of the same nominal composition and diameter as the production part and a minimum of one half of the length. A 10 mm ($^3/_8$ in.) diameter × 76 mm (3 in.) deep flat bottom hole shall be drilled in one end of the bar and plugged to full depth. A distance amplitude correction curve shall be established by scanning from both ends of the test bar.

(4) Any discontinuity which causes an indication in excess of that produced by the calibration hole in the reference specimen as corrected by the distance amplitude correction curve is not acceptable.

3.7.3 THREADING AND MACHINING OF STUDS

3.7.3.1 Studs shall be threaded the full length, or shall be machined down to the root diameter of the thread in the unthreaded portion, provided that the threaded portions are at least 1.5 diameters in length.

3.7.3.2 Studs greater than 8 diameters in length may have an unthreaded portion which has the nominal diameter of the thread, provided the following requirements are met:

(a) The threaded portion shall be at least 1.5 diameters in length.

(b) The stud shall be machined down to the root diameter of the thread for a minimum distance of 0.5 diameters adjacent to the threaded portion.

(c) Suitable transition shall be provided between the root diameter and the unthreaded portion.

(d) Particular consideration shall be given to any dynamic loadings.

3.7.4 USE OF WASHERS

When washers are used in conjunction with torquing methods (e.g., the use of manual or hydraulic torque wrenches) for the purpose of bolt tightening, they shall be designed to provide a smooth and low-friction contact surface for the nuts, which are important considerations when torquing methods are used for bolt tightening.

NOTE: Flat washers typically should be 6 mm ($^1/_4$ in.) thick and made of through-hardened, wrought low alloy steel. See ASME PCC-1 for more information.

3.7.5 FERROUS BOLTING

3.7.5.1 Material for Ferrous Bolting.

(a) Approved specifications for ferrous bolting are given in Annex 3-A, Tables 3-A.8, 3-A.9, 3-A.10, and 3-A.11.

(b) High alloy steel studs, bolts, and nuts may be used with carbon and low alloy steel components, provided they are suitable for the application (see Section II, Part D, Nonmandatory Appendix A, A-300).

(c) Nonferrous nuts and washers may be used with ferrous bolts and studs, provided they are suitable for the application. Consideration shall be given to the differences in thermal expansion and possible corrosion resulting from combination of dissimilar materials.

3.7.5.2 Material for Ferrous Nuts and Washers.

(a) Material for nuts and washers shall conform to SA-194, SA-563, or to the requirements for nuts in the specification for the bolting material with which they are to be used.

(b) Materials for ferrous nuts and washers shall be selected as follows:

(1) Carbon or low alloy steel nuts and carbon or low alloy steel washers of approximately the same hardness as the nuts may be used for metal temperatures not exceeding 480°C (900°F).

(2) Alloy steel nuts shall be used for metal temperatures exceeding 480°C (900°F). Washers, if used, shall be of alloy steel equivalent to the nut material.

3.7.5.3 Requirements for Ferrous Nuts.

(a) Nuts shall be semifinished, chamfered, and trimmed. Nuts shall be threaded to Class 2B or finer tolerances according to ASME B1.1.

(b) For use with flanges conforming to ASME/ANSI B16.5, nuts shall conform to at least to the dimensions given in ASME/ANSI B18.2.2 for Heavy Series Nuts.

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(c) For use with connections designed in accordance with rules in 4.16, nuts may be of the American National Standard Heavy Series or they may be of other dimensions provided their strength is equal to that of the bolting, giving due consideration to the bolt hole clearance, bearing area, thread form and class of it, thread shear, and radial thrust from threads.

(d) Nuts shall engage the threads for the full depth of the nut or, in the case of cap nuts, to a depth equivalent to the depth of a standard nut.

(e) Nuts of special design may be used, provided their strength is equal to that of the bolting.

3.7.6 NONFERROUS BOLTING

3.7.6.1 Material for Nonferrous Bolting. Approved specifications for Nonferrous bolting are given in Annex 3-A, Tables 3-A.9, 3-A.10, and 3-A.11.

3.7.6.2 Condition of Material Selected and Allowable Stress Value.

(a) When nonferrous bolts are machined from heat-treated, hot-rolled, or cold-worked material and are not subsequently hot worked or annealed, the allowable design stress values in Section II, Part D, Subpart 1, Table 3 to be used in design shall be based on the condition of material selected.

(b) When nonferrous bolts are fabricated by hot heading, the allowable design stress values for annealed materials in Section II, Part D, Subpart 1, Table 3 shall apply unless the manufacturer can furnish adequate control data to show that the tensile properties of hot-rolled or heat-treated bars or hot-finished or heat-treated forgings are being met, in which case the allowable stress values for the material in the hot finished condition may be used.

(c) When nonferrous bolts are fabricated by cold heading, the allowable design stress values for annealed materials in Section II, Part D, Subpart 1, Table 3 shall apply unless the manufacturer can furnish adequate control data to show that higher design stresses, as agreed upon may be used. In no case shall such stresses exceed the allowable stress values given in Section II, Part D, Subpart 1, Table 3 for cold-worked bar stock.

3.7.6.3 Materials for Nonferrous Nuts and Washers.

(a) Materials for ferrous nuts used with nonferrous bolting shall conform to 3.7.5.3.

(b) Nonferrous nuts and washers may be made of any suitable material listed in Tables 3-A.5, 3-A.6, and 3-A.7.

3.7.6.4 Requirements for Nonferrous Nuts. Nonferrous nuts shall meet the requirements in 3.7.5.3.

3.7.7 MATERIALS FOR FERROUS AND NONFERROUS NUTS OF SPECIAL DESIGN

Nuts of special design, such as wing nuts, may be made of any suitable wrought material permitted by this Division, and shall be either: hot or cold forged; or machined from hot-forged, hot-rolled, or cold-drawn bars.

3.8 SUPPLEMENTAL REQUIREMENTS FOR CASTINGS

3.8.1 GENERAL

3.8.1.1 Each casting shall be marked with the name, trademark, or other traceable identification of the manufacturer and the casting identification, including material designation. The casting manufacturer shall furnish certification that each casting conforms to all the applicable requirements in the casting specification and the requirements of this Division. The certification of castings shall also indicate the nature, location, and extent of any repairs.

3.8.1.2 All castings to be welded shall be of weldable grade.

3.8.2 REQUIREMENTS FOR FERROUS CASTINGS

3.8.2.1 Centrifugal Steel Castings. In addition to the minimum requirements of the material specification, all surfaces of centrifugal castings shall be machined after heat treatment to a finish not coarser than 6.35 μmm (250 μin.) arithmetic average deviation.

3.8.2.2 Nondestructive Examination of Ferrous Castings.

(a) General – Castings shall be examined by radiographic, ultrasonic, magnetic particle and liquid penetrant methods examination as provided herein and shall meet the requirements of (a) through (d), inclusive. Radiographic examination, and when required ultrasonic examination, of castings shall be made after at least one austenitizing heat treatment, except austenitic castings not requiring heat treatment may have radiographic and ultrasonic examination performed at any stage of manufacture. Magnetic particle or liquid penetrant examinations shall be made after final heat treatment and after final machining of machined areas.

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(b) Radiographic Examination – All parts of ferrous castings regardless of thickness shall be fully radiographed in accordance with the procedures of Section V, Article 2. The radiographs shall be compared to the appropriate Radiographic Standard listed below, and the maximum acceptable severity levels for imperfection shall be as follows:

(1) For castings having radiographed thickness of less than 50 mm (2 in.), ASTM E446, Standard Reference Radiographs for Steel Castings up to 2 in. (50 mm) in Thickness, and with maximum severity levels as shown in Table 3.10.

(2) For castings having radiographed thickness from 50 mm to 305 mm (2 in. to 12 in.), ASTM E186, Standard Reference Radiographs for Heavy-Walled [2 to 4½ in. (50.8 to 114 mm)] Steel Castings, or ASTM E280, Standard Reference Radiographs for Heavy-Walled [4½ to 12 in. (114 to 305 mm)] Steel Castings, as appropriate, and with maximum severity levels as shown in Table 3.11.

(c) Ultrasonic Examination – All parts of ferrous castings over 305 mm (12 in.) thick shall be examined by ultrasonic methods in accordance with the procedures of Section V, Article 5. Castings with imperfections shown by discontinuities whose reflections exceed the height equal to 20% of the normal back reflection, or which reduce the height of the back reflections by more than 30% during movement of the transducer 50 mm (2 in.) in any direction are unacceptable unless other methods of nondestructive testing, such as radiographic examination, demonstrate to the satisfaction of the vessel Manufacturer and the Inspector that the indications are acceptable or unless such imperfections are removed and the casting is repaired.

(d) Magnetic Particle Examination – Castings of ferromagnetic material shall be examined on all surfaces by a magnetic particle method in accordance with Part 7 of this Division. Castings with imperfections shown by Type I indications or by indications exceeding Degree I of Types II, III, IV, and V of ASTM E125, Reference Photographs for Magnetic Particle Indications on Ferrous Castings, are unacceptable unless the imperfections are removed and casting is repaired.

(e) Liquid Penetrant Examination – Castings of nonferromagnetic material shall be examined on all surfaces by a liquid penetrant method in accordance with Part 7 of this Division. Castings with cracks and linear imperfections exceeding the following limits are unacceptable:

(1) Linear indications resulting in more than six indications in any 40 mm × 150 mm (1½ in. × 6 in.) rectangle or 90 mm (3.5 in.) diameter circle with these taken in the most unfavorable location relative to the indications being evaluated.

(2) Linear imperfections resulting in indications more than 6 mm (¼ in.) in length for thicknesses up to 19 mm (¾ in.), one third of the thickness in length for thicknesses from 19 mm (¾ in.) to 57 mm (2.25 in.), and 19 mm (¾ in.) in length for thicknesses over 57 mm (2.25 in.). Aligned acceptable imperfections separated from one another by a distance equal to the length of the longer imperfection are acceptable.

(3) All nonlinear imperfections which are indicated to have any dimension which exceeds 2.5 mm (0.0938 in.).

3.8.2.3 Repairing of Ferrous Castings.

(a) Castings with unacceptable imperfections may be repaired. Whenever an imperfection is removed and subsequent repair by welding is not required, the affected area shall be blended into the surrounding surface so as to avoid sharp notches, crevices, or corners.

(b) Repairing of Ferrous Castings by Welding – Castings having imperfections in excess of the maximum sizes permitted in 3.8.2.2 may be repaired by welding if the imperfections are removed and providing prior approval is obtained from the vessel Manufacturer. To ensure complete removal of such imperfections prior to making repairs the base metal shall be reexamined by either magnetic particle or liquid penetrant examination, if it is ferromagnetic, or by liquid penetrant examination, if it is nonferromagnetic.

(1) Requirements for Examining Repairs in Castings – All weld repairs of depth exceeding 10 mm (⅜ in.) or 20% of the section thickness, whichever is the lesser, shall be examined by radiography and by magnetic particle examination or liquid penetrant examination, if the material is magnetic, or by liquid penetrant examination, if it is nonferromagnetic, in accordance with 3.8.2.2. Where the depth of the repairs is less than 20% of the section thickness or 25 mm (1 in.), whichever is the lesser, and where the repaired section cannot be radiographed effectively, the first layer of each 6 mm (¼ in.) thickness of deposited weld metal and the finished weld surface shall be examined, as indicated previously by magnetic particle or liquid penetrant examination. The finished surface examination shall be made after any heat treating operations that are applied to the casting. Weld repairs resulting from ultrasonic examination shall be examined by ultrasonic methods.

(2) Postweld Heat Treatment of Repaired Castings – When repair welding is done after heat treatment of the casting, the casting shall be postweld heat treated after repair welding of the casting.

(3) Required Welding Procedure and Welder Qualifications – All welding shall be performed with a welding procedure qualified in accordance with Section IX. The procedure qualification tests shall be performed on specimens of cast material of the same specification and subject to the same heat treatment before and after welding as will be applied to the work. All welders and operators performing this welding shall also be qualified in accordance with Section IX.

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(4) Certification of Weld Repairs – The location and extent of the weld repairs together with the repair procedure and examination results shall be recorded and transmitted as part of the certification.

3.8.3 REQUIREMENTS FOR NONFERROUS CASTINGS

3.8.3.1 Examination of Nonferrous Castings. All nonferrous castings shall be examined in accordance with the following:

(a) Each casting shall be subjected to 100% visual examination and to liquid penetrant examination on all surfaces in accordance with 3.8.2.2(e). These examinations shall be performed following the final heat treatment applied to the casting.

(b) All parts of castings shall be subjected to complete radiographic examination and the radiographs shall be compared with the radiographic standards of ASTM E272, Reference Radiographs for Inspection of High Strength Copper Base and Nickel-Copper Castings. Acceptable castings shall meet Class 1 standards, if the wall thickness is less than 25 mm (1 in.) or Class 2 standards if the wall thickness is greater than or equal to 25 mm (1 in.) as defined in the Specification.

(c) All parts of castings with a thickness greater than 305 mm (12 in.) shall be ultrasonically examined in accordance with the procedures given in SE-114. Any imperfections whose reflections do not exceed a height equal to 20% of the normal back reflection or do not reduce the height of the back reflection by more than 30% during movement of the transducer 50 mm (2 in.), in any direction, shall be considered acceptable. The above limits are established for the use of transducers having approximately 645 mm^2 (1 $in.^2$) of area.

3.8.3.2 Repairing of Nonferrous Castings by Welding. Upon approval by the vessel Manufacturer, castings subject to rejection because of these examinations may be repaired in accordance with the following requirements.

(a) Castings having imperfections in excess of the maximum sizes permitted in 3.8.3.1 may be repaired by welding, if the imperfections are removed and provided prior approval is obtained from the vessel Manufacturer. To assure complete removal of such imperfections, prior to making repairs, the base metal shall be reexamined by liquid penetrant examination.

(b) All weld repairs of depth exceeding 10 mm ($^3/_8$ in.), or 20% of the section thickness, whichever is the lesser, shall be examined by radiography and by liquid penetrant examination in accordance with 3.8.3.1. Where the depth of repairs is less than 20% of the section thickness or 25 mm (1 in.), whichever are the lesser, and where the repaired section cannot be radiographed effectively, the first layer of each 6 mm ($^3/_4$ in.) thickness of deposited weld metal and the finished weld surface shall be examined, as indicated previously, by liquid penetrant examination. The finished surface examination shall be made after any heat treating operation that is applied to the casting. Weld repairs resulting from ultrasonic examination shall be examined by ultrasonic methods.

(c) When repair welding is done after heat treatment of the casting, the casting shall be postweld heat treated after repair welding.

(d) All welding shall be performed using welding procedures qualified in accordance with Section IX. The procedure qualifications shall be performed on test specimens of cast material of the same specification and subject to the same heat treatments before and after welding as will be applied to the work. All welders and welding operators performing this welding shall be qualified in accordance with Section IX.

(e) The location and extent of the weld repairs together with the repair procedure and examination results shall be recorded and transmitted as part of the certification.

3.9 SUPPLEMENTAL REQUIREMENTS FOR HUBS MACHINED FROM PLATE

3.9.1 GENERAL

The supplemental requirements of 3.9 are required for plate materials that are used in the fabrication of hubs for tubesheets, lap joint stub ends, and flat heads machined from plate when the hub length is in the through thickness direction of the plate.

3.9.2 MATERIAL REQUIREMENTS

3.9.2.1 Plate shall be manufactured by a process that produces material having through thickness properties which are at least equal to those specified in the material specification. Such plate can be but is not limited to that produced by methods such as electroslag (ESR) and vacuum arc remelt (VAR). The plate must be tested and examined in accordance with the requirements of the material specification and the additional requirements specified in the following paragraphs.

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3.9.2.2 Test specimens, in addition to those required by the material specifications, shall be taken in a direction parallel to the axis of the hub and as close to the hub as practical, as shown in Figure 3.4. At least two tensile test specimens shall be taken from the plate in the proximity of the hub, with one specimen taken from the center third of the plate width as rolled, and the second specimen taken at 90 deg around the circumference from the other specimen. Both specimens shall meet the mechanical property requirements of the material specification. For carbon and low alloy steels, the reduction of area shall not be less than 30%; for those materials for which the material specification requires a reduction of area value greater than 30%, the higher value shall be met.

3.9.2.3 Subsize test specimens conforming to the requirements of SA-370, Figure 5 may be used if necessary, in which case the value for percent elongation in 50 mm (2 in.), required by the material specification, shall apply to the gage length specified in SA-370, Figure 5.

3.9.2.4 Tension test specimen locations are shown in Figure 3.4.

3.9.3 EXAMINATION REQUIREMENTS

3.9.3.1 After machining the part, regardless of thickness, shall be ultrasonically examined by the straight beam technique in accordance with SA-388. The examination shall be in two directions approximately at right angles, i.e., from the cylindrical or flat rectangular surfaces of the hub and in the axial direction of the hub. The part shall be unacceptable if

(a) the examination results show one or more indications accompanied by loss of back reflection larger than 60% of the reference back reflection, and

(b) the examination results show indications larger than 40% of the reference back reflection when accompanied by a 40% loss of back reflection.

3.9.3.2 Before welding the hub of the tubesheet flange or flat head to the adjacent shell, the hub shall be examined by magnetic particle or liquid penetrant methods in accordance with Part 7.

3.9.3.3 After welding, the weld and the area of the hub for at least 13 mm (½ in.) from the edge of the weld shall be 100% radiographed in accordance with Part 7. As an alternate, the weld and hub area adjacent to the weld may be ultrasonically examined in accordance with Part 7.

3.9.4 DATA REPORTS AND MARKING

Whenever the provisions of this supplemental requirement are used, they shall be indicated on the Data Report. Special markings are not required.

3.10 MATERIAL TEST REQUIREMENTS

3.10.1 GENERAL

Material tests required by this Division shall be performed in accordance with 3.10.

3.10.2 REQUIREMENTS FOR SAMPLE TEST COUPONS

3.10.2.1 Heat Treatment. Heat treatment as used in this Division shall include all thermal treatments during fabrication at 480°C (900°F) and above.

3.10.2.2 Provisions of Sample Test Coupons. When material is subjected to heat treatment during fabrication, the test specimens required by this Division shall be obtained from sample coupons which have been heat treated in the same manner as the material, including such heat treatments as were applied by the material producer before shipment. The required tests may be performed by the material producer or the fabricator.

3.10.2.3 Heat Treating of Sample Test Coupons.

(a) The material used in the vessel shall be represented by test specimens that have been subjected to the same manner of heat treatment, including postweld heat treatment. The kind and number of tests and test results shall be as required by the material specification. The vessel Manufacturer shall specify the temperature, time, and cooling rates to which the material will be subject during fabrication. Material from which the specimens are prepared shall be heated at the specified temperature within the tolerance established by the manufacturer for use in actual fabrication. The total time at temperature shall be within at least 80% of the total time at temperature during actual heat treatment of the product and may be performed in a single cycle. Simulation of postweld heat treatment may be applied to the test specimen blanks.

(b) Heat treatment of material is not intended to include such local heating as flame or arc cutting, preheating, welding, or heating below the critical range of tubing or pipe for bending or sizing.

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3.10.3 EXEMPTIONS FROM REQUIREMENT OF SAMPLE TEST COUPONS

3.10.3.1 Standard Pressure Parts. An exception to the requirements of 3.10.2.2 and 3.10.2.3 shall apply to standard nonwelded items such as described in 3.2.8.3 and 3.2.8.4. These may be subjected to postweld heat treatment with the vessel or vessel part without the same treatment being required of the test specimens. This exception shall not apply to castings that are specially designed or to cast wrought fittings.

3.10.3.2 For Materials When PWHT to Table 6.16. Materials listed in Section IX, Table QW/QB-422 as P-No. 1 Group 3 and P-No. 3, Groups 1 and 2 that are certified in accordance with 3.10.2.2 and 3.10.2.3 from test specimens subjected to the PWHT requirements of Table 6.8 or Table 6.9 need not be recertified if subjected to the alternative PWHT conditions permitted in Table 6.16.

3.10.3.3 Re-Austenitized Materials. All thermal treatments which precede a thermal treatment that fully austenitizes the material need not be accounted for by the specimen heat treatments, provided the austenitizing temperature is at least as high as any of the preceding thermal treatments.

3.10.4 PROCEDURE FOR OBTAINING TEST SPECIMENS AND COUPONS

3.10.4.1 Plates.

(a) Unless otherwise specified, test specimens shall be taken in accordance with the requirements of the applicable material specification, except for the provisions in (b), (c), and (d) below. Tension test specimens and Charpy V-notch specimens shall be orientated in the direction perpendicular to the final direction of the plate rolling.

(b) When the plate is heat treated with a cooling rate faster than still-air cooling from the austenitizing temperature, the specimens shall be taken in accordance with requirements of applicable material specifications and $1t$ from any heat-treated edge, where t is the nominal thickness of the material.

(c) Where a separate test coupon is used to represent the vessel material, it shall be of sufficient size to ensure that the cooling rate of the region from which the test specimens are removed represents the cooling rate of the material at least $^1/_4t$ deep and $1t$ from any edge of the product. Unless cooling rates applicable to the bulk pieces or product are simulated in accordance with 3.10.5, the dimensions of the coupon shall be not less than $3t \times 3t \times 1t$, where t is the nominal thickness of the material.

(d) When flat heads, tubesheets, and flanges with integral hubs for butt welding are to be machined from plate, additional specimens shall be taken in the locations as shown in Figure 3.4.

3.10.4.2 Forgings.

(a) Test specimens shall be taken in accordance with the applicable material specification, except for the provisions in (b), (c), and (d) below.

(b) When the forging is heat treated with a cooling rate faster than still-air cooling from the austenitizing temperature the specimens shall be taken at least $^1/_4t$ of the maximum heat-treated thickness from one surface and $1t$ from a second surface. This is normally referred to as $^1/_4t \times 1t$, where t is the maximum heat-treated thickness. A thermal buffer may be used to achieve these conditions unless cooling rates applicable to the bulk forgings are simulated in accordance with 3.10.5.

(c) For thick and complex forgings, such as contour nozzles, thick tubesheets, flanges, and other complex forgings that are contour shaped or machined to essentially the finished product configuration prior to heat treatment, the registered engineer who prepares the Design Report shall designate the surfaces of the finished product subject to high tensile stresses in service. Test specimens for these products shall be removed from prolongations or other stock provided on the product. The specimens shall be removed as follows:

(1) The distance from the longitudinal axis of the specimen to the nearest heat-treated surface shall be no less than the distance from the location where the maximum tensile stress is expected to the nearest heat-treated surface. This distance shall be at least 19 mm ($^3/_4$ in.).

(2) The distance from the mid-length of the specimen to a second heat-treated surface shall be at least twice the distance in (1). This distance shall be at least 38 mm (1.5 in.).

(d) With prior approval of the vessel Manufacturer, test specimens for flat ring and simple ring forgings may be taken from a separately forged piece under the following conditions.

(1) The separate test forging shall be of the same heat of material and shall be subjected to substantially the same reduction and working as the production forgings it represents.

(2) The separate test forging shall be heat treated in the same furnace charge and under the same conditions as the production forgings.

(3) The separate test forging shall be of the same nominal thickness as the production forgings. Test specimen material shall be removed as required in (a) and (b).

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3.10.4.3 Tubular Products. Specimens shall be taken in accordance with the requirements of the applicable material specification.

3.10.4.4 Bars and Bolting Materials.

(a) Test specimens shall be taken in accordance with the requirements of the applicable material specification, except for the provisions of (b) below.

(b) Test specimens shall be at least $^1/_4t$ from the outside or rolled surface and with the end of the specimen no closer than one diameter or thickness from the heat-treated end.

(c) For bolting, the specimens shall be taken in conformance with the applicable material specification and with the end of the specimen no closer than one diameter or thickness from a heat-treated end.

3.10.4.5 Castings.

(a) The conventional separately cast test coupon meets the intent of 3.10.5 where normalizing or accelerated cooling heat treatments are employed on castings having a maximum thickness of less than 50 mm (2 in.).

(b) For castings having a thickness of 50 mm (2 in.) and over, the specimens shall be taken from the casting (or the extension of it) at least $^1/_4t$ of the maximum heat-treated thickness from one surface and $1t$ from a second surface. A thermal buffer may be used.

(c) For massive castings that are cast or machined to essentially the finished product configuration prior to heat treatment, the registered engineer who prepares the Design Report shall designate the surfaces of the finished product subject to high tensile stresses in service. Test specimens for these products shall be removed from prolongations or other stock provided on the product. The specimens shall be removed as follows:

(1) The distance from the longitudinal axis of the specimen to the nearest heat-treated surface shall be no less than the distance from the location where the maximum tensile stress is expected to the nearest heat-treated surface. This distance shall be at least 19 mm ($^3/_4$ in.).

(2) The distance from the mid-length of the specimen to a second heat-treated surface shall be at least twice the distance in (1). This distance shall be at least 38 mm (1.5 in.).

(d) With prior approval of the vessel Manufacturer, test specimens may be taken from a separately cast test coupon under the following conditions:

(1) The separate test coupon shall be of the same heat of material and shall be subjected to substantially the same casting practices as the production casting it represents.

(2) The separate test coupon shall be heat treated in the same furnace charge and under the same conditions as the production casting, unless cooling rates applicable to bulk castings are simulated in accordance with 3.10.5.

(3) The separate test coupon shall be of the same nominal thickness as the production casting. Test specimen material shall be removed from the region midway between mid-thickness and the surface and shall not be nearer than on thickness to a second surface.

3.10.5 PROCEDURE FOR HEAT TREATING TEST SPECIMENS FROM FERROUS MATERIALS

3.10.5.1 General requirements for heat treating of sample test coupons are covered in 3.10.2.3.

3.10.5.2 When ferritic steel products are subjected to normalizing or accelerated cooling from the austenitizing temperature, the test specimens representing those products shall be cooled at a rate similar to and no faster than the main body of the product except in the case of certain forgings and castings [see 3.10.4.2(c) and 3.10.4.5(c)]. This rule shall apply for specimens taken directly from the product as well as those taken from separate test coupons representing the product. The following general techniques may be applied to all product forms or test coupons representing the product.

(a) Any procedure may be applied which can be demonstrated to produce a cooling rate in the test specimen that matches the cooling rate of the main body of the product at the region midway between mid-thickness and surface ($^1/_4t$) and no nearer any heat-treated edge than a distance equal to the nominal thickness, t, being cooled within 14°C (25°F) and 20 sec at all temperatures after cooling begins from the austenitizing temperature.

(b) Faster cooling rates at product edges may be compensated for by:

(1) Taking the test specimens at least $1t$ from a quenched edge where t equals the product thickness.

(2) Attaching a steel pad at least $1t$ wide by a partial penetration weld to the product edge where specimen are to be removed.

(3) Using thermal buffers or insulation at the product edge where specimens are to be removed.

(c) If cooling rate data for the product and cooling rate device control devices for the test specimens are available, the test specimens may be heat treated in the device to represent the product, provided that the provisions of (a) are met.

(d) When the material is clad or weld deposit overlayed by the product prior to normalizing or accelerated cooling from the austenitizing temperature, the full thickness samples shall be clad or the weld deposit overlayed before such heat treatments.

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3.10.6 TEST COUPON HEAT TREATMENT FOR NONFERROUS MATERIALS

3.10.6.1 Fabrication heat treatments of nonferrous material are normally not necessary. If heat treatment is performed, it shall be by agreement between the user and the vessel Manufacturer.

3.10.6.2 Materials where the mechanical properties are affected by fabrication heat treatments shall be represented by test specimens that have been subjected to the simulated fabrication heat treatments. The vessel Manufacturer shall specify the pertinent fabrication heat treatment parameters to the material manufacturer.

3.10.6.3 The requirements of 3.10.6.2 above exclude annealing and stress relieving.

3.11 MATERIAL TOUGHNESS REQUIREMENTS

3.11.1 GENERAL

3.11.1.1 Charpy V-notch impact tests shall be made for materials used for shells, heads, nozzles, and other pressure-containing parts, as well as for the structural members essential to structural integrity of the vessel, unless exempted by the rules of 3.11.

(a) Toughness requirements for materials listed in Table 3-A.1 (carbon and low alloy steel materials except bolting materials) are given in 3.11.2.

(b) Toughness requirements for materials listed in Table 3-A.2 (quenched and tempered steels with enhanced tensile properties) are given in 3.11.3.

(c) Toughness requirements for materials listed in Table 3-A.3 (high alloy steels except bolting materials) are given in 3.11.4.

(d) Toughness requirements for materials listed in Tables 3-A.4 through 3-A.7 (nonferrous alloys) are given in 3.11.5.

(e) Toughness requirements for all bolting materials are given in 3.11.6.

3.11.1.2 Toughness testing procedures and requirements for impact testing of welds and vessel test plates of ferrous materials are given in 3.11.7 and 3.11.8, respectively.

3.11.1.3 Throughout 3.11, reference is made to the Minimum Design Metal Temperature (MDMT). The MDMT is part of the design basis of the vessel and is defined in 4.1.5.2(e). The rules in 3.11 are used to establish an acceptable MDMT for the material based on the materials of construction, product form, wall thickness, stress state, and heat treatment.

3.11.2 CARBON AND LOW ALLOY STEELS EXCEPT BOLTING

3.11.2.1 Toughness Requirements for Carbon and Low Alloy Steels.

(a) Impact tests shall be performed on carbon and low alloy materials listed in Table 3-A.1 for all combinations of materials and MDMTs except as exempted by 3.11.2.3, 3.11.2.4, 3.11.2.5, or 3.11.2.8.

(b) When impact testing is necessary, the following toughness values are required.

(1) If the specified minimum tensile strength is less than 655 MPa (95 ksi), then the required minimum energy for all specimen sizes shall be that shown in Figures 3.5 and 3.6 for welded vessel parts not subject to postweld heat treatment (PWHT) and welded vessels parts subject to PWHT or nonwelded parts, respectively, multiplied by the ratio of the actual specimen width along the notch to the width of a full-size specimen, except as otherwise provided in 3.11.7.2(b).

(2) If the specified minimum tensile strength is greater than or equal to 655 MPa (95 ksi), then the minimum lateral expansion (see Figure 3.7) opposite the notch for all specimen sizes shall not be less than the values shown in Figure 3.8.

3.11.2.2 Required Impact Testing Based on the MDMT, Thickness, and Yield Strength.

(a) If the governing thickness (see 3.11.2.3(b) at any welded joint or of any nonwelded part exceeds 100 mm (4 in.) and the MDMT is colder than 43°C (110°F), then impact testing is required.

(b) Materials having a specified minimum yield strength greater than 450 MPa (65 ksi) shall be impact tested.

(25) **3.11.2.3 Exemption From Impact Testing Based on the MDMT, Thickness, and Material Specification.**

(a) Figure 3.9 for welded parts not subject to PWHT or Figure 3.10 for welded parts subject to PWHT shall be used to establish impact testing exemptions based on the impact test exemption curve for the subject material specification and grade or class of the steel, MDMT, and governing thickness of a welded part. If an MDMT and thickness combination for the subject material is on or above the applicable impact test exemption curve in Figure 3.9 or Figure 3.10, then impact testing is not required except as required by 3.11.8 for weld metal and heat-affected zones.

(b) The governing thickness, t_g, of a part is determined using the following criteria. Examples of the governing thickness for some typical vessel details are shown in Figures 3.11, 3.12, and 3.13.

(1) For all welded product forms except castings:

(-a) For butt joints except those in flat heads, tubesheets, and other flat components subjected to primary bending stress, the nominal thickness of the thickest welded joint [see Figure 3.11, sketch (a)],

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(-b) For corner, fillet, or lap-welded joints, including attachments as defined in 3.11.1.1, the thinner of the two parts joined,

(-c) For flat heads, tubesheets, and other flat components subjected to primary bending stress, the larger of (-b) above or the flat component thickness divided by 4.

(2) The governing thickness of a casting shall be its largest nominal thickness.

(3) The governing thickness of flat nonwelded parts, such as bolted flanges, tubesheets, and flat heads, is the flat component thickness divided by 4.

(4) The governing thickness of a nonwelded dished head is the greater of the flat flange thickness divided by 4 or the minimum thickness of the dished portion.

(c) Components such as shells, heads, nozzles, manways, reinforcing pads, stiffening rings, flanges, tubesheets, flat cover plates, backing strips, and attachments that are essential to the structural integrity of the vessel when welded to pressure-retaining components shall be treated as separate components. Each component shall be evaluated for impact test requirements based on its individual material classification, governing thickness [see (b)], and the MDMT. For welded assemblies comprised of more than two components (e.g., nozzle-to-shell joint with reinforcing pad), the governing thickness and permissible MDMT of each of the individual welded joints of the assembly shall be determined, and the warmest MDMT shall be used as the permissible MDMT of the welded assembly.

(d) Figure 3.9 limits the maximum nominal governing thickness for welded parts not subject to postweld heat treatment to 38 mm (1½ in.). Some vessels may have welded non-postweld-heat-treated pressure parts whose thickness exceeds the nominal governing thickness of 38 mm (1½ in.). Examples of such welded and non-postweld-heat-treated pressure parts are thick tubesheets, flat heads, and thick insert plates (with beveled edges) with nozzles or load-carrying structural attachments. Such welded non-postweld-heat-treated pressure parts shall be impact tested and shall meet the impact test requirements of this Division.

(e) Impact testing is not required for materials with a thickness of 2.5 mm (0.099 in.) and thinner, but such exempted materials shall not be used at design metal temperatures colder than −48°C (−55°F). For components made from DN 100 (NPS 4) pipe or smaller and for equivalent size of tubes of P-No. 1 materials, the following exemptions from impact testing are also permitted as a function of the specified minimum yield strength (SMYS) of the material for metal temperatures of −104°C (−155°F) and warmer:

(1) For SMYS between 140 MPa and 240 MPa (20 ksi and 35 ksi), inclusive, the thickness exemption for impact testing is 6 mm (¼ in.).

(2) For SMYS between 250 MPa and 310 MPa (36 ksi and 45 ksi), inclusive, the thickness exemption for impact testing is 3.2 mm (⅛ in.).

(3) For SMYS higher than 315 MPa (46 ksi), inclusive, the thickness exemption for impact testing is 2.5 mm (0.099 in.).

(f) Note that the rules in this paragraph for the exemption of impact testing do not provide assurance that all test results for these materials will satisfy the impact test acceptance criteria of 3.11.2.1(b).

3.11.2.4 Exemption From Impact Testing Based on Material Specification and Product Form.

(a) Impact testing is not required for the ferritic steel flanges shown below when produced to fine grain practice and supplied in heat-treated condition (normalized, normalized and tempered, or quenched and tempered after forging) when used at design temperatures no colder than −29°C (−20°F) and no colder than −18°C (0°F) when supplied in the as-forged condition. A certification statement on a Material Test Report or Certificate of Compliance attesting to production to fine grain practice is sufficient.

(1) ASME B16.5 flanges.

(2) ASME B16.47 flanges.

(3) Long weld neck flanges, defined as forged nozzles that meet the dimensional requirements of a flanged fitting given in ASME B16.5 but have a straight hub/neck. The neck inside diameter shall not be less than the nominal size of the flange, and the outside diameter of the neck and any nozzle reinforcement shall not exceed the diameter of the hub as specified in ASME B16.5.

(b) Materials produced and impact tested in accordance with the requirements of the specifications shown below are exempt from impact testing by the rules of this Division at MDMTs not more than 3°C (5°F) colder than the test temperature required by the specification.

(1) SA-333

(2) SA-334

(3) SA-350

(4) SA-352

(5) SA-420

(6) SA-765

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(25) **3.11.2.5 Exemption From Impact Testing Based on Design Stress Values.**

(a) A colder MDMT for a component than that derived from 3.11.2.2 or 3.11.2.3 may be determined in accordance with the procedure outlined below.

Step 1. For the welded part under consideration, determine the nominal thickness of the part, t_n, and the required governing thickness of the part, t_g, using 3.11.2.3(b).

Step 2. Determine the applicable material toughness curve to be used in Figure 3.9 for welded parts not subject to PWHT or Figure 3.10 for welded parts subject to PWHT. See 3.11.2.2(b) for materials having a specified minimum yield strength greater than 450 MPa (65 ksi).

Step 3. Determine the MDMT from Figure 3.9 for welded parts not subject to PWHT or Figure 3.10 for welded parts subject to PWHT based on the applicable toughness curve and the governing thickness, t_g. For materials having a specified minimum yield strength greater than 450 MPa (65 ksi), the MDMT shall be determined by impact testing per 3.11.2.2(b).

Step 4. Based on the design loading conditions at the MDMT, determine the stress ratio, R_{ts}, using one of the equations below. For pressure vessel attachments that are exposed to tensile stresses from internal pressure (e.g., nozzle reinforcement pads, horizontal vessel saddle attachments, and stiffening rings), the coincident ratio shall be that of the shell or head to which each component is attached. Note that this ratio can be computed in terms of required design thickness and nominal thickness, applied stress and allowable design stress, or applied pressure and maximum allowable working pressure based on the design rules in this Division or ASME/ANSI pressure–temperature ratings.

$$R_{ts} = \frac{t_r E^*}{t_n - \mathrm{CA}} \qquad \text{(Thickness Basis)} \tag{3.1}$$

$$R_{ts} = \frac{S^* E^*}{SE} \qquad \text{(Stress Basis)} \tag{3.2}$$

$$R_{ts} = \frac{P_a}{P_{\text{rating}}} \qquad \text{(Pressure–Temperature Rating Basis)} \tag{3.3}$$

Step 5. Determine the final value of the MDMT and evaluate results.

(a) If the computed value of the R_{ts} ratio from Step 4 is less than or equal to 0.24, then set the MDMT to −104°C (−155°F).

(b) If the computed value of the R_{ts} ratio from Step 4 is greater than 0.24, then determine the temperature reduction, T_R. If the specified minimum yield strength is less than or equal to 450 MPa (65 ksi), then determine T_R from Figure 3.14 for parts not subject to PWHT or Figure 3.15 for parts subject to PWHT based on the R_{ts} ratio from Step 4. If the specified minimum yield strength is greater than 450 MPa (65 ksi) for parts subject to PWHT, then determine the temperature reduction, T_R from eq. (3.4). The final computed value of the MDMT is determined using eq. (3.5). The reduction in the MDMT given by eq. (3.5) shall not exceed 55°C (100°F). Impact testing is not required if the specified MDMT is warmer than the computed MDMT. However, if the specified MDMT is colder than −48°C (−55°F), impact testing is required.

$$T_R = \frac{\left(\begin{array}{c} -27.20656 - 76.98828R_{ts} + \\ 103.0922R_{ts}^2 + 7.433649(10)^{-3}S_y \end{array}\right)}{\left(\begin{array}{c} 1 - 1.986738R_{ts} - 1.758474(10)^{-2}S_y + \\ 6.479033(10)^{-5}S_y^2 \end{array}\right)} \qquad (°\mathrm{F}, \mathrm{ksi}) \tag{3.4}$$

$$\mathrm{MDMT} = \mathrm{MDMT}_{\mathrm{STEP3}} - T_R \tag{3.5}$$

(b) The procedure in 3.11.2.5(a) above is repeated for each welded part, and the warmest MDMT of all welded parts is the MDMT for the vessel.

(c) For a flange attached by welding, the procedure in 3.11.2.5(a) above can be used by determining the temperature reduction as determined for the neck or shell to which the flange is attached. The bolt-up condition need not be considered when determining the temperature reduction for flanges.

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(d) For components not stressed in general primary membrane tensile stress such as flat heads, covers, tubesheets, and flanges, the MDMT shall not be colder than the MDMT derived from 3.11.2.3, 3.11.2.4(a), or the impact test temperature less the allowable temperature reduction as determined in 3.11.2.5(a). The ratio used in 3.11.2.5(a) shall be the ratio of the maximum design pressure at the MDMT to the maximum allowable pressure (MAP) of the component at the MDMT.

(e) Longitudinal tensile stress in the vessel due to net-section bending that results in general primary membrane tensile stress (e.g., due to wind or earthquake in a vertical vessel, at mid-span and in the plane of the saddles of a saddle-supported horizontal vessel) shall be considered when calculating the R_{ts} ratio in (a), Step 4.

3.11.2.6 Adjusting the MDMT for Impact Tested Materials.

(a) For components that are impact tested, the components may be used at a MDMT colder than the impact test temperature, provided the stress ratio defined in 3.11.2.5(a), Step 4 is less than one and the MDMT is not colder than −104°C (−155°F). For such components, the MDMT shall not be colder than the impact test temperature less the allowable temperature reduction as determined from 3.11.2.5 (i.e., the starting point for the MDMT calculation in 3.11.2.5(a), Step 3, is the impact test temperature). For pressure vessel attachments that are exposed to tensile stresses from internal pressure (e.g., nozzle reinforcement pads, horizontal vessel saddle attachments, and stiffening rings), the coincident ratio shall be that of the shell or head to which each component is attached. [See 3.11.2.4(b)].

(b) One common usage of the exemptions in 3.11.2.5 and 3.11.2.6 will be for vessels in which the pressure is dependent on the vapor pressure of the contents (e.g., vessels in refrigeration, or hydrocarbon processing plants with operating systems that do not permit immediate repressurization). For such services, the primary thickness calculations (shell and head) normally will be made for the maximum design pressure coincident with the design (MDMT) temperature expected. The ratio of required thickness/nominal thickness as defined in 3.11.2.5(a), Step 4, for the design condition is then calculated. Thickness calculations are also made for other expected pressures at coincident temperature, along with the ΔT difference from the MDMT [see 3.11.2.5(a), Step 3], and the thickness ratio defined in 3.11.2.5(a), Step 4. Ratio/ΔT points that are on or below the line in Figure 3.14 (for as-welded parts) or Figure 3.15 (for PWHT or non-welded parts), as applicable, are acceptable, but in no case may the operating temperature be colder than −104°C (−155°F). Comparison of pressure–temperature coincident ratios or stress coincident ratios may also be used as illustrated in 3.11.2.5(a), Step 4.

3.11.2.7 Vessel or Components Operating Below the MDMT. Vessels or components may be operated at temperatures colder than the MDMT stamped on the nameplate if:

(a) The provisions of 3.11.2 are met when using the reduced (colder) operating temperature as the MDMT, but in no case shall the operating temperature be colder than −104°C (−155°F); or

(b) For vessels or components whose thicknesses are based on pressure loading only, the coincident operating temperature may be as cold as the MDMT stamped on the nameplate less the allowable temperature reduction as determined from 3.11.2.5. The ratio used in 3.11.2.5(a), Step 4, of the procedure in 3.11.2.5 shall be the ratio of maximum pressure at the coincident operating temperature to the design pressure of the vessel at the stamped MDMT, but in no case shall the operating temperature be colder than −104°C (−155°F).

3.11.2.8 Establishment of the MDMT Using a Fracture Mechanics Methodology. (25)

(a) In lieu of the procedures in 3.11.2.1 through 3.11.2.7, the MDMT may be established using a fracture mechanics approach. The fracture mechanics procedures shall be in accordance with API 579-1/ASME FFS-1, Part 9, Level 2 or Level 3.

(b) The assessment used to determine the MDMT shall include a systematic evaluation of all factors that control the susceptibility to brittle fracture, e.g., stresses from the applied loadings including thermal stresses, flaw size, fracture toughness of the base metal and welded joints, heat treatment, and the loading rate.

(c) Reference Flaw Size

(1) The reference flaw size used in the fracture mechanics evaluation shall be a surface flaw with a depth of a = min[t/4, 25 mm (1 in.)] and a length of $2c = 6a$ where t is the thickness of the plate containing the reference flaw.

(2) If approved by the user, an alternative reference flaw size may be used based on the weld joint geometry and the NDE that will be used and demonstrated for qualification of the vessel (see Part 7). When alternative flaw size is considered, the following shall apply:

(-a) A factor of 1.2 shall be applied to the flaw size established using NDE.

(-b) The factored flaw size shall be used in the fracture analysis in (a) and the assessment approach in (b).

(-c) Flaw size shall include expected flaw growth in service (e.g., fatigue, environmental cracking).

(-d) A factor of 1.4 shall be applied to the stresses from applied loadings, including thermal stresses, which are to be used in the facture mechanics analysis in (a).

(d) Fracture Toughness

(1) The material fracture toughness shall be established using API 579-1/ASME FFS-1, Annex 9-F.

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(2) If approved by the user, an alternative material fracture toughness may be used based on valid fracture toughness test results obtained using ASTM E399 or ASTM E1820 test method at a temperature colder than or equal to MDMT. Three specimens shall be tested in weak fracture orientation. Minimum fracture toughness value of the three specimens divided by 1.2 shall be used in the fracture analysis specified in (a).

(e) When approved by the user, the MDMT may be based on a life assessment using fracture mechanics in accordance with Section VIII, Division 3, Part KD-4 or Part KD-10 for vessels in cyclic service in lieu of (a) through (d).

(f) The MDMT established using a fracture mechanics approach shall not be colder than that given in 3.11.2.3(e).

(25) **3.11.2.9 Postweld Heat Treatment Requirements for Materials in Low Temperature Service.**

(a) If the MDMT is colder than −48°C (−55°F) and the stress ratio defined in 3.11.2.5(a), Step 4 is greater than or equal to 0.24, then welded joints shall be subject to PWHT in accordance with the requirements of 6.4.2.

(b) The requirement in (a) above does not apply to the welded joints listed in (1) and (2) below in vessel or vessel parts fabricated of P-No. 1 materials that are impact tested at the MDMT or colder in accordance with 3.11.2.1. The minimum average energy requirement for base metal, weld metal, and heat-affected zones shall be 41 J (30 ft-lb) instead of the values shown in Figure 3.5 for welded parts not subject to PWHT or Figure 3.6 for welded parts subject to PWHT or for nonwelded parts.

(1) Type 1 Category A and B joints, not including cone-to-cylinder junctions, that have been 100% radiographed. Category A and B joints attaching sections of unequal thickness shall have a transition with a slope not exceeding 3:1.

(2) Fillet welds having leg dimensions not exceeding 10 mm ($^{3}/_{8}$ in.) attaching lightly loaded attachments, provided the attachment material and the attachment weld meet the requirements of 3.11.2 and 3.11.8. Lightly loaded attachments, for this application, are defined as attachments in which the stress in the attachment weld does not exceed 25% of the allowable stress. All such welds shall be examined by liquid penetrant or magnetic particle examination in accordance with Part 7 of this Division.

3.11.2.10 Impact Tests of Welding Procedures.

(a) For welded construction, the welding procedure qualification shall include impact testing of weld metals in accordance with 3.11.2.1 when required by (b) or (c).

(b) Welds made with filler metal shall be deposited using welding procedures qualified with impact testing when

(1) either base metal is required to be impact tested by the rules of this Division; or

(2) any individual weld pass exceeds 13 mm ($^{1}/_{2}$ in.) in thickness and the MDMT is colder than 21°C (70°F); or

(3) joining base metals exempt from impact testing by 3.11.2.3, 3.11.2.4, and 3.11.2.5 when the MDMT is colder than −48°C (−55°F); or

(4) joining base metals from Figure 3.9 or Figure 3.10, Curves C or D, or metals exempted from impact testing by 3.11.2.4(b), and the MDMT is colder than −29°C (−20°F) but not colder than −48°C (−55°F). Qualification of the welding procedure with impact testing is not required when no individual weld pass in the fabrication weld exceeds 6 mm ($^{1}/_{4}$ in.) in thickness, and each heat and/or lot of filler metal or combination of heat and/or lot of filler metal and batch of flux has been classified by their manufacturer through impact testing per the applicable SFA specification at a temperature not warmer than the MDMT. Additional testing beyond the scope of the SFA specification may be performed by the filler metal and/or flux manufacturer to expand their classification for a broader range of temperatures.

(c) Except for welds made as part of the material specification, welds made without the use of filler metal shall be completed using welding procedures qualified with impact testing when

(1) either base metal is required to be impact tested by the rules of this Division; or

(2) the thickness at the weld exceeds 13 mm ($^{1}/_{2}$ in.) for all MDMTs, or 8 mm ($^{5}/_{16}$ in.) when the MDMT is colder than 10°C (50°F); or

(3) joining base metals exempt from testing by 3.11.2.4(b) when the MDMT is colder than −48°C (−55°F).

3.11.3 QUENCHED AND TEMPERED STEELS

(25) **3.11.3.1 Toughness Requirements for Quenched and Tempered Ferritic Steels.**

(a) All quenched and tempered steels listed in Table 3-A.2 shall be subject to Charpy V-notch testing.

(b) Impact tests shall be conducted at a temperature not warmer than the MDMT determined in 4.1.5.2(e). However, in no case shall the impact test temperature be warmer than 0°C (32°F).

(c) Materials may be used at temperatures colder than the MDMT as permitted below.

(1) When the stress ratio defined in 3.11.2.5(a), Step 4 is 0.24 or less, the corresponding MDMT shall not be colder than −104°C (−155°F).

(2) When the stress ratio defined in 3.11.2.5(a), Step 4 is greater than 0.24, the corresponding MDMT shall not be colder than the impact test temperature less the allowable temperature reduction as determined in 3.11.2.5(a) and shall in no case be colder than −104°C (−155°F).

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3.11.3.2 Impact Testing.

(a) Preparation of Test Specimens – All test specimens shall be prepared from the material in its final heat-treated condition according to the requirements of 3.11.7.2.

(b) Number of Impact Tests and Test Specimens – One Charpy V-notch impact test shall consist of three test specimens. For as-rolled plates, one Charpy V-notch test shall be made from each as-rolled plate. For heat-treated plates (normalized, normalized and tempered, or quenched and tempered), one Charpy V-notch test shall be made from each plate-as-heat-treated. One Charpy V-notch test shall be made from each heat of bars, pipe, tubing, rolled sections, forged parts or castings included in any one heat treatment lot. The number of impact tests shall not be less than required by the material specification.

(c) Locations and Orientation of Test Specimens – The location and orientation of the specimens shall be the same as required for Charpy type impact tests by 3.11.7.2 and 3.11.7.3 except that specimens from plates shall be transverse to the final direction of rolling and for forgings and pipe, transverse to the direction of major work (see Figure 3.16).

(d) The minimum lateral expansion shall be in accordance with 3.11.2.1(b)(2).

(e) Retesting shall be in accordance with 3.11.7.6.

3.11.3.3 Drop-Weight Tests.

(a) When the MDMT is colder than −29°C (−20°F), drop-weight tests as defined by ASTM E208, Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels, shall be made on all materials listed in Table 3-A.2, with the following exceptions:

(1) SA-522 for any MDMT;

(2) SA-353 and SA-553 when the temperature is not colder than −196°C (−320°F);

(3) SA-645 Grade A when the temperature is not colder than −170°C (−275°F).

(b) Number of Tests for Plates – For plates 16 mm ($^5/_8$ in.) thick and greater, one drop-weight test (two specimens) shall be made for each plate in the as-heat-treated condition (see 3.11.3.2).

(c) Number of Tests for Forgings and Castings – For forgings and castings of all thicknesses, one drop-weight test (two specimens) shall be made for each heat in any one heat treatment lot. The sampling procedure shall comply with the requirements of ASTM E208. Specimen locations for forgings shall be the same as specified in SA-350 for location of impact test specimens (see SA-350, paragraph 7.2.3).

(d) Required Test Results – Each of the two test specimens shall meet the “no-break” criterion, as defined by ASTM E208, at the test temperature.

3.11.4 HIGH ALLOY STEELS EXCEPT BOLTING

3.11.4.1 Toughness Requirements for High Alloy Steels.

(a) Impact tests shall be performed on high alloy materials listed in Table 3-A.3 for all combinations of materials and MDMTs except as exempted by 3.11.4.3 or 3.11.4.5. Impact testing is required for UNS S17400 materials. Impact tests shall be made from sets of three specimens: one set from the base metal, one set from the weld metal, one set from the heat-affected zone (HAZ). Specimens shall be subjected to the same thermal treatments as the part or vessel that the specimens represent.

(b) When the MDMT is −196°C (−320°F) and warmer, impact tests shall be conducted at the MDMT or colder, and the minimum lateral expansion opposite the notch shall be no less than 0.38 mm (0.015 in.) for MDMTs of −196°C (−320°F) and warmer.

(c) When the MDMT is colder than −196°C (−320°F), production welding processes shall be limited to shielded metal arc welding (SMAW), flux-cored arc welding (FCAW), gas metal arc welding (GMAW), submerged arc welding (SAW), plasma arc welding (PAW), and gas tungsten arc welding (GTAW). Each heat, lot, or batch of filler metal and filler metal/flux combination shall be pre-use tested as required by 3.11.4.5(d)(1) through 3.11.4.5(d)(3). Exemption from pre-use testing as allowed by 3.11.4.5(d)(4) and 3.11.4.5(d)(5) is not applicable. Toughness testing shall be performed as specified in (1) or (2) below, as appropriate.

(1) If using Type 316L weld filler metal, or Type 308L filler metal welded with the GTAW, FCAW, or GMAW process,

(-a) Weld metal deposited from each heat of Type 316L filler metal shall have a Ferrite Number (FN) no greater than 10, and a weld metal deposited from each heat of Type 308L filler metal shall have a FN in the range of 4 to 14, as measured by a ferritescope or magna gauge calibrated in accordance with AWS A4.2, or as determined by applying the chemical composition from the test weld to Figure 3.17.

(-b) Toughness tests shall be conducted at −196°C (−320°F) on three sets of three specimens: one set from the base metal, one set from the weld metal, one set from the HAZ.

(-c) Each of the three specimens from each test set shall have a lateral expansion opposite the notch not less than 0.53 mm (0.021 in.).

(2) When the qualifying conditions of (1) cannot be met:

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(-a) Weld metal deposited from each heat or lot of austenitic stainless steel filler metal used in production shall have a FN no greater than the FN determined for the test weld.

(-b) Toughness tests shall be conducted at −196°C (−320°F) on a set of three specimens from the base metal. Each of three specimens shall have a lateral expansion opposite the notch no less than 0.53 mm (0.021 in.).

(-c) ASTM E1820 J_{Ic} tests shall be conducted on two sets of two specimens: one set from the HAZ, one set from the weld metal, at a test temperature no warmer than MDMT. The HAZ specimen orientation shall be T-L. A K_{Ic} (J) value no less than $132\,\text{MPa}\sqrt{\text{m}}$ $\left(120\,\text{ksi}\sqrt{\text{in.}}\right)$ is required for all specimens tested.

(3) When the required toughness test specimens do not meet the lateral expansion requirements in (1)(-c) or (2)(-b), ASTM E1820 J_{Ic} tests shall be conducted on an additional set of two specimens representing the failed set of toughness test specimens at a test temperature no warmer than MDMT. The specimen orientation for the base metal and HAZ shall be T-L. A K_{Ic} (J) value no less than $132\,\text{MPa}\sqrt{\text{m}}$ $\left(120\,\text{ksi}\sqrt{\text{in.}}\right)$ is required for all specimens tested.

3.11.4.2 Required Impact Tests When Thermal Treatments Are Performed. Impact tests are required at the test temperature in accordance with 3.11.4.1 but no warmer than 21°C (70°F) whenever thermal treatments within the temperature ranges listed for the following materials are applied.

(a) Austenitic stainless steels thermally treated between 480°C and 900°C (900°F and 1,650°F), except for Types 304, 304L, 316, and 316L which are thermally treated at temperatures between 480°C and 705°C (900°F and 1,300°F), are exempt from impact testing, provided the MDMT is −29°C (−20°F) and warmer and vessel production impact tests of the thermally treated weld metal are performed for Category A and B joints.

(b) Austenitic-ferritic duplex stainless steels thermally treated at temperatures between 315°C and 955°C (600°F and 1,750°F).

(c) Ferritic chromium stainless steels and martensitic chromium stainless steels thermally treated at temperatures between 425°C and 730°C (800°F and 1,350°F).

Thermal treatments of materials do not include thermal cutting.

(25) **3.11.4.3 Exemptions From Impact Testing for Base Materials and HAZs.** Impact testing is not required for the following combinations of base metals and HAZs (if welded) and MDMT, except as modified in 3.11.4.2.

(a) For austenitic chromium-nickel stainless steels as follows:

(1) Those having a carbon content not exceeding 0.10% at MDMTs of −196°C (−320°F) and warmer. (The value of the carbon content may be specified by the purchaser, or must be within the limits of the material specification.);

(2) Those types having a carbon content exceeding 0.10% (the value of the carbon content may be as specified by the purchaser) at MDMTs of −48°C (−55°F) and warmer;

(3) For castings at MDMTs of −29°C (−20°F) and warmer.

(b) For austenitic chromium-manganese-nickel stainless steels (200 series) as follows:

(1) Having a carbon content not exceeding 0.10% at MDMTs of −196°C (−320°F) and warmer;

(2) Having a carbon content exceeding 0.10% at MDMTs of −48°C (−55°F) and warmer;

(3) For castings at MDMTs of −29°C (−20°F) and warmer.

(c) For the following steels in all product forms at MDMTs of −29°C (−20°F) and warmer:

(1) Austenitic-ferritic duplex steels with a nominal material thickness of 10 mm (3/8 in.) and thinner;

(2) Ferritic chromium stainless steels with a nominal material thickness of 3 mm (1/8 in.) and thinner;

(3) Martensitic chromium stainless steels with a nominal material thickness of 6 mm (1/4 in.) and thinner.

(d) Impact tests are not required where the maximum obtainable Charpy specimen has a width along the notch less than 2.5 mm (0.099 in.).

(e) Impact testing of materials is not required, except as modified by 3.11.4.2, when the coincident ratio of applied stress in tension to allowable tensile stress is less than 0.24. The applied stress is the stress from pressure and nonpressure loadings, including those listed in Table 4.1.1 which result in general primary membrane tensile stress.

3.11.4.4 Exemptions From Impact Testing for Welding Procedure Qualifications. For welding procedure qualifications, impact testing is not required for the following combinations of weld metals and MDMT except as modified by 3.11.4.2.

(a) For austenitic chromium-nickel stainless steel base materials having a carbon content not exceeding 0.10%, welded without the addition of filler metal, at MDMTs of −104°C (−155°F) and warmer.

(b) For austenitic weld metal:

(1) Having a carbon content not exceeding 0.10% and produced with filler metals conforming to SFA-5.4, SFA-5.9, SFA-5.11, SFA-5.14, and SFA-5.22 at MDMTs of −104°C (−155°F) and warmer;

(2) Having a carbon content exceeding 0.10% and produced with filler metals conforming, to SFA- 5.4, SFA-5.9, SFA-5.11, SFA-5.14, and SFA-5.22 at MDMTs of −48°C (−55°F) and warmer.

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(c) For the following weld metal, if the base metal of similar chemistry is exempt as stated in 3.11.4.3(c) above, then the weld metal shall also be exempt at MDMTs of −29°C (−20°F) and warmer:

(1) Austenitic-ferritic duplex steels;

(2) Ferritic chromium stainless steels; and

(3) Martensitic chromium stainless steels.

3.11.4.5 Required Impact Testing for Austenitic Stainless Steel Welding Consumables With MDMT Colder Than −104°C (−155°F). For production welds at MDMTs colder than −104°C (−155°F), all of the following conditions shall be satisfied:

(a) The welding processes are limited to SMAW, SAW, FCAW, GMAW, GTAW, and PAW;

(b) The applicable Welding Procedure Specifications (WPSs) are supported by Procedure Qualification Records (PQRs) with impact testing in accordance with the requirements of 3.11.7 and 3.11.4.1, or when the applicable PQR is exempted from impact testing by other provisions of this Division;

(c) The weld metal (produced with or without filler metal) has a carbon content not exceeding 0.10%, except when using ER310 or SFA-5.4 E310-15 or E310-16.

(d) The weld metal is produced by filler metal conforming to Section II, Part C, SFA-5.4, SFA-5.9, SFA-5.11, SFA-5.14, and SFA-5.22 as modified below.

(1) Each heat and/or lot of welding consumables to be used in production welding with the SMAW, FCAW, and GMAW processes shall be pre-use tested by conducting impact tests in accordance with 3.11.4.1. Test coupons shall be prepared in accordance with Section II, Part C, SFA-5.4, A9.3.5 utilizing the WPS to be used in production welding.

(2) Each heat of filler metal and batch of flux combination to be used in production welding with the SAW process shall be pre-use tested by conducting impact tests in accordance with 3.11.4.1. Test coupons shall be prepared in accordance with Section II, Part C, SFA-5.4, A9.3.5 utilizing the WPS to be used in production welding.

(3) Combining more than one welding process or more than one heat, lot, and/or batch of welding material into a single test coupon is unacceptable. Pre-use testing in accordance with 3.11.4.1 may be conducted by the welding consumable manufacturer, provided mill test reports are furnished with the consumables.

(4) The following filler metals may be used without pre-use testing of each heat, lot, and/or batch provided that the procedure qualification impact testing in accordance with 3.11.8 at the MDMT or colder is performed using the same manufacturer brand and type filler metal: ENiCrFe-2; ENiCrFe-3; ENiCrMo-3; ENiCrMo-4; ENiCrMo-6; ERNiCr-3; ERNiCrMo-3; ERNiCrMo-4; SFA-5.4, E310-15 or 16.

(5) The following filler metals may be used without pre-use testing of each heat and/or lot provided that procedure qualification impact testing in accordance with 3.11.8 at the MDMT or colder is performed: ER308L, ER316L, and ER310 used with the GTAW or PAW processes.

3.11.4.6 Required Impact Testing for Vessel Production Test Plates.

(a) For welded construction, of duplex stainless steels, ferritic stainless steels and martensitic stainless steels, vessel production impact tests in accordance with 3.11.8.4 are required if the welding procedure qualification requires impact testing, unless otherwise exempted by the rules of this Division.

(b) For welded construction of austenitic stainless steels, vessel (production) impact tests in accordance with 3.11.8.4 are required unless exempted as follows in (1) and (2):

(1) At MDMTs of −104°C (−155°F) and warmer, vessel (production) impact tests are exempted, provided the impact test exemption requirements for the applicable Weld Procedure Qualification in 3.11.4.4 are satisfied.

(2) At MDMTs colder than −104°C (−155°F) but no colder than −196°C (−320°F), vessel (production) impact tests are exempted, provided the pre-use test requirements in 3.11.4.5 are satisfied.

(3) At MDMTs colder than −196°C (−320°F), vessel (production) impact tests or ASTM E1820 J_{Ic} tests shall be conducted in accordance with 3.11.4.1(c).

(c) Vessel Production Impact Testing for Autogeneous Welds in Austenitic Stainless Steels – For autogenous welds (welded without filler metal) in austenitic stainless steels, vessel (production) impact tests are not required when all of the following conditions are satisfied:

(1) The material is solution annealed after welding.

(2) The MDMT is not colder than −196°C (−320°F).

3.11.5 NONFERROUS ALLOYS

3.11.5.1 Nonferrous materials listed in Tables 3-A.4 through 3-A.7, together with deposited weld metal within the range of composition for material in that Table, do not undergo a marked drop in impact resistance at subzero temperature. Therefore, additional requirements are not specified for:

(a) Wrought aluminum alloys when they are used at temperature down to −269°C (−452°F);

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(b) Copper and copper alloys, nickel and nickel alloys, and cast aluminum alloys when they are used at temperatures down to −198°C (−325°F); and

(c) Titanium or zirconium and their alloys used at temperatures down to −59°C (−75°F).

3.11.5.2 The nonferrous materials listed in Tables 3-A.4 through 3-A.7 may be used at lower temperatures than those specified herein and for other weld metal compositions, provided the user satisfies himself by suitable test results such as determinations of tensile elongation and sharp-notch tensile strength (compared to unnotched tensile strength) that the material has suitable ductility at the design temperature.

3.11.6 BOLTING MATERIALS

3.11.6.1 Bolting Materials for Use With Flanges Designed to 4.16.

(a) Impact tests are not required for bolting materials listed in Tables 3.5, 3.6, 3.7, and 3.8 when used at MDMTs equal to or warmer than those shown in these Tables.

(b) Bolting materials produced and impact tested in accordance with the requirements of the specifications in (1) through (4) are exempt from impact testing by the rules of this Division at MDMTs not more than 3°C (5°F) colder than the test temperature required by the specification.

(1) SA-320

(2) SA-437

(3) SA-508 Grade 5 Class 2

(4) SA-540, except for materials produced under Table 2, note 4 in this specification

(c) Bolting materials to be used for colder temperatures than those shown in Tables 3.5 and 3.6 shall be impact tested. When impact testing is performed

(1) for materials listed in Table 3.5, Charpy V-notch acceptance criteria in accordance with 3.11.2.1(b) shall be applied

(2) for materials listed in Table 3.6, Charpy V-notch acceptance criteria in accordance with 3.11.4.1(b) shall be applied

3.11.6.2 Bolting Materials for Use With Flanges Designed to Part 5 of This Division. Impact testing is required for the ferrous bolting materials listed in Table 3-A.11 for use with flanges designed in accordance with Part 5 of this Division. The average for three Charpy V-notch impact specimens shall be at least 41 J (30 ft-lb), with the minimum value for any individual specimen not less than 34 J (25 ft-lb).

3.11.7 TOUGHNESS TESTING PROCEDURES

3.11.7.1 Test Procedures.

(a) Impact test procedures and apparatus shall conform to the applicable paragraphs of SA-370 or ISO 148 (Parts 1, 2, and 3).

(b) The impact test temperature shall not be warmer than the MDMT [see 4.1.5.2(e)].

3.11.7.2 Test Specimens.

(a) Each set of impact tests shall consist of three specimens.

(b) The impact test specimens shall be of the Charpy V-notch type and shall conform in all respects to the specimen requirements of SA-370 (for Type A specimens). The standard full-size (10 mm × 10mm) specimen, when obtainable, shall be used, except that for materials that normally have absorbed energy in excess of 244 J (180 ft-lb) when tested using full size specimens at the specified testing temperature, subsize (10 mm × 6.7 mm) specimens may be used in lieu of full-size specimens. However, when this option is used, the acceptance value shall be 102 J (75 ft-lb) minimum for each specimen.

(c) For material from which full-size specimens cannot be obtained, either due to the material shape or thickness, the specimens shall be either the largest possible subsize specimen obtainable or specimens of full material thickness which may be machined to remove surface irregularities [the test temperature criteria of 3.11.7.5 shall apply for carbon and low alloy materials having a specified minimum tensile strength less than 655 MPa (95 ksi) when the width along the notch is less than 80% of the material thickness]. Alternatively, such material may be reduced in thickness to produce the largest possible Charpy subsize specimen. Toughness tests are not required where the maximum obtainable Charpy specimen has a width along the notch less than 2.5 mm (0.099 in.), but carbon steels too thin to impact test shall not be used for design temperatures colder than −48°C (−55°F), subject to the exemptions provided by 3.11.2.9.

3.11.7.3 Product Forms.

(a) Impact test specimens of each product form shall be located and oriented in accordance with the requirements of 3.10.4.

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(b) The manufacturer of small parts, either cast or forged, may certify a lot of not more than 20 duplicate parts by reporting the results of one set of impact specimens taken from one such part selected at random, provided the same specification and heat of material and the same process of production, including heat treatment, were used for all of the lot. When the part is too small to provide the three specimens of at least minimum size indicated in 3.11.7.2, then impact test do not need to be performed [see 3.11.7.2(c)].

3.11.7.4 Certification of Compliance With Impact Test Requirements.

(a) Certified reports of impact tests by the materials manufacturer will be acceptable evidence that the material meets the requirements of this paragraph, provided:

(1) The specimens taken are representative of the material delivered [see 3.11.7.3(a)] and the material is not subjected to heat treatment during or following fabrication that will materially reduce its impact properties; or

(2) The materials from which the specimens are removed are heat treated separately such that they are representative of the material in the finished vessel.

(b) The Manufacturer of the vessel may have impact tests made to prove the suitability of a material which the materials manufacturer has not impact tested, provided the number of tests and the method of taking the test specimens shall be as specified for the materials manufacturer.

3.11.7.5 Impact Test Temperature Criteria. For all Charpy impact tests, the following test temperature criteria shall be observed.

(a) Materials of Thickness Equal to or Greater Than 10 mm (0.394 in.) – Where the largest obtainable Charpy V-notch specimen has a width along the notch of at least 8 mm (0.315 in.), the Charpy test of such a specimen shall be conducted at a temperature not warmer than the MDMT. Where the largest possible test specimen has a width along the notch less than 8 mm (0.315 in.), the test shall be conducted at a temperature colder than the MDMT by the amount shown in Table 3.12 for the specimen width. Note that this requirement does not apply when the option of 3.11.7.2(b) is used.

(b) Materials With Thickness Less Than 10 mm (0.394 in.) – Where the largest obtainable Charpy V-notch specimen has a width along the notch of at least 80% of the material thickness, the Charpy test of such a specimen shall be conducted at a temperature not warmer than the MDMT. Where the largest possible test specimen has a width along the notch of less than 80% of the material thickness, the test for carbon steel and low alloy materials having a specified minimum tensile strength of less than 655 MPa (95 ksi) shall be conducted at a temperature colder than the MDMT by an amount equal to the difference, see Table 3.12, between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to the Charpy specimen width actually tested. This requirement does not apply when the option of 3.11.7.2(b) is used. For Table 3-A.2, carbon and low alloy materials having a specified minimum tensile strength greater than or equal to 655 MPa (95 ksi), for high alloy materials and quenched and tempered material with enhanced tensile properties, the test shall be conducted at a temperature not warmer than the MDMT.

3.11.7.6 Retests.

(a) Absorbed Energy Criteria – If the absorbed energy criteria are not met, retesting in accordance with the applicable procedures of SA-370 shall be permitted.

(b) Lateral Expansion Criteria – retests shall be performed as follows:

(1) Retesting is permitted if the average value for three specimens equals or exceeds the value required.

(-a) For materials of Table 3-A.1 (carbon and low alloy steels) having specified minimum tensile strengths of 655 MPa (95 ksi) or greater, if the measured value of lateral expansion for one specimen in a group of three is less than that required in Figure 3.8.

(-b) For materials of Table 3-A.3 (high alloy steels) for MDMTs no colder than −196°C (−320°F), if the measured value of lateral expansion for one specimen in a group of three is less than 0.38 mm (0.015 in.), but not less than two-thirds of the value required.

(-c) For materials of Table 3-A.3 (high alloy steels) for for MDMTs colder than −196°C (−320°F), if the value of lateral expansion for one specimen of a set is less than 0.53 mm (0.021 in.).

(-d) For materials of Table 3-A.2 (Q&T steel with enhanced strength properties), if the measured value of lateral expansion for one specimen in a group of three is less than that required in Figure 3.8 but not less than two-thirds of the required value.

(2) The retest shall consist of three additional specimens. For materials of Table 3-A.1 (carbon and low alloy steels) having specified minimum tensile strengths of 655 MPa (95 ksi) or greater and for Table 3-A.2 (Q&T steels with enhanced strength properties) materials, the retest value for each specimen must equal or exceed the value required in Figure 3.8. For materials of Table 3-A.3 (high alloy steels), the retest value for each specimen must equal or exceed 0.38 mm (0.015 in.) for MDMTs no colder than −196°C (−320°F). For MDMTs colder than −196°C (−320°F), see 3.11.2.1(b)(2) and 3.11.4.1(b).

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(3) In the case of materials with properties enhanced by heat treatment, the material may be reheat treated and retested if the required values are not obtained in the retest or if the values in the initial test are less than the values required for retest. After reheat treatment, a set of three specimens shall be made; for acceptance, the lateral expansion of each of the specimens must equal or exceed the value required in Figure 3.8.

(c) When an erratic result is caused by a defective specimen or there is uncertainty in the test procedure, a retest will be allowed. When the option of 3.11.7.2(b) is used for the initial test and the acceptance of 102 J (75 ft-lb) minimum is not attained, a retest using full-size (10 mm × 10 mm) specimens will be allowed.

3.11.8 IMPACT TESTING OF WELDING PROCEDURES AND TEST PLATES OF FERROUS MATERIALS

3.11.8.1 Impact Tests.

(a) For steel vessels of welded construction, the impact toughness of welds and heat-affected zones of procedure qualification test plates and vessel test plates (production impact test plates) shall be determined as required in this paragraph.

(b) All test plates shall be subjected to heat treatment, including the aggregate time at temperature or temperatures as established by the manufacturer for use in actual manufacture. Heat treatment requirements of 3.10.2, 3.10.4, and 6.4.2 shall apply to test plates, except that the provisions of 3.10.3.2 are not applicable to test plates for welds joining P-No. 3, Groups 1 and 2 materials. For P-No. 1, Groups 1, 2, and 3 materials, impact testing of the welds and heat-affected zones of the weld procedure qualification and production test plates need not be repeated when the fabrication heat treatment differs from the heat treatment applied to the test plates, provided the PWHT or simulated heat treatment cycles applied to the test plates and the production welds were applied observing the holding temperatures and times specified in Table 6.8 or the holding temperatures and times permitted in Table 6.16.

3.11.8.2 Weld Impact Testing.

(a) The impact specimens shall be full size or the largest subsize Charpy V-notch specimens that can be obtained from the material to be tested. The specimens shall be oriented so that the notch is perpendicular to the surface of the material. Where the maximum obtainable specimen has a width along the notch less than 2.5 mm (0.099 in.), impact tests are not required.

(b) Each set of weld metal specimens shall be tested using specimens taken transverse to the weld axis with the notch in the weld metal. One face of the specimen shall be within 1.5 mm ($\frac{1}{16}$ in.) of the surface of the material except that the specimens may be located at any depth when the weld has been postweld heat treated.

(c) Each set of heat-affected zone specimens shall be tested using specimens taken transverse to the axis of the weld. Specimens shall be of sufficient length to locate, after etching, the fusion line.

(1) When the material to be tested is less than 25 mm (1 in.) thick, the specimens shall be taken at the depth that maximizes the amount of the heat-affected zone at the notch centerline. When the material to be tested is 25 mm (1 in.) thick or thicker, the centerline of the specimens shall be located between one-half and one-quarter of the material thickness below the surface. See Figure 3.18.

(2) The notch shall be normal to the material surface. Where the angle of the heat-affected zone is approximately normal to the material surface, the notch centerline shall be approximately 1 mm (0.04 in.) from the fusion line. When the heat-affected zone is at an angle to the material surface, the middle of the notch centerline shall be located approximately 2 mm (0.08 in.) from the fusion line as shown in Figure 3.19.

(d) For welds made by a solid-state welding process, such as for electric resistance-welded (ERW) pipe, the weld impact tests shall consist only of one set of three specimens taken across the weld with the notch at the weld centerline. Each specimen shall be oriented so that the notch is normal to the surface of the material and one face of the specimen shall be within 1.5 mm ($\frac{1}{16}$ in.) of the surface of the material.

(e) The test temperature for welds and heat-affected zones shall not be higher than for the base materials.

(f) Impact values shall be at least as high as those required for the base materials (see 3.11.2, 3.11.3, and 3.11.4, as applicable).

(g) When qualifying a WPS for welding base metals having different impact testing requirements and acceptance criteria, the following shall apply:

(1) The weld metal impact test specimens shall meet the acceptance criteria for either base metal.

(2) When HAZ tests are required, separate test specimens shall be removed from the HAZ of each base metal that requires impact testing, and those specimens shall meet the acceptance criteria for the base metal from which they were removed.

3.11.8.3 Impact Tests of Welding Procedure Qualification Test Coupons.

(a) Welding procedure specifications shall be qualified with impact testing when base materials are required to be impact tested, except as exempted by 3.11.4.4 and 3.11.2.10.

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(b) If impact tests are required for the weld, but the base material is exempted from impact tests, the test coupon shall be made from the same P-Number and Group number material as that of the vessel. Testing of the weld metal shall be in accordance with 3.11.8.2.

(c) Welding procedures used for fillet welds shall be qualified by a groove weld test. The qualification test plate or pipe material shall meet the requirements of 3.11.7 when impact testing is a requirement.

(d) When impact testing is a requirement, the supplementary essential variables in Section IX, QW-250 and the following shall apply:

(1) The weld metal and heat-affected zones of the procedure qualification test coupons shall be tested in accordance with 3.11.8.2.

(2) A joint design where only one side of the joint is beveled (i.e., a single- or double-bevel groove weld) should be used to sample as much of the heat-affected zone as possible. See Figure 3.19.

(e) For materials of Table 3-A.1 (carbon steel and low alloy steel), the test plate material shall satisfy the following requirements relative to the material to be used in production:

(1) The test coupon material shall be in the same heat-treatment condition (as-rolled, normalized, quenched and tempered, etc.) before welding as the vessel to be constructed. The heat-treatment condition shall be recorded on the PQR and specified on the WPS. This requirement does not apply to P-No. 1, Gr. Nos. 1 and 2 materials except for SA-737 and SA-841.

(2) The test coupon material shall meet the minimum toughness requirements 3.11.2, 3.11.3, and 3.11.4, as applicable for the thickest material of the range of base material qualified by the procedure.

(f) Each welding process shall be qualified using impact tests. More than one set of specimens may be required to satisfy this requirement and 3.11.8.2. Each process may be qualified using single- or multiprocess test coupons. If more than one set of essential or supplementary essential variables for a process is recorded on a procedure qualification record (e.g., a change in filler metal F-number), the requirements in (1) though (4) for multiprocess testing shall apply to each set of essential or supplementary essential variables as if that set were a separate welding process. When more than one welding process is included in a test coupon

(1) the specimens shall be full size or the largest subsize specimen that can be obtained based on the thickness of the test coupon. The weld metal test specimens shall contain as much of the weld metal from each process as is practical. When the test coupon contains more than two welding processes, it is not possible to locate specimens within 1.5 mm ($^1/_{16}$ in.) of a surface. In this case, additional weld metal impact specimens shall be taken at the thickness where those processes are located.

(2) when specimens contain weld metal from more than one process, the test results apply to all those processes contained in the specimens.

(3) heat-affected zone specimens shall be prepared from material that was removed at the thickness plane associated with weld metal from each process. These specimens may contain material that was affected by the heat from more than one welding process

(4) procedure qualifications that were made in accordance with the 2017 or later Edition where subsize specimens were tested remain acceptable.

3.11.8.4 Vessel Production Weld Impact Testing.

(a) When the base material or welding procedure qualification requires impact testing, impact tests of welds and heat-affected zones shall be made for Category A and B joints in accordance with 3.11.8.2 and 3.11.8.3 for each qualified welding procedure followed on each vessel. The test plate shall be from one of the heats of steel used for the vessel or group of vessels and shall be welded as an extension to the end of a production Category A joint where practicable, or welded as close to the start of production welding as practicable, utilizing equipment, welding materials, and procedures which are to be used on the production joint. The test plate shall also represent each welding process or welding process combination used in production on Category A joints.

(b) For Category B joints that are welded following a different welding procedure than used on Category A joints, a test plate shall be welded under the production welding conditions used for the vessel, using the same type of equipment and at the same location and following the same procedures as used for the joint, and it shall be welded concurrently with the production welds or as close to the start of production welding as practicable. The test plate shall also represent each welding process or welding process combination used in production on Category B joints.

(c) Number of Vessel Impact Test Plates Required

(1) For each vessel, one test plate shall be made for each welding procedure used for joints of Categories A and B, unless the vessel is one of several as defined in (2). In addition, for Category A and B joints, the following requirements shall apply:

(-a) If automatic, machine, or semiautomatic welding is performed, a test plate shall be made in each position employed in the vessel welding.

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(-b) If manual welding is also employed, a test plate shall be made in the flat position only, except if welding is to be performed in other positions a test plate need be made in the vertical position only (where the major portions of the layers of welds are deposited in the vertical upward direction). The vertically welded test plate will qualify the manual welding in all positions.

(2) For several vessels or parts of vessels, welded within any 3 month period at one location, the plate thickness of which does not vary by more than 6 mm ($\frac{1}{4}$ in.) or 25%, whichever is greater, and of the same specification and grade of material, a test plate shall be made for each 122 m (400 ft) of joints welded by the same procedure.

(d) If the vessel test plate fails to meet the impact requirements, the welds represented by the test plate shall be unacceptable. Reheat treatment and retesting, or retesting only, are permitted.

3.12 ALLOWABLE DESIGN STRESSES

The design stresses for materials permitted by this Division are given in Annex 3-A.

3.13 STRENGTH PARAMETERS

The strength parameters for materials permitted by this Division are given in Annex 3-D.

3.14 PHYSICAL PROPERTIES

The following physical properties for all permissible materials of construction are given in the tables referenced in Annex 3-E.

(a) Young's Modulus
(b) Thermal Expansion Coefficient
(c) Thermal Conductivity
(d) Thermal Diffusivity

3.15 DESIGN FATIGUE CURVES

Design fatigue curves for nonwelded and for welded construction are provided in Annex 3-F. As an alternative, the adequacy of a part to withstand cyclic loading may be demonstrated by means of fatigue test following the requirements of Annex 5-F. However, the fatigue test shall not be used as justification for exceeding the allowable values of primary or primary plus secondary stresses.

3.16 DESIGN VALUES FOR TEMPERATURES COLDER THAN −30°C (−20°F)

For design temperatures colder than −30°C (−20°F), the allowable design stress values and strength parameter values to be used in design shall not exceed those given in the pertinent tables in Section II, Part D for −30°C to 40°C (−20°F to 100°F), unless specifically addressed elsewhere in this Division.

3.17 NOMENCLATURE

a = reference flaw depth
$2c$ = reference flaw length
E = joint efficiency (see Part 7) used in the calculation of t_r. For castings, the quality factor or joint efficiency E, whichever governs design, shall be used.
E^* = E^* equal to E except that E^* shall not be less than 0.80, or E^* = max[E, 0.80]
CA = corrosion allowance
MDMT = minimum design metal temperature
P_a = applied pressure for the condition under consideration
P_{rating} = maximum allowable working pressure based on the design rules in this Division of ASME/ANSI pressure–temperature ratings

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R_{ts} = stress ratio defined as the stress for the operating condition under consideration divided by the stress at the design minimum temperature. The stress ratio may also be defined in terms of required and actual thicknesses, and for components with pressure–temperature ratings, the stress ratio is computed as the applied pressure for the condition under consideration divided by the pressure rating at the MDMT.
S = allowable stress from Annex 3-A
S_y = specified minimum yield strength
S^* = applied general primary stress
t = reference flaw plate thickness
t_g = governing thickness
t_n = nominal uncorroded thickness. For welded pipe where a mill undertolerance is allowed by the material specification, the thickness after mill undertolerance has been deducted shall be taken as the nominal thickness. Likewise, for formed heads, the minimum specified thickness after forming shall be used as the nominal thickness.
t_r = required thickness of the part under consideration in the corroded condition for all applicable loadings
T_R = reduction in MDMT based on available excess thickness

3.18 DEFINITIONS

The definitions for the terminology used in this Part are contained in Annex 1-B.

3.19 TABLES (25)

Table 3.1
Criteria and Requirements for Bar per 3.2.5.2(c)

Direction of Primary Stresses Relative to the Bar Axis		Bar Nominal Size, mm (in.)	Design Stress Penalty Required per 3.2.5.2(c)(1)(-a), %	Volumetric Ultrasonic Examination Required per 3.2.5.2(c)(2)(-b) and 3.2.5.2(c)(2)(-c)	Transverse Tension Testing Required per 3.2.5.2(c)(2)(-a)	Surface Examination Required per 3.2.5.2(c)(1)(-b)
Parallel	Not Parallel					
X	...	Any	None	None	None	None
...	X	≤205 (≤8.00)	50%	None	None	X
...	X	>205 (>8.00)	50%	X	None	X
...	X	Any	None	X	X	X

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(25)

Table 3.2
Material Specifications

Nominal Composition	Type/Grade	Specification	Product Form
2¼Cr–1Mo	Grade 8, Cl. A	SA-487	Castings
	Grade 22, Cl. 3	SA-508	Forgings
	Grade 22, Cl. 3	SA-541	Forgings
	Type B, Cl. 4	SA-542	Plates
2¼Cr–1Mo–¼V	Grade F22V	SA-182	Forgings
	Grade F22V	SA-336	Forgings
	Grade 22V	SA-541	Forgings
	Type D, Cl. 4a	SA-542	Plates
	Grade 22V	SA-832	Plates
3Cr–1Mo–¼V–Cb–Ca	Grade F3VCb	SA-182	Forgings
	Grade F3VCb	SA-336	Forgings
	Grade 3VCb	SA-508	Forgings
	Grade 3VCb	SA-541	Forgings
	Type E, Cl. 4a	SA-542	Plates
	Grade 23V	SA-832	Plates
3Cr–1Mo–¼V–Ti–B	Grade F3V	SA-182	Forgings
	Grade F3V	SA-336	Forgings
	Grade 3V	SA-508	Forgings
	Grade 3V	SA-541	Forgings
	Type C, Cl. 4a	SA-542	Plates
	Grade 21 V	SA-832	Plates

GENERAL NOTE: The materials in this table have a specified minimum tensile strength of 585 MPa (85 ksi) or greater.

Table 3.3
Composition Requirements for 2.25Cr–1Mo–0.25V Weld Metal

Welding Process	C	Mn	Si	Cr	Mo	P	S	V	Cb
SAW	0.05–0.15	0.50–1.30	0.05–0.35	2.00–2.60	0.90–1.20	0.015 max	0.015 max	0.20–0.40	0.010–0.040
SMAW	0.05–0.15	0.50–1.30	0.20–0.50	2.00–2.60	0.90–1.20	0.015 max	0.015 max	0.20–0.40	0.010–0.040
GTAW	0.05–0.15	0.30–1.10	0.05–0.35	2.00–2.60	0.90–1.20	0.015 max	0.015 max	0.20–0.40	0.010–0.040
GMAW	0.05–0.15	0.30–1.10	0.20–0.50	2.00–2.60	0.90–1.20	0.015 max	0.015 max	0.20–0.40	0.010–0.040

Table 3.4
Toughness Requirements for 2.25Cr–1Mo Materials

Number of Specimens	Impact Energy, J (ft-lb)
Average of 3	54 (40)
Only one in the set	48 (35)

GENERAL NOTE: Full size Charpy V-notch, transverse, tested at the MDMT.

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Table 3.5
Low Alloy Bolting Materials for Use With Flanges Designed to 4.16

(25)

Material Specification	Material Type/Grade	Diameter, mm (in.)	MDMT Without Impact Testing, °C (°F)
Low Alloy Bolting			
SA-193	B5	Up to 102 (4), inclusive	−29 (−20)
	B7	64 (2½) and under	−48 (−55)
		Over 64 to 102 (2½ to 4), inclusive	−40 (−40)
		Over 102 to 178 (4 to 7), inclusive	−40 (−40)
	B7M	64 (2½) and under	−48 (−55)
	B16	64 (2½) and under	−48 (−55)
		Over 64 to 102 (2½ to 4), inclusive	−29 (−20)
		Over 102 to 178 (4 to 7), inclusive	−29 (−20)
SA-320	L7	64 (2½) and under	See 3.11.6.1(b)
	L7 A	Up to 64 (2½), inclusive	See 3.11.6.1(b)
	L7M	64 (2½) and under	See 3.11.6.1(b)
	L43	25 (1) and under	See 3.11.6.1(b)
SA-325	1	13 to 38 (½ to 1½), inclusive	−29 (−20)
SA-354	BC	Up to 102 (4),	−18 (0)
	BD	Up to 102 (4), inclusive	−7 (+20)
SA-437	B4B, B4C	All diameters	See 3.11.6.1(b)
SA-449	...	Up to 76 (3), inclusive	−29 (−20)
SA-508	5 Cl. 2	All diameters	See 3.11.6.1(b)
SA-540	B21	All diameters	Impact test is required
	B23 Cl. 1 & 2	All diameters	Impact test is required
	B23 Cl. 3 & 4	Up to 152 (6), inclusive	See 3.11.6.1(b)
		Over 152 to 241 (6 to 9½), inclusive	Impact test is required
	B23 Cl. 5	Up to 203 (8), inclusive	See 3.11.6.1(b)
		Over 203 to 241 (8 to 9½), inclusive	Impact test is required
	B24 Cl. 1	Up to 152 (6), inclusive	See 3.11.6.1(b)
		Over 152 to 203 (6 to 8), inclusive	Impact test is required
	B24 Cl. 2	Up to 178 (7), inclusive	See 3.11.6.1(b)
		Over 178 to 241 (7 to 9½), inclusive	Impact test is required
	B24 Cl. 3 & 4	Up to 203 (8), inclusive	See 3.11.6.1(b)
		Over 203 to 241 (8 to 9½), inclusive	Impact test is required
	B24 Cl. 5	Up to 241 (9½), inclusive	See 3.11.6.1(b)
	B24V Cl. 3	All diameters	See 3.11.6.1(b)
Low Alloy Steel Nuts			
SA-194	2, 2H, 2HM, 3, 4, 7, 7M, 16	All diameters	−48 (−55)
SA-540	B21, B23, B24, B24V	All diameters	−48 (−55)

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Table 3.6
High Alloy Bolting Materials for Use With Flanges Designed to 4.16

Material Specification	Material Type/Grade	Diameter, mm (in.)	MDMT Without Impact Testing, °C (°F)
SA-193	B6	102 (4) and under	−29 (−20)
	B8 Cl. 1	All diameters	−254 (−425)
	B8 Cl. 2	Up to 38 (1½), inclusive	Impact test is required
	B8C Cl. 1	All diameters	−254 (−425)
	B8C Cl. 2	19 to 38 (0.75 to 1½), inclusive	Impact test is required
SA-193	B8M Cl. 1	All diameters	−254 (−425)
	B8M2	51 to 64 (2 to 2½), inclusive	Impact test is required
	B8MNA Cl. 1A	All diameters	−196 (−320)
	B8NA Cl. 1A	All diameters	−196 (−320)
	B8P Cl. 1	All diameters	Impact test is required
	B8P Cl. 2	Up to 38 (1½), inclusive	Impact test is required
	B8S, 88SA	All diameters	Impact test is required
	B8T Cl. 1	All diameters	−254 (−425)
	B8T Cl, 2	19 to 25 (¾ to 1), inclusive	Impact test is required
SA-320	B8 Cl. 1	All diameters	See 3.11.6.1(b)
	B8 Cl. 2	Up to 25 (1), inclusive	See 3.11.6.1(b)
	B8A Cl. 1A	All diameters	See 3.11.6.1(b)
	B8C Cl. 1 & 1A	All diameters	See 3.11.6.1(b)
	B8C Cl. 2	Up to 25 (1), inclusive	See 3.11.6.1(b)
	B8CA Cl. 1A	All diameters	See 3.11.6.1(b)
	B8F Cl. 1	All diameters	See 3.11.6.1(b)
	B 8FA Cl. 1A	All diameters	See 3.11.6.1(b)
	B8M Cl. 1	All diameters	See 3.11.6.1(b)
	B8M Cl. 2	Up to 38 (1½), inclusive	See 3.11.6.1(b)
	B8MA Cl. 1A	All diameters	See 3.11.6.1(b)
	B8T Cl. 1	All diameters	See 3.11.6.1(b)
	B8T Cl. 2	Up to 38 (1½), inclusive	See 3.11.6.1(b)
	B8TA Cl. 1A	All diameters	See 3.11.6.1(b)
SA-453	651 Cl. A & B	All diameters	Impact test is required
	660 Cl. A & B	All diameters	−196 (−320)
SA-479	XM-19	Up to 8 (203), inclusive	Impact test is required
SA-564	630	Up to 8 (203), inclusive.	Impact test is required
SA-705	630	Up to 8 (203), inclusive.	Impact test is required

Table 3.7
Aluminum Alloy, Copper, and Copper Alloy Bolting Materials for Use With Flanges Designed to 4.16

Material Specification	UNS
SB-98	C65100, C65500, C66100
SB-150	C61400, C62300, C63000, C64200
SB-187	C10200, C11000
SB-211	A92014, A92024, A96061

GENERAL NOTE: The MDMT for all bolting material listed in this Table is −196°C (-320°F).

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Table 3.8
Nickel and Nickel Alloy Bolting Materials for Use With Flanges Designed to 4.16

Material Specification	UNS
SB-160	N02200, N02201
SB-164	N04400 N04405
SB-166	N06600
SB-335	N10001, N10665
SB-408	N08800, N08810
SB-425	N08825
SB-446	N06625
SB-572	N06002, R30556
SB-573	N10003
SB-574	N06022, N06455, N10276
SB-581	N06007, N06030, N06975
SB-621	N08320
SB-637	N07718, N07750

GENERAL NOTE: The MDMT for all bolting material listed in this Table is −196°C (−320°F).

Table 3.9
Bolting Materials for Use With Flanges Designed to Part 5

Material Specification	Material Grade
SA-193	B5, B6, B7, B7M, B8, B8C, B8M, B8MNA, B8NA, B8R, B8RA, B8S, B8SA, B8T, B16
SA-320	L43
SA-437	B4B, B4C
SA-453	651, 660
SA-540	B21, B22, B23, B24, B24V
SA-564	630
SA-705	630
SB-164	N04400, N04405
SB-637	N07718, N07750

GENERAL NOTE: See 3.11.6.2 for impact testing requirements.

Table 3.10
Maximum Severity Levels for Castings With a Thickness of Less Than 50 mm (2 in.)

Imperfection Category	Thickness <25 mm (1 in.)	Thickness 25 mm < 50 mm (1 in. < 2 in.)
A – Gas porosity	1	2
B – Sand and slag	2	3
C – Shrinkage (four types)	1	3
D – Cracks	0	0
E – Hot tears	0	0
F – Inserts	0	0
G – Mottling	0	0

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Table 3.11
Maximum Severity Levels for Castings With a Thickness of 50 mm to 305 mm (2 in. to 12 in.)

Imperfection Category	Thickness 50 mm to 115 mm (2 in. to 4 1/2 in.)	Thickness >115 mm to 305 mm (>4 1/2 in. to 12 in.)
A - Gas porosity	2	2
B – Sand and slag inclusions	2	2
C – Shrinkage – Type 1	1	2
C – Shrinkage – Type 2	2	2
C – Shrinkage – Type 3	3	2
D – Cracks	0	0
E – Hot tears	0	0

Table 3.12
Charpy Impact Test Temperature Reduction Below the Minimum Design Metal Temperature

Actual Material Thickness [See 3.11.7.5(b)] or Charpy Impact Specimen Width Along the Notch		Temperature Reduction	
mm	in.	°C	°F
10 (full-size standard bar)	0.394	0	0
9	0.354	0	0
8	0.315	0	0
7.5 (3/4 size bar)	0.295	3	5
7	0.276	4	8
6.65 (2/3 size bar)	0.262	6	10
6	0.236	8	15
5 (1/2 size bar)	0.197	11	20
4	0.158	17	30
3.33 (1/3 size bar)	0.131	19	35
3	0.118	22	40
2.5 (1/4 size bar)	0.099	28	50

GENERAL NOTES:
(a) Straight line interpolation for intermediate values is permitted.
(b) For carbon and low alloy materials having a specified minimum tensile strength of less than 655 MPa (95 ksi) when the subsize Charpy impact width is less than 80% of the material thickness.

Table 3.13
Charpy V-Notch Impact Test Requirements for Full-Size Specimens for Carbon and Low Alloy Steels as a Function of the Minimum Specified Yield Strength — Welded Parts Not Subject to PWHT (See Figures 3.5 and 3.5M)

Thickness, mm	CVN, (J) Specified Minimum Yield Strength, MPa					Thickness, in.	CVN, (ft-lb) Specified Minimum Yield Strength, ksi				
	205	260	345	450	550		30	38	50	65	80
6	27	27	27	27	27	0.25	20	20	20	20.	20
10	27	27	27	27	31	0.375	20	20	20	20	23
13	27	27	27	27	36	0.5	20	20	20	20	27
16	27	27	27	29	43	0.625	20	20	20	21	32
19	27	27	27	34	51	0.75	20	20	20	25	37
25	27	27	27	45	62	1	20	20	20	33	46
32	27	27	34	53	72	1.25	20	20	25	39	53
38	27	27	40	61	82	1.5	20	20	30	45	60

GENERAL NOTE: The Charpy V-notch values given in this table represent a smooth curve in Figures 3.5 and 3.5M.

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Table 3.14
Charpy V-Notch Impact Test Requirements for Full-Size Specimens for Carbon and Low Alloy Steels as a Function of the Minimum Specified Yield Strength — Welded Parts Subject to PWHT or Nonwelded Parts (See Figures 3.6 and 3.6M)

Thickness, mm	CVN, J — Specified Minimum Specified Yield Strength, MPa					Thickness, in.	CVN, ft-lb — Specified Minimum Specified Yield Strength, ksi				
	205	260	345	450	550		30	38	50	65	80
6	27	27	27	27	27	0.25	20	20	20	20	20
10	27	27	27	27	27	0.375	20	20	20	20	20
13	27	27	27	27	27	0.5	20	20	20	20	20
16	27	27	27	27	27	0.625	20	20	20	20	20
19	27	27	27	27	27	0.75	20	20	20	20	20
25	27	27	27	27	27	1	20	20	20	20	20
32	27	27	27	27	34	1.25	20	20	20	20	25
38	27	27	27	27	40	1.5	20	20	20	20	30
44	27	27	27	31	47	1.75	20	20	20	23	35
51	27	27	27	35	52	2	20	20	20	26	38
57	27	27	27	40	56	2.25	20	20	20	29	41
64	27	27	27	43	60	2.5	20	20	20	32	44
70	27	27	29	46	64	2.75	20	20	21	34	47
76	27	27	31	49	68	3	20	20	23	36	50
83	27	27	33	52	71	3.25	20	20	25	38	52
89	27	27	35	54	74	3.5	20	20	26	40	54
95	27	27	37	56	76	3.75	20	20	27	42	56
102	27	27	38	58	78	4	20	20	28	43	58.
108	27	27	39	59	80	4.25	20	20	29	44	59
114	27	27	40	60	81	4.5	20	20	29	45	60
121	27	27	40	61	82	4.75	20	20	30	45	60
127	27	27	41	61	82	5	20	20	30	45	61
133	27	27	41	61	82	5.25	20	20	30	45	61
140	27	27	41	61	82	5.5	20	20	30	45.	61
146	27	27	41	61	82	5.75	20	20	30	45	61
152	27	27	41	61	82	6	20	20	30	45	61
159	27	27	41	61	82	6.25	20	20	30	45	61
165	27	27	41	61	82	6.5	20	20	30	45	61
171	27	27	41	61	82	6.75	20	20	30	45	61
178	27	27	41	61	82	7	20	20	30	45	61

GENERAL NOTE: The Charpy V-notch values given in this table represent a smooth curve in Figures 3.6 and 3.6M.

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Table 3.15
Impact Test Exemption Curves — Parts Not Subject to PWHT (See Figures 3.9 and 3.9M)

Thickness, mm	Exemption Curve, °C				Thickness, in.	Exemption Curve, °F			
	A	B	C	D		A	B	C	D
0	20.5	−0.6	−21.7	−36.1	0	68.9	30.9	−7.1	−33.1
10	20.5	−0.6	−21.7	−36.1	0.394	68.9	30.9	−7.1	−33.1
13	22.9	1.8	−19.3	−33.7	0.5	73.3	35.3	−2.7	−28.7
16	26.3	5.1	−16.0	−30.4	0.625	79.3	41.3	3.3	−22.7
19	29.6	8.5	−12.6	−27.1	0.75	85.3	47.3	9.3	−16.7
25	35.2	14.1	−7.0	−21.4	1	95.4	57.4	19.4	−6.6
32	39.7	18.6	−2.6	−17.0	1.25	103.4	65.4	27.4	1.4
38	43.4	22.3	1.2	−13.2	1.5	110.2	72.2	34.2	8.2

GENERAL NOTE: The Charpy V-notch values given in this table represent a smooth curve in Figures 3.9 and 3.9M.

Table 3.16
Impact Test Exemption Curves — Parts Subject to PWHT and Nonwelded Parts (See Figures 3.10 and 3.10M)

Thickness, mm	Exemption Curve, °C				Thickness, in.	Exemption Curve, °F			
	A	B	C	D		A	B	C	D
0	0.6	−20.5	−41.6	−48.3	0	33.2	−4.8	−42.8	−55.0
10	0.6	−20.5	−41.6	−48.3	0.394	33.2	−4.8	−42.8	−55.0
13	3.8	−17.3	−38.4	−48.3	0.5	38.9	0.9	−37.1	−55.0
16	7.9	−13.2	−34.3	−48.3	0.625	46.2	8.2	−29.8	−55.0
19	11.7	−9.4	−30.5	−45.0	0.75	53.0	15.0	−23.0	−49.0
25	17.5	−3.6	−24.7	−39.2	1	63.5	25.5	−12.5	−38.5
32	21.7	0.5	−20.6	−35.0	1.25	71.0	33.0	−5.0	−31.0
38	24.9	3.8	−17.3	−31.8	1.5	76.8	38.8	0.8	−25.2
44	27.7	6.6	−14.6	−29.0	1.75	81.8	43.8	5.8	−20.2
51	30.1	9.0	−12.1	−26.5	2	86.2	48.2	10.2	−15.8
57	32.4	11.3	−9.9	−24.3	2.25	90.3	52.3	14.3	−11.7
64	34.4	13.3	−7.8	−22.3	2.5	93.9	55.9	17.9	−8.1
70	36.2	15.1	−6.0	−20.5	2.75	97.2	59.2	21.2	−4.8
76	37.8	16.7	−4.4	−18.9	3	100.0	62.0	24.0	−2.0
83	39.2	18.1	−3.0	−17.5	3.25	102.6	64.6	26.6	0.6
89	40.4	19.3	−1.8	−16.3	3.5	104.7	66.7	28.7	2.7
95	41.4	20.3	−0.8	−15.3	3.75	106.5	68.5	30.5	4.5
102	42.2	21.1	−0.1	−14.5	4	107.9	69.9	31.9	5.9

GENERAL NOTE: The Charpy V-notch values given in this table represent a smooth curve in Figures 3.10 and 3.10M.

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Table 3.17
Reduction in the MDMT, T_R, Without Impact Testing — Parts Not Subject to PWHT (See Figures 3.14 and 3.14M)

Stress or Thickness Ratio	T_R, °C		T_R, °F	
	Specified Minimum Yield Strength, MPa		Specified Minimum Yield Strength, ksi	
	≤345 MPa	>345 MPa ≤450 MPa	≤50 ksi	>50 ksi ≤65 ksi
1.000	0.0	0.0	0.0	0.0
0.940	2.7	2.5	4.9	4.5
0.884	5.2	4.7	9.3	8.4
0.831	7.3	6.6	13.2	11.9
0.781	9.3	8.4	16.7	15.1
0.734	11.1	10.0	20.0	18.1
0.690	12.8	11.5	23.0	20.8
0.648	14.3	13.0	25.8	23.3
0.610	15.8	14.3	28.5	25.7
0.573	17.2	15.5	31.0	27.9
0.539	18.5	16.7	33.3	30.0
0.506	19.7	17.7	35.5	31.9
0.476	20.9	18.8	37.6	33.8
0.447	22.0	19.7	39.6	35.5
0.421	23.1	20.6	41.5	37.1
0.395	24.0	21.5	43.3	38.7
0.372	25.0	22.3	45.0	40.1
0.349	25.9	23.1	46.6	41.5
0.328	26.7	23.8	48.1	42.8
0.309	27.5	24.5	49.6	44.0
0.2908	28.3	25.1	50.9	45.2
0.273	29.0	25.7	52.2	46.3
0.256	29.7	26.3	53.5	47.3
0.241	30.4	26.8	54.6	48.3

GENERAL NOTE: The temperature reduction values given in this table represent a smooth curve in Figures 3.14 and 3.14M.

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Table 3.18
Reduction in the MDMT, T_R, Without Impact Testing — Parts Subject to PWHT and Nonwelded Parts
(See Figures 3.15 and 3.15M)

Stress or Thickness Ratio	T_R, °C		T_R, °F	
	Specified Minimum Yield Strength, MPa		Specified Minimum Yield Strength, ksi	
	≤345 MPa	>345 MPa ≤450 MPa	≤50 ksi	>50 ksi ≤65 ksi
1.000	0.0	0.0	0.0	0.0
0.940	3.0	2.6	5.4	4.6
0.884	5.9	5.0	10.6	8.9
0.831	8.7	7.3	15.6	13.1
0.781	11.5	9.5	20.7	17.2
0.734	14.3	11.7	25.8	21.1
0.690	17.3	13.9	31.1	25.0
0.648	20.3	16.1	36.5	29.0
0.610	23.5	18.3	42.2	32.9
0.573	26.9	20.5	48.4	36.8
0.539	30.6	22.7	55.0	40.9
0.506	34.7	25.0	62.5	45.0
0.476	39.5	27.3	71.1	49.2
0.447	45.3	29.8	81.6	53.6
0.421	52.9	32.3	95.2	58.1
0.395	...	35.0	...	62.9
0.372	...	37.8	...	68.1
0.349	...	40.9	...	73.6
0.328	...	44.3	...	79.7
0.309	...	48.0	...	86.4
0.290	...	52.3	...	94.2
0.273	...	...	...	...
0.256	...	...	...	...
0.241	...	...	...	...

GENERAL NOTE: The temperature reduction values given in this table represent a smooth curve in Figures 3.15 and 3.15M.

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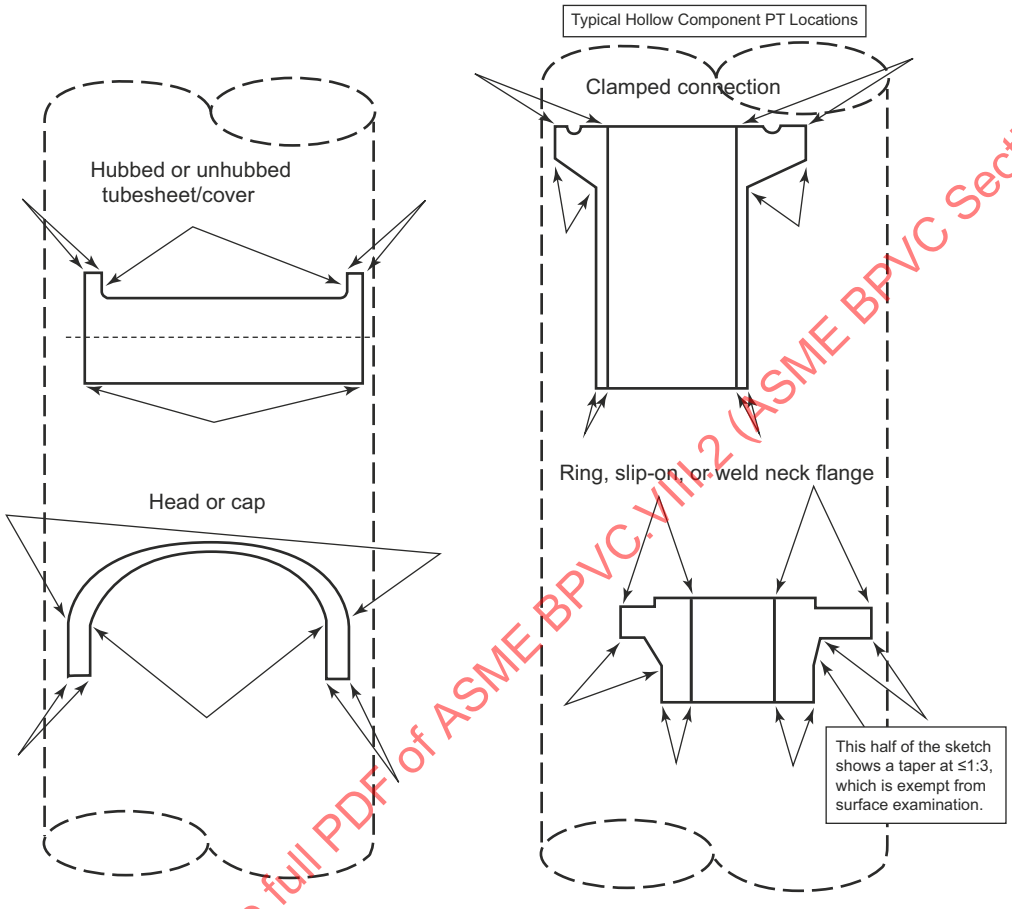
3.20 FIGURES

(25)

Figure 3.1
Typical Component Surface Examination Locations and Machined Features Requiring Axial Ultrasonic Examination



GENERAL NOTES:
(a) The areas between the arrows shall be surface examined.
(b) The features delineated between the arrows also indicate examples of parts for which axial ultrasonic examination would be required, when practicable, in the machined part or in the bar prior to machining.

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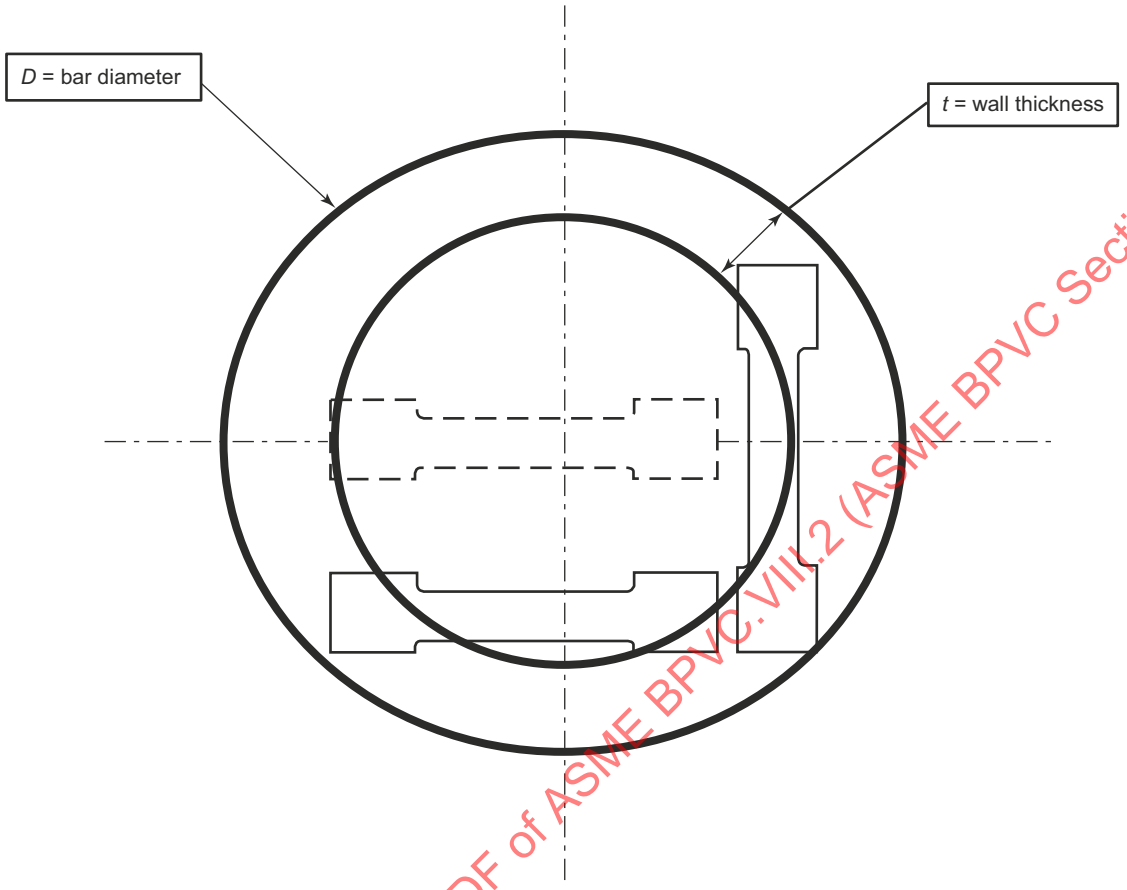
Figure 3.2
Transverse Tension Test Specimen Locations and Orientations



GENERAL NOTES:
(a) The thick solid outlines are illustrative of a finished part geometry.
(b) The thin solid specimens are the two mandatory locations.
(c) The thin dashed specimen is the third specimen when the centerline material remains in the finished part.

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Figure 3.3
Cr–Mo Heat Treatment Criteria

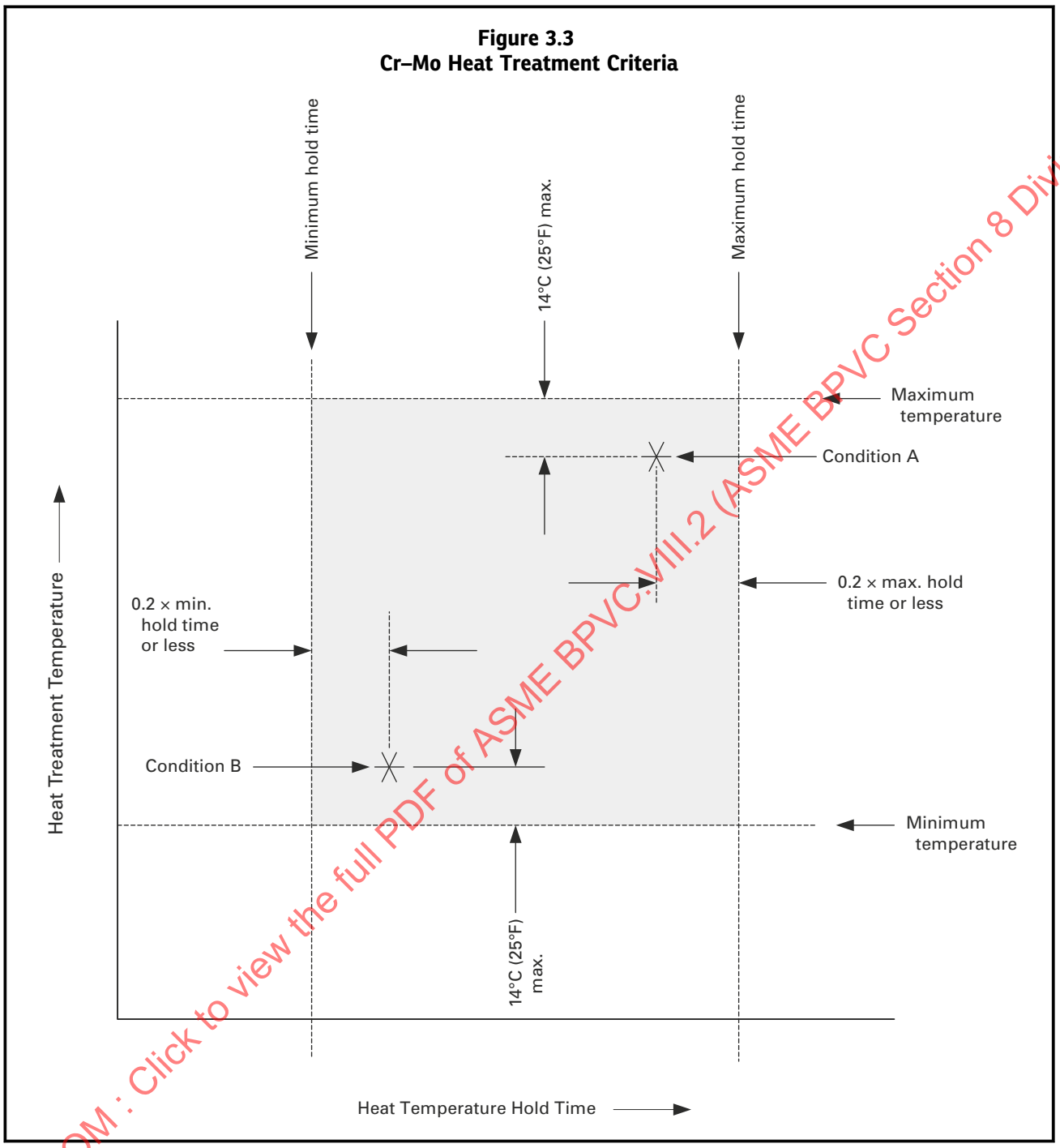

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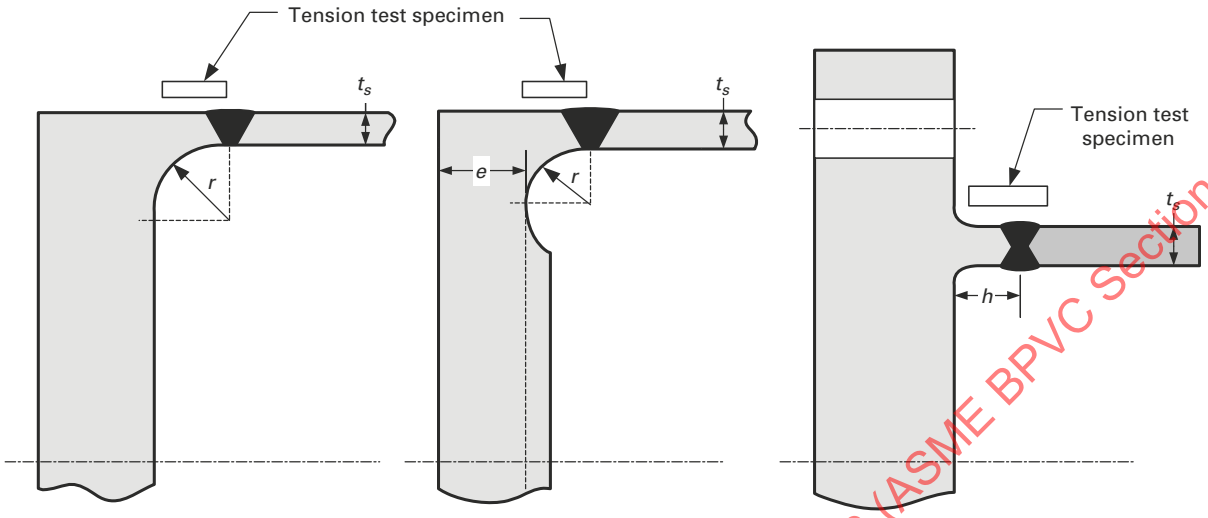
Figure 3.4
Typical Locations for Tensile Specimens



GENERAL NOTE: These details are not permissible if machined from plate unless the requirements of 3.9 are satisfied.

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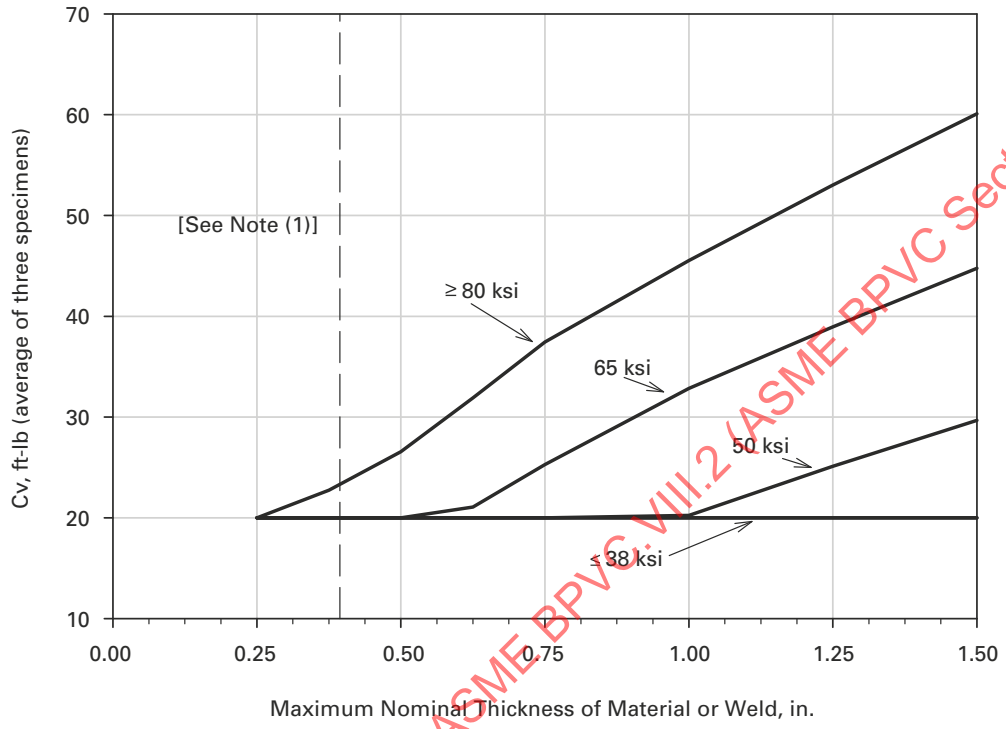
Figure 3.5
Charpy V-Notch Impact Test Requirements for Full-Size Specimens for Carbon and Low Alloy Steels as a Function of the Minimum Specified Yield Strength — Welded Parts Not Subject to PWHT



GENERAL NOTES:
(a) Interpolation between yield strength values is permitted.
(b) The minimum impact energy for one specimen shall not be less than two-thirds of the average impact energy required for three specimens.
(c) Materials produced and impact tested in accordance with SA-320, SA-333, SA-334, SA-350, SA-352, SA-420, SA-437, SA-508 Grade 5 Class 2, SA-540 (except for materials produced under Table 2, Note 4 in the specification), SA-723, and SA-765 do not have to satisfy these energy values. Materials produced to these specifications are acceptable for use at a minimum design metal temperature not colder than the test temperature when the energy values required by the applicable specification are satisfied.
(d) If the material specified minimum tensile strength is greater than or equal to 655 MPa (95 ksi), then the material toughness requirements shall be in accordance with 3.11.2.1(b)(2).
(e) Data of Figures 3.5 and 3.5M are shown in Table 3.13.

NOTE:
(1) See 3.11.2.1(b)(1) for Charpy V-notch specimen thicknesses less than 10 mm (0.394 in.).

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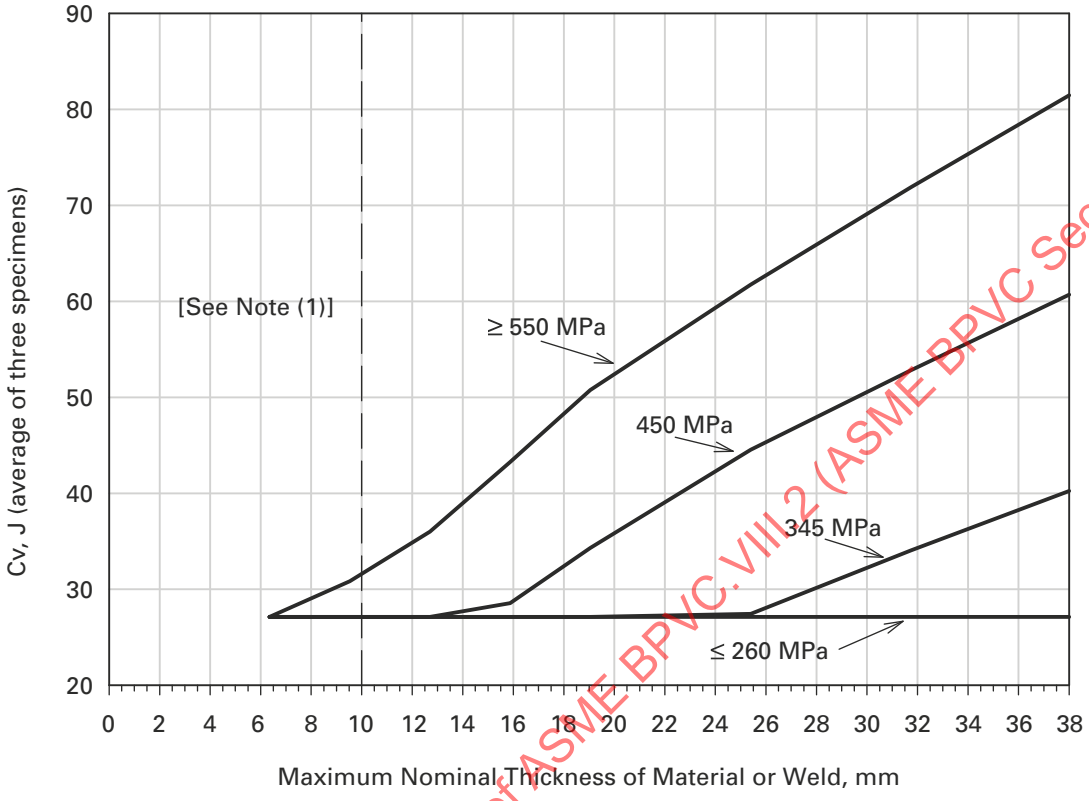
Figure 3.5M
Charpy V-Notch Impact Test Requirements for Full-Size Specimens for Carbon and Low Alloy Steels as a Function of the Minimum Specified Yield Strength — Welded Parts Not Subject to PWHT



GENERAL NOTES:
(a) Interpolation between yield strength values is permitted.
(b) The minimum impact energy for one specimen shall not be less than two-thirds of the average impact energy required for three specimens.
(c) Materials produced and impact tested in accordance with SA-320, SA-333, SA-334, SA-350, SA-352, SA-420, SA-437, SA-508 Grade 5 Class 2, SA-540 (except for materials produced under Table 2, Note 4 in the specification), SA-723, and SA-765 do not have to satisfy these energy values. Materials produced to these specifications are acceptable for use at a minimum design metal temperature not colder than the test temperature when the energy values required by the applicable specification are satisfied.
(d) If the material specified minimum tensile strength is greater than or equal to 655 MPa (95 ksi), then the material toughness requirements shall be in accordance with 3.11.2.1(b)(2).
(e) Data of Figures 3.5 and 3.5M are shown in Table 3.13.

NOTE:
(1) See 3.11.2.1(b)(1) for Charpy V-notch specimen thicknesses less than 10 mm (0.394 in.).

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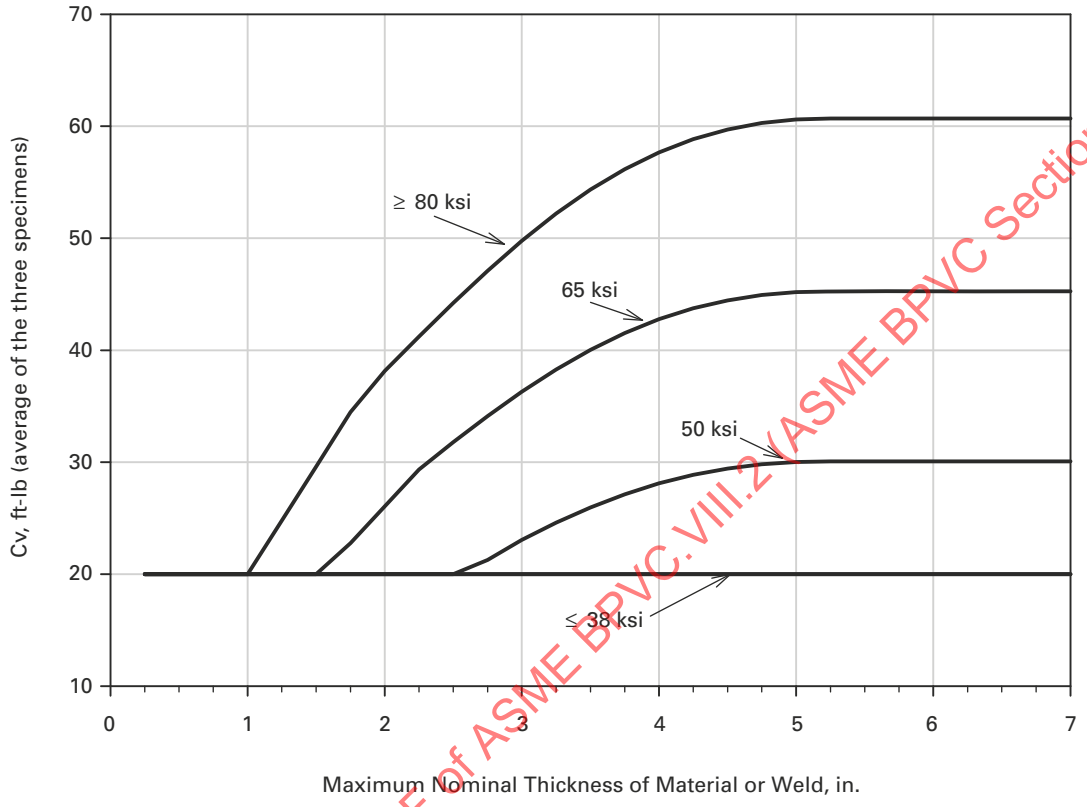
Figure 3.6
Charpy V-Notch Impact Test Requirements for Full-Size Specimens for Carbon and Low Alloy Steels as a Function of the Minimum Specified Yield Strength — Welded Parts Subject to PWHT or Nonwelded Parts



GENERAL NOTES:
(a) Interpolation between yield strength values is permitted.
(b) The minimum impact energy for one specimen shall not be less than two-thirds of the average impact energy required for three specimens.
(c) Materials produced and impact tested in accordance with SA-320, SA-333, SA-334, SA-350, SA-352, SA-420, SA-437, SA-508 Grade 5 Class 2, SA-540 (except for materials produced under Table 2, Note 4 in the specification), SA-723, and SA-765 do not have to satisfy these energy values. Materials produced to these specifications are acceptable for use at a minimum design metal temperature not colder than the test temperature when the energy values required by the applicable specification are satisfied.
(d) If the material specified minimum tensile strength is greater than or equal to 655 MPa (95 ksi), then the material toughness requirements shall be in accordance with 3.11.2.1(b)(2).
(e) Data of Figures 3.6 and 3.6M are shown in Table 3.14.
(f) See 3.11.2.1(b)(4) for Charpy V-notch specimen thicknesses less than 10 mm (0.394 in.).

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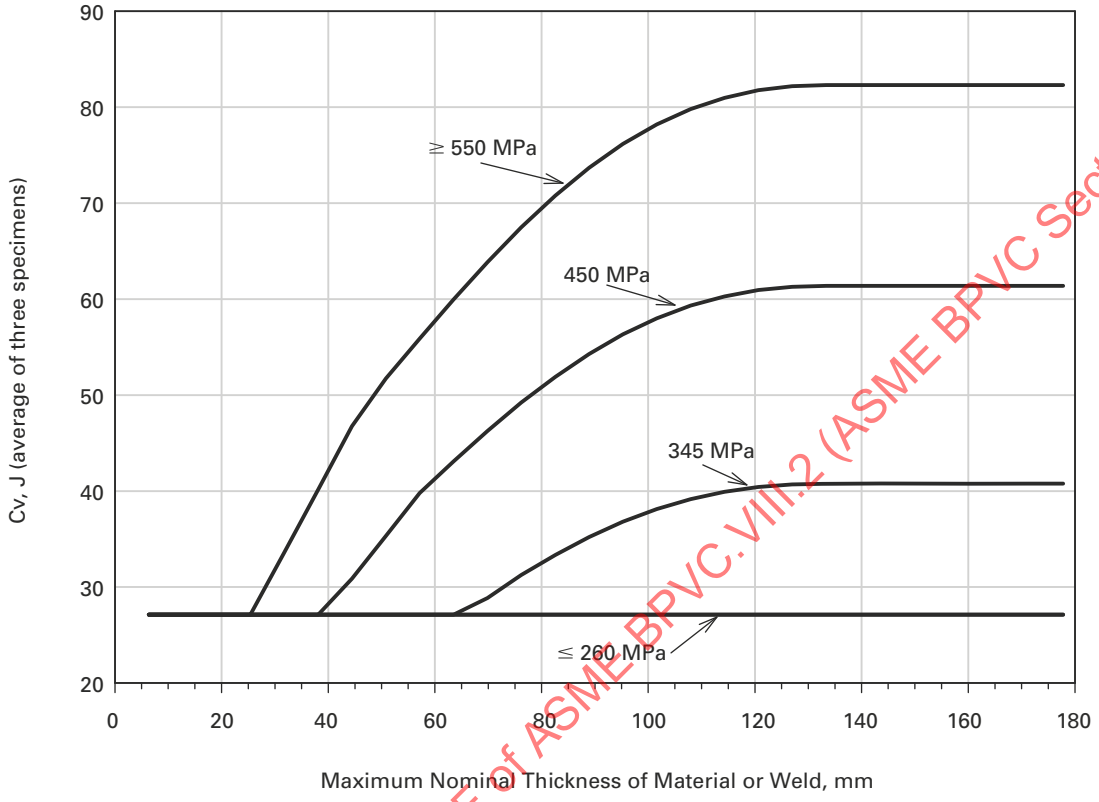
Figure 3.6M
Charpy V-Notch Impact Test Requirements for Full-Size Specimens for Carbon and Low Alloy Steels as a Function of the Minimum Specified Yield Strength — Welded Parts Subject to PWHT or Nonwelded Parts



GENERAL NOTES:
(a) Interpolation between yield strength values is permitted.
(b) The minimum impact energy for one specimen shall not be less than two-thirds of the average impact energy required for three specimens.
(c) Materials produced and impact tested in accordance with SA-320, SA-333, SA-334, SA-350, SA-352, SA-420, SA-437, SA-508 Grade 5 Class 2, SA-540 (except for materials produced under Table 2, Note 4 in the specification), SA-723, and SA-765 do not have to satisfy these energy values. Materials produced to these specifications are acceptable for use at a minimum design metal temperature not colder than the test temperature when the energy values required by the applicable specification are satisfied.
(d) If the material specified minimum tensile strength is greater than or equal to 655 MPa (95 ksi), then the material toughness requirements shall be in accordance with 3.11.2.1(b)(2).
(e) Data of Figures 3.6 and 3.6M are shown in Table 3.14.
(f) See 3.11.2.1(b)(1) for Charpy V-notch specimen thicknesses less than 10 mm (0.394 in.).

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Figure 3.7
Illustration of Lateral Expansion in a Broken Charpy V-Notch Specimen

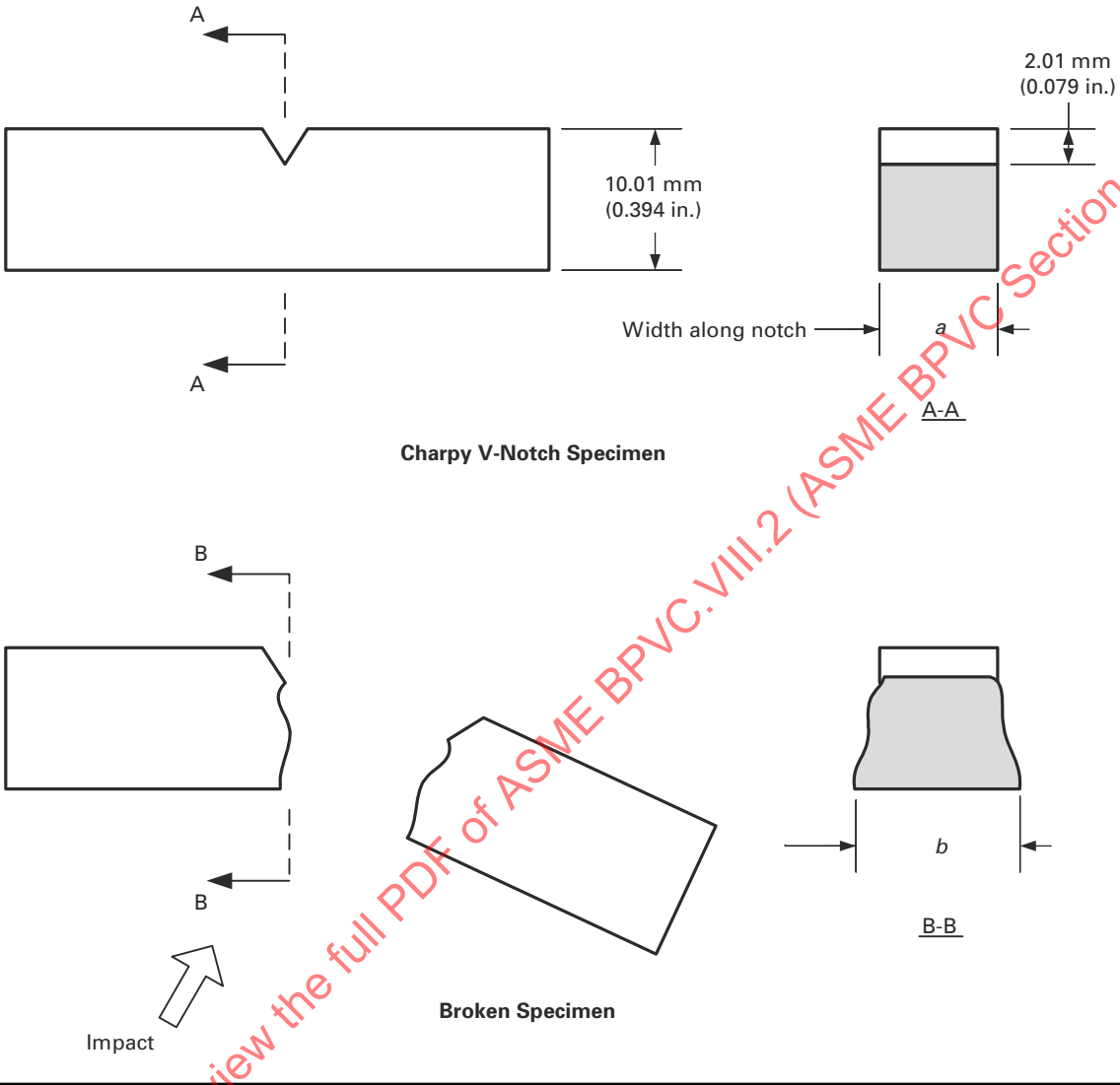

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Figure 3.8
Lateral Expansion Requirements

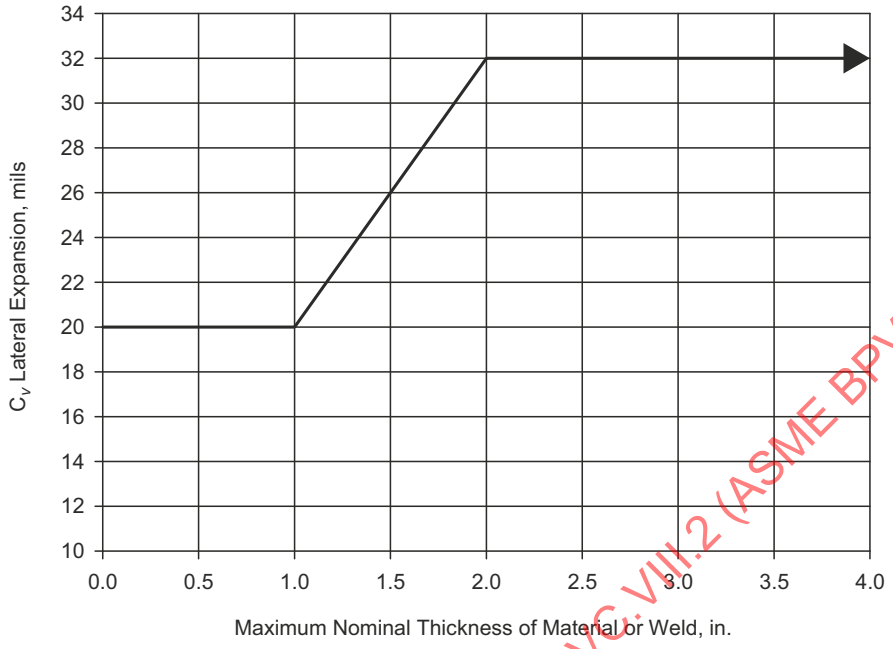

Figure 3.8M
Lateral Expansion Requirements

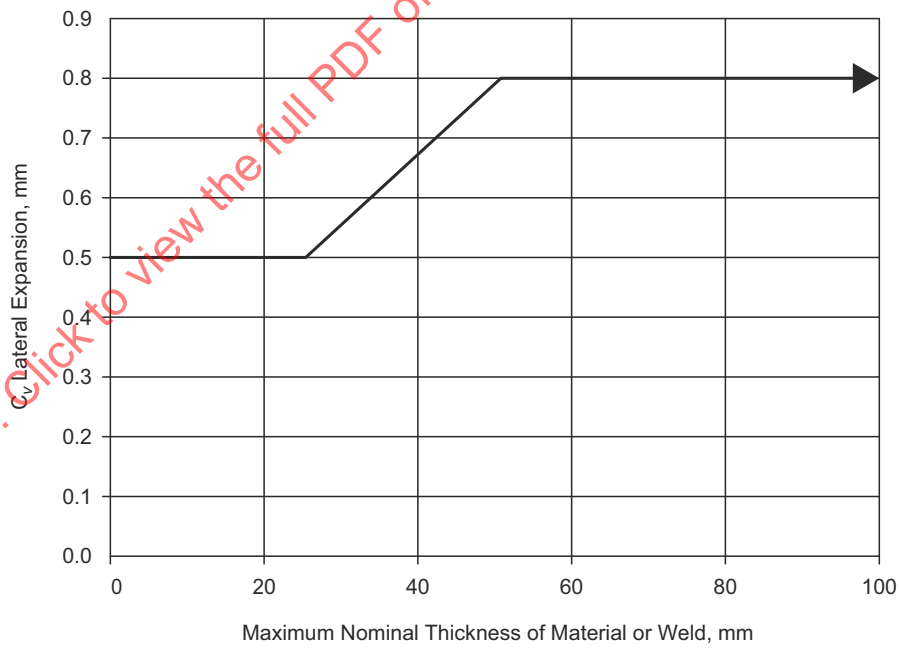

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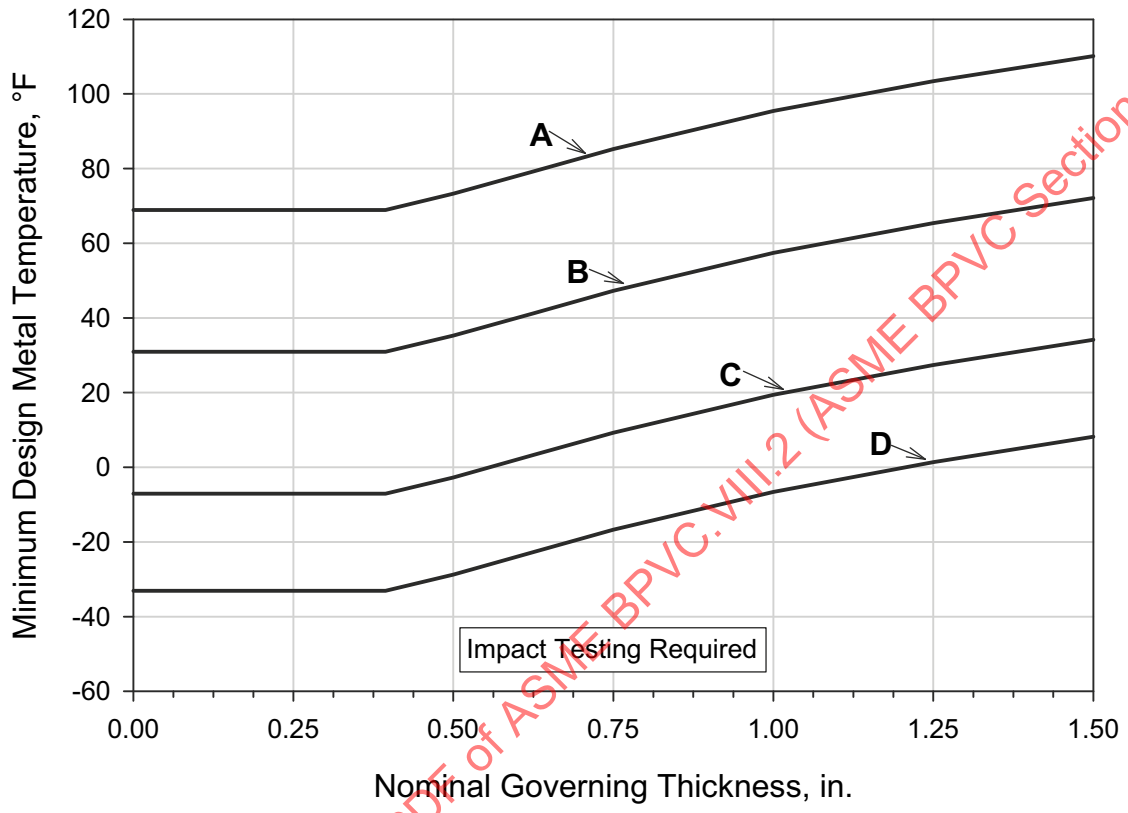
Figure 3.9
Impact Test Exemption Curves — Welded Parts Not Subject to PWHT



Curve	Material Assignment
A	*(a)* All carbon and all low alloy steel plates, structural shapes, and bars not listed in Curves B, C, and D below *(b)* SA-216 Grades WCB and WCC if normalized and tempered or water-quenched and tempered; SA -217 Grade WC6 if normalized and tempered or water-quenched and tempered *(c)* A/SA-105 forged flanges supplied in the as-forged condition
B	*(a)* SA-216 Grades WCA if normalized and tempered or water-quenched and tempered; Grades WCB and WCC for thicknesses not exceeding 50 mm (2 in.) if produced to a fine grain practice and water-quenched and tempered *(b)* SA-217 Grade WC9 if normalized and tempered *(c)* SA-285 Grades A and B *(d)* SA-299 *(e)* SA-414 Grade A *(f)* SA-515 Grades 60 *(g)* SA-516 Grades 65 and 70 if not normalized *(h)* SA-662 Grade B if not normalized *(i)* SA/EN 10028-2 Grade P355GH as-rolled *(j)* Except for cast steels, all materials of Curve A if produced to fine grain practice and normalized which are not listed for Curve C and D below *(k)* Pipe; fittings; forgings; A/SA-105 forged flanges that are produced to fine grain practice and normalized, normalized and tempered, or quenched and tempered after forging; and tubing not listed for Curves C and D below *(l)* Parts permitted from 3.2.8 shall be included in Curve B even when fabricated from plate that otherwise would be assigned to a different curve.
C	*(a)* SA-182 Grades F21 and F22 if normalized and tempered *(b)* SA-302 Grades C and D *(c)* SA-336 Grades F21 and F22 if normalized and tempered, or liquid quenched and tempered *(d)* SA-387 Grades 21 and 22 if normalized and tempered, or liquid quenched and tempered

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Figure 3.9
Impact Test Exemption Curves — Welded Parts Not Subject to PWHT (Cont'd)

Curve	Material Assignment
	(e) SA-516 Grades 55 and 60 if not normalized *(f)* SA-533 Types B and C, Class 1 *(g)* SA-662 Grade A *(h)* SA/EN 10028-2 Grade 10CrMo9–10 if normalized and tempered *(i)* All materials listed in (a) through (i) and in (k) for Curve B if produced to fine grain practice and normalized, normalized and tempered, or liquid quenched and tempered as permitted in the material specification, and not listed for Curve D below
D	*(a)* SA-203 *(b)* SA-299 if normalized *(c)* SA-508 Class 1 *(d)* SA-516 if normalized *(e)* SA-524 Classes 1 and 2 *(f)* SA-537 Classes 1, 2, and 3 *(g)* SA-612 if normalized; except that the increased Cb limit in the footnote of Table 1 of SA-20 is not permitted *(h)* SA-662 if normalized *(i)* SA-738 Grade A *(j)* SA-738 Grade A with Cb and V deliberately added in accordance with the provisions of the material specification, not colder than −29°C (−20°F) *(k)* SA-738 Grade B not colder than −29°C (−20°F) *(l)* SA/EN 10028-2 Grade P355GH if normalized [See General Note (d)(3)]

GENERAL NOTES:
(a) Castings not listed as Curve A and B shall be impact tested.
(b) For bolting see 3.11.6.
(c) When a class or grade is not shown in a material assignment, all classes and grades are indicated.
(d) The following apply to all material assignments:
(1) Cooling rates faster than those obtained in air, followed by tempering, as permitted by the material specification, are considered equivalent to normalizing and tempering heat treatments.
(2) Fine grain practice is defined as the procedures necessary to obtain a fine austenitic grain size as described in SA-20.
(3) Normalized rolling condition is not considered as being equivalent to normalizing.
(e) Data of Figures 3.9 and 3.9M are shown in Table 3.15.

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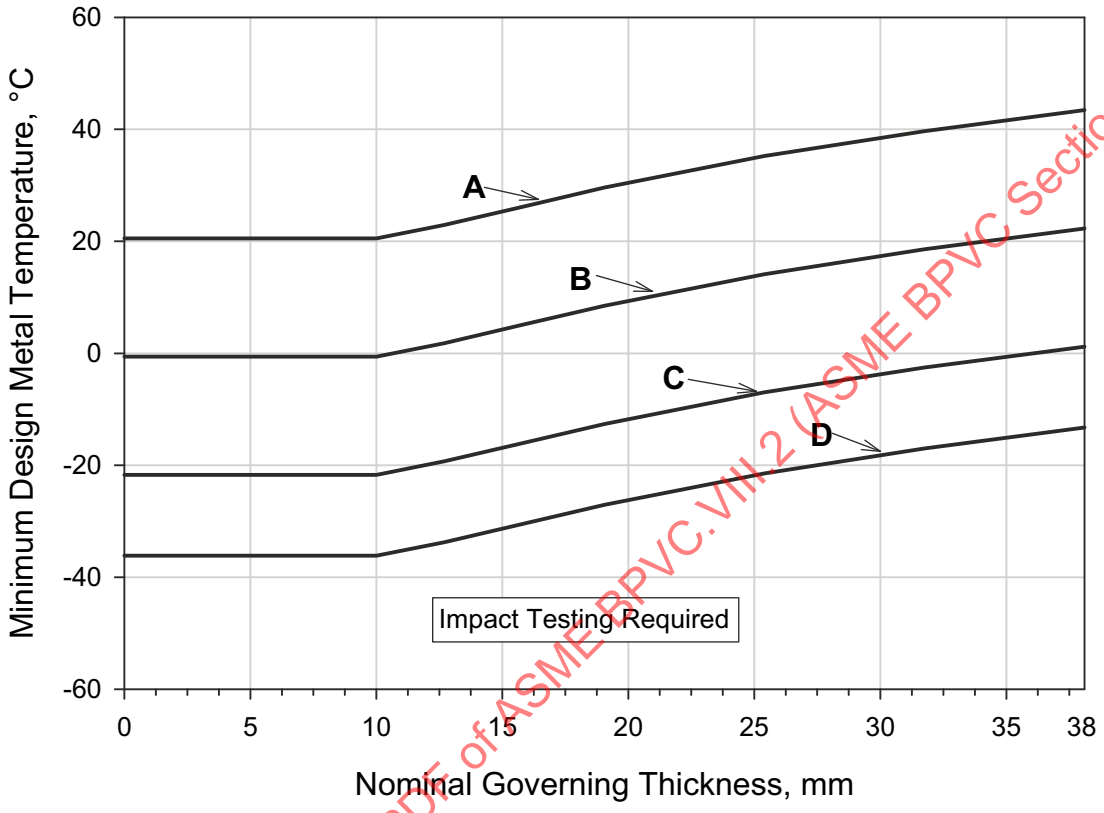
Figure 3.9M
Impact Test Exemption Curves — Welded Parts Not Subject to PWHT



Curve	Material Assignment
A	*(a)* All carbon and all low alloy steel plates, structural shapes, and bars not listed in Curves B, C, and D below *(b)* SA-216 Grades WCB and WCC if normalized and tempered or water-quenched and tempered; SA -217 Grade WC6 if normalized and tempered or water-quenched and tempered *(c)* A/SA-105 forged flanges supplied in the as-forged condition
B	*(a)* SA-216 Grades WCA if normalized and tempered or water-quenched and tempered; Grades WCB and WCC for thicknesses not exceeding 50 mm (2 in.) if produced to a fine grain practice and water-quenched and tempered *(b)* SA-217 Grade WC9 if normalized and tempered *(c)* SA-285 Grades A and B *(d)* SA-299 *(e)* SA-414 Grade A *(f)* SA-515 Grades 60 *(g)* SA-516 Grades 65 and 70 if not normalized *(h)* SA-662 Grade B if not normalized *(i)* SA/EN 10028-2 Grade P355GH as-rolled *(j)* Except for cast steels, all materials of Curve A if produced to fine grain practice and normalized which are not listed for Curve C and D below *(k)* Pipe; fittings; forgings; A/SA-105 forged flanges that are produced to fine grain practice and normalized, normalized and tempered, or quenched and tempered after forging; and tubing not listed for Curves C and D below *(l)* Parts permitted from 3.2.8 shall be included in Curve B even when fabricated from plate that otherwise would be assigned to a different curve.
C	*(a)* SA-182 Grades F21 and F22 if normalized and tempered *(b)* SA-302 Grades C and D *(c)* SA-336 Grades F21 and F22 if normalized and tempered, or liquid quenched and tempered

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Figure 3.9M
Impact Test Exemption Curves — Welded Parts Not Subject to PWHT (Cont'd)

Curve	Material Assignment
	(d) SA-387 Grades 21 and 22 if normalized and tempered, or liquid quenched and tempered
	(e) SA-516 Grades 55 and 60 if not normalized
	(f) SA-533 Types B and C, Class 1
	(g) SA-662 Grade A
	(h) SA/EN 10028-2 Grade 10CrMo9–10 if normalized and tempered
	(i) All materials listed in (a) through (i) and in (k) for Curve B if produced to fine grain practice and normalized, normalized and tempered, or liquid quenched and tempered as permitted in the material specification, and not listed for Curve D below
D	*(a)* SA-203
	(b) SA-299
	(c) SA-508 Class 1
	(d) SA-516 if normalized
	(e) SA-524 Classes 1 and 2
	(f) SA-537 Classes 1, 2, and 3
	(g) SA-612 if normalized; except that the increased Cb limit in the footnote of Table 1 of SA-20 is not permitted
	(h) SA-662 if normalized
	(i) SA-738 Grade A
	(j) SA-738 Grade A with Cb and V deliberately added in accordance with the provisions of the material specification, not colder than −29°C (−20°F)
	(k) SA-738 Grade B not colder than −29°C (−20°F)
	(l) SA/EN 10028-2 Grade P355GH if normalized [See General Note (d)(3)]

GENERAL NOTES:
(a) Castings not listed as Curve A and B shall be impact tested.
(b) For bolting see 3.11.6.
(c) When a class or grade is not shown in a material assignment, all classes and grades are indicated.
(d) The following apply to all material assignments:
(1) Cooling rates faster than those obtained in air, followed by tempering, as permitted by the material specification, are considered equivalent to normalizing and tempering heat treatments.
(2) Fine grain practice is defined as the procedures necessary to obtain a fine austenitic grain size as described in SA-20.
(3) Normalized rolling condition is not considered as being equivalent to normalizing.
(e) Data of Figures 3.9 and 3.9M are shown in Table 3.15.

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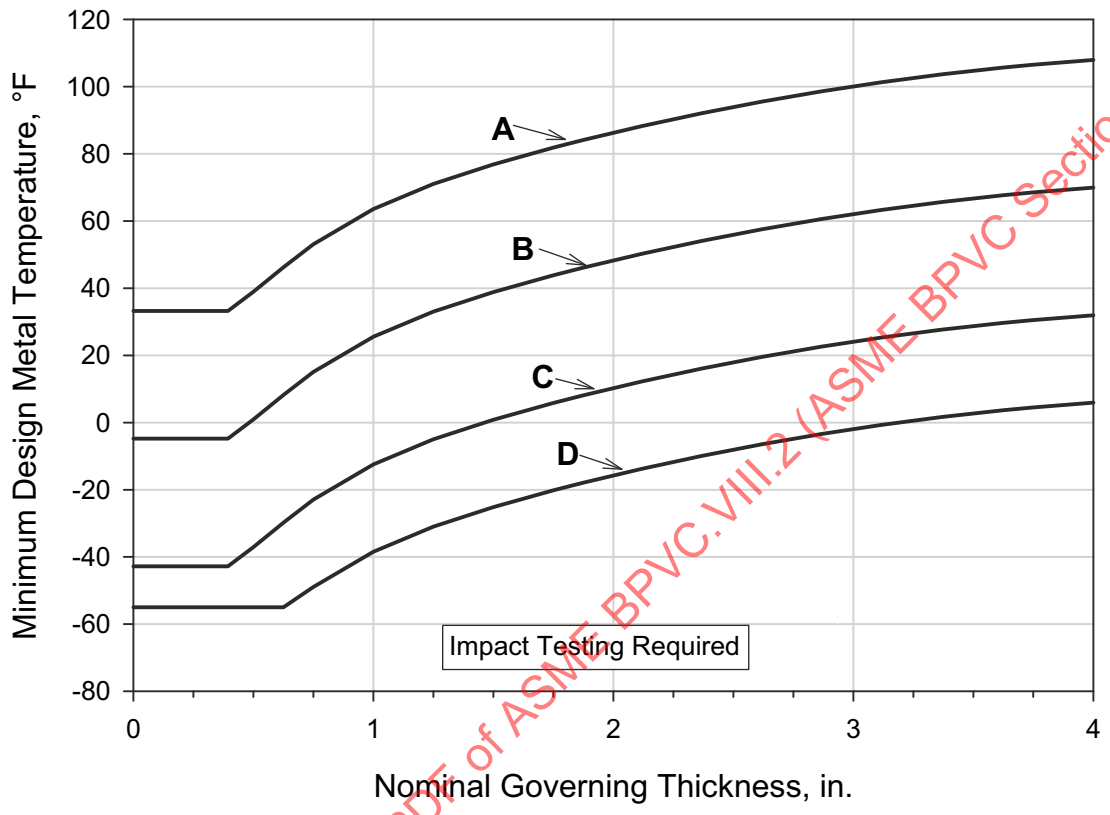
Figure 3.10
Impact Test Exemption Curves — Welded Parts Subject to PWHT and Nonwelded Parts



Curve	Material Assignment
A	*(a)* All carbon and all low alloy steel plates, structural shapes, and bars not listed in Curves B, C, and D below *(b)* SA-216 Grades WCB and WCC if normalized and tempered or water-quenched and tempered; SA -217 Grade WC6 if normalized and tempered or water-quenched and tempered *(c)* A/SA-105 forged flanges supplied in the as-forged condition
B	*(a)* SA-216 Grades WCA if normalized and tempered or water-quenched and tempered; Grades WCB and WCC for thicknesses not exceeding 50 mm (2 in.) if produced to a fine grain practice and water-quenched and tempered *(b)* SA-217 Grade WC9 if normalized and tempered *(c)* SA-285 Grades A and B *(d)* SA-299 *(e)* SA-414 Grade A *(f)* SA-515 Grades 60 *(g)* SA-516 Grades 65 and 70 if not normalized *(h)* SA-662 Grade B if not normalized *(i)* SA/EN 10028-2 Grade P355GH as-rolled *(j)* Except for cast steels, all materials of Curve A if produced to fine grain practice and normalized which are not listed for Curve C and D below *(k)* Pipe; fittings; forgings; A/SA-105 forged flanges that are produced to fine grain practice and normalized, normalized and tempered, or quenched and tempered after forging; and tubing not listed for Curves C and D below *(l)* Parts permitted from 3.2.8 shall be included in Curve B even when fabricated from plate that otherwise would be assigned to a different curve.
C	*(a)* SA-182 Grades F21 and F22 if normalized and tempered *(b)* SA-302 Grades C and D *(c)* SA-336 Grades F21 and F22 if normalized and tempered, or liquid quenched and tempered

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Figure 3.10
Impact Test Exemption Curves — Welded Parts Subject to PWHT and Nonwelded Parts (Cont'd)

Curve	Material Assignment
	(d) SA-387 Grades 21 and 22 if normalized and tempered, or liquid quenched and tempered
	(e) SA-516 Grades 55 and 60 if not normalized
	(f) SA-533 Types B and C, Class 1
	(g) SA-662 Grade A
	(h) SA/EN 10028-2 Grade 10CrMo9–10 if normalized and tempered
	(i) All materials listed in (a) through (i) and in (k) for Curve B if produced to fine grain practice and normalized, normalized and tempered, or liquid quenched and tempered as permitted in the material specification, and not listed for Curve D below
D	*(a)* SA-203
	(b) SA-299 if normalized
	(c) SA-508 Class 1
	(d) SA-516 if normalized
	(e) SA-524 Classes 1 and 2
	(f) SA-537 Classes 1, 2, and 3
	(g) SA-612 if normalized; except that the increased Cb limit in the footnote of Table 1 of SA-20 is not permitted
	(h) SA-662 if normalized
	(i) SA-738 Grade A
	(j) SA-738 Grade A with Cb and V deliberately added in accordance with the provisions of the material specification, not colder than −29°C (−20°F)
	(k) SA-738 Grade B not colder than −29°C (−20°F)
	(l) SA/EN 10028-2 Grade P355GH if normalized [See General Note (d)(3)]

GENERAL NOTES:
(a) Castings not listed as Curve A and B shall be impact tested.
(b) For bolting see 3.11.6.
(c) When a class or grade is not shown in a material assignment, all classes and grades are indicated.
(d) The following apply to all material assignments:
(1) Cooling rates faster than those obtained in air, followed by tempering, as permitted by the material specification, are considered equivalent to normalizing and tempering heat treatments.
(2) Fine grain practice is defined as the procedures necessary to obtain a fine austenitic grain size as described in SA-20.
(3) Normalized rolling condition is not considered as being equivalent to normalizing.
(e) Data of Figures 3.10 and 3.10M are shown in Table 3.16.

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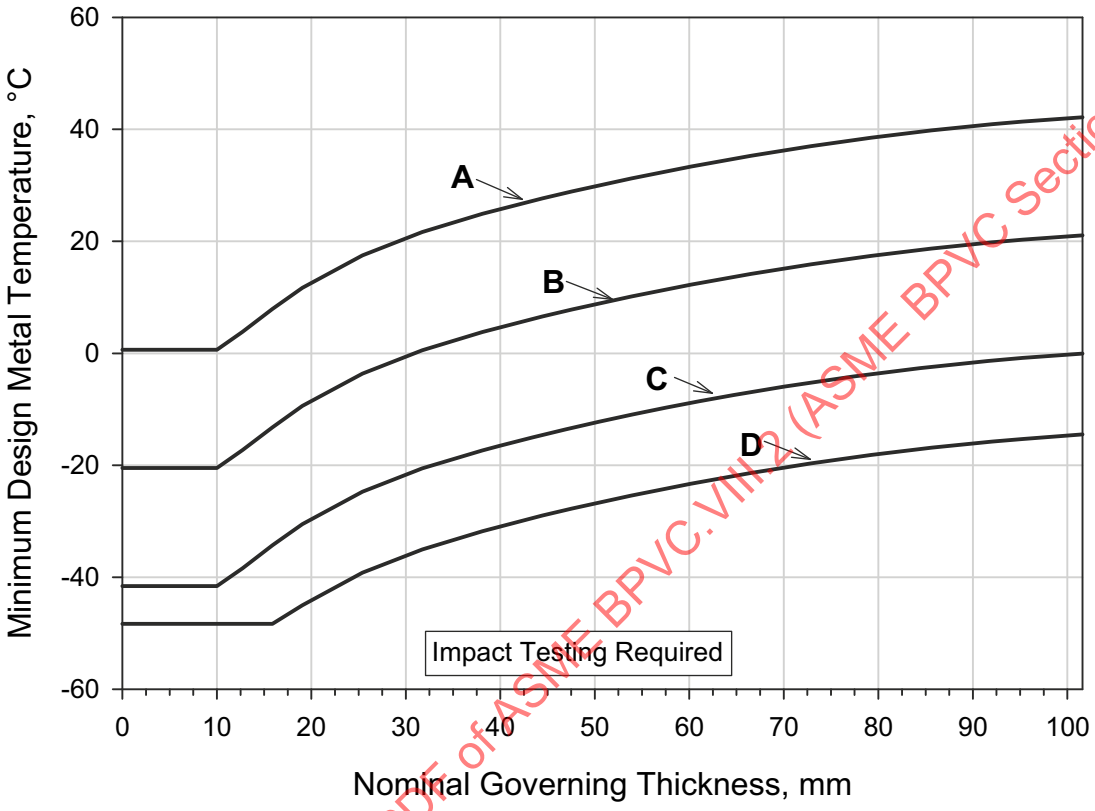
Figure 3.10M
Impact Test Exemption Curves — Welded Parts Subject to PWHT and Nonwelded Parts



Curve	Material Assignment
A	*(a)* All carbon and all low alloy steel plates, structural shapes, and bars not listed in Curves B, C, and D below *(b)* SA-216 Grades WCB and WCC if normalized and tempered or water-quenched and tempered; SA -217 Grade WC6 if normalized and tempered or water-quenched and tempered *(c)* A/SA-105 forged flanges supplied in the as-forged condition
B	*(a)* SA-216 Grades WCA if normalized and tempered or water-quenched and tempered; Grades WCB and WCC for thicknesses not exceeding 50 mm (2 in.) if produced to a fine grain practice and water-quenched and tempered *(b)* SA-217 Grade WC9 if normalized and tempered *(c)* SA-285 Grades A and B *(d)* SA-299 *(e)* SA-414 Grade A *(f)* SA-515 Grades 60 *(g)* SA-516 Grades 65 and 70 if not normalized *(h)* SA-662 Grade B if not normalized *(i)* SA/EN 10028-2 Grade P355GH as-rolled *(j)* Except for cast steels, all materials of Curve A if produced to fine grain practice and normalized which are not listed for Curve C and D below *(k)* Pipe; fittings; forgings; A/SA-105 forged flanges that are produced to fine grain practice and normalized, normalized and tempered, or quenched and tempered after forging; and tubing not listed for Curves C and D below *(l)* Parts permitted from 3.2.8 shall be included in Curve B even when fabricated from plate that otherwise would be assigned to a different curve.
C	*(a)* SA-182 Grades F21 and F22 if normalized and tempered *(b)* SA-302 Grades C and D *(c)* SA-336 Grades F21 and F22 if normalized and tempered, or liquid quenched and tempered

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Figure 3.10M
Impact Test Exemption Curves — Welded Parts Subject to PWHT and Nonwelded Parts (Cont'd)

Curve	Material Assignment
	(d) SA-387 Grades 21 and 22 if normalized and tempered, or liquid quenched and tempered
	(e) SA-516 Grades 55 and 60 if not normalized
	(f) SA-533 Types B and C, Class 1
	(g) SA-662 Grade A
	(h) SA/EN 10028-2 Grade 10CrMo9–10 if normalized and tempered
	(i) All materials listed in (a) through (i) and in (k) for Curve B if produced to fine grain practice and normalized, normalized and tempered, or liquid quenched and tempered as permitted in the material specification, and not listed for Curve D below
D	*(a)* SA-203
	(b) SA-299 if normalized
	(c) SA-508 Class 1
	(d) SA-516 if normalized
	(e) SA-524 Classes 1 and 2
	(f) SA-537 Classes 1, 2, and 3
	(g) SA-612 if normalized; except that the increased Cb limit in the footnote of Table 1 of SA-20 is not permitted
	(h) SA-662 if normalized
	(i) SA-738 Grade A
	(j) SA-738 Grade A with Cb and V deliberately added in accordance with the provisions of the material specification, not colder than −29°C (−20°F)
	(k) SA-738 Grade B not colder than −29°C (−20°F)
	(l) SA/EN 10028-2 Grade P355GH if normalized [See General Note (d)(3)]

GENERAL NOTES:
(a) Castings not listed as Curve A and B shall be impact tested.
(b) For bolting see 3.11.6.
(c) When a class or grade is not shown in a material assignment, all classes and grades are indicated.
(d) The following apply to all material assignments:
(1) Cooling rates faster than those obtained in air, followed by tempering, as permitted by the material specification, are considered equivalent to normalizing and tempering heat treatments.
(2) Fine grain practice is defined as the procedures necessary to obtain a fine austenitic grain size as described in SA-20.
(3) Normalized rolling condition is not considered as being equivalent to normalizing.
(e) Data of Figures 3.10 and 3.10M are shown in Table 3.16.

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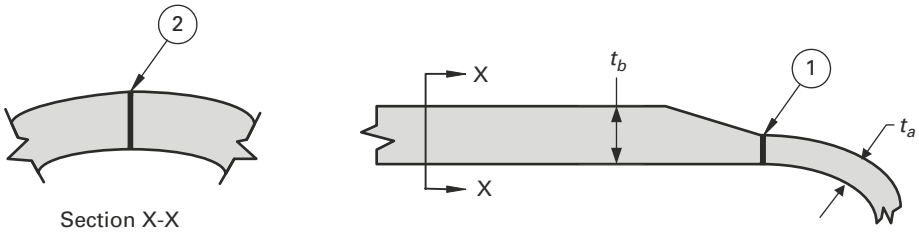
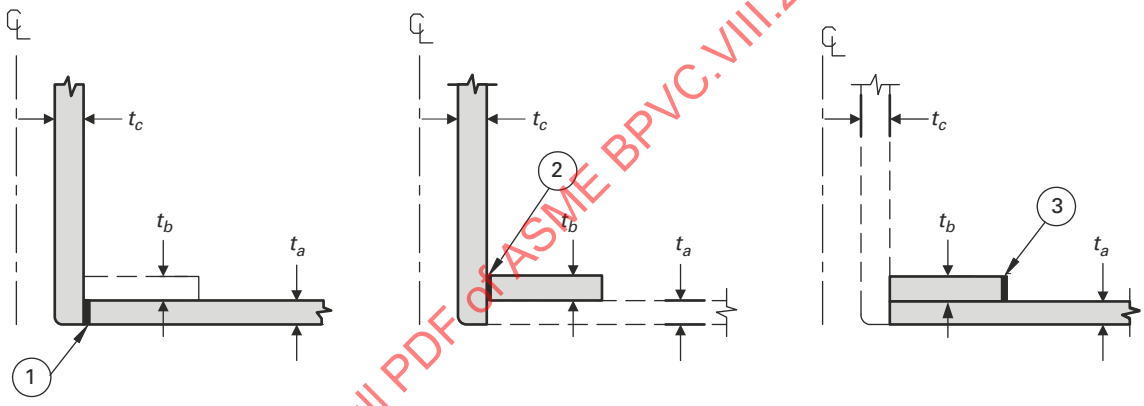
Figure 3.11
Typical Vessel Details Illustrating the Governing Thickness



$t_{g1} = t_a$
$t_{g2} = t_a$ (seamless) or t_b (welded)

(a) Butt-Welded Components



t_{g1} = min. (t_a, t_c)
t_{g2} = min. (t_b, t_c)
t_{g3} = min. (t_a, t_b)

(b) Welded Connection With or Without a Reinforcing Plate

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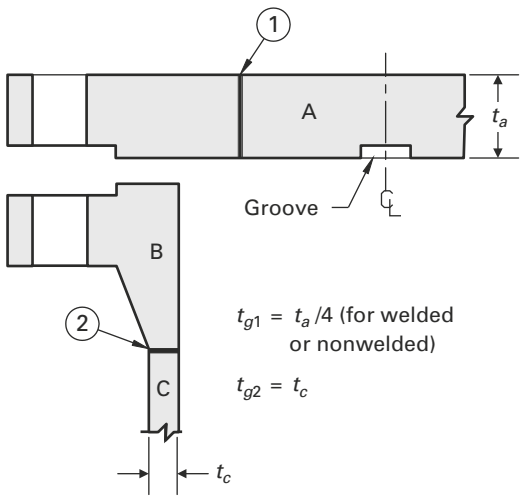
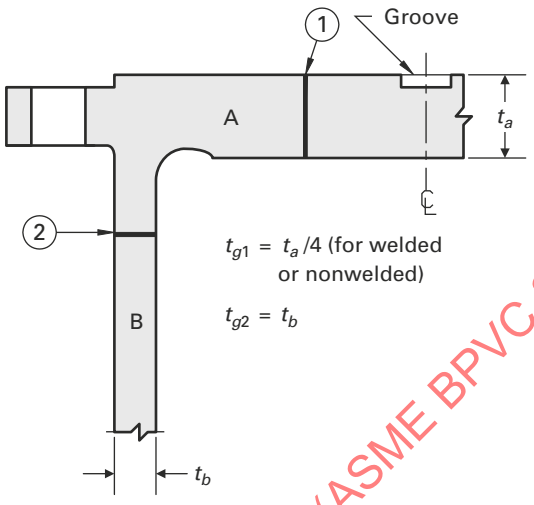
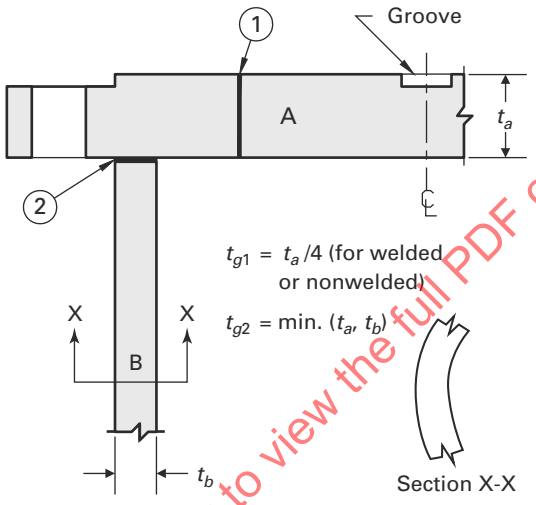
Figure 3.12
Typical Vessel Details Illustrating the Governing Thickness



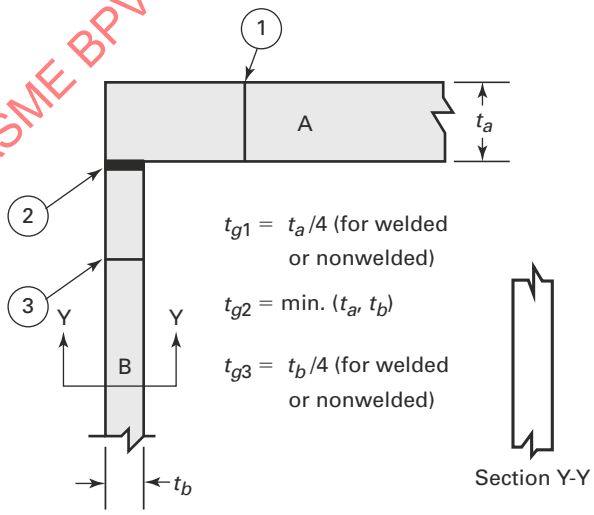
(a) Bolted Flat Head or Tubesheet and Flange



(b) Integral Flat Head or Tubesheet [Note (1)]



(c) Flat Head or Tubesheet Forming a Corner Joint With Cylinder [Note (1)]



(d) Two Flat Plates With a Corner Joint [Note (2)]

NOTES:
(1) The governing thickness of the integral flat head or tubesheet is max(t_{g1}, t_{g2}). The governing thickness of the shell is t_{g2}.
(2) The governing thickness of component A is max(t_{g1}, t_{g2}). The governing thickness of component B is max(t_{g2}, t_{g3}).

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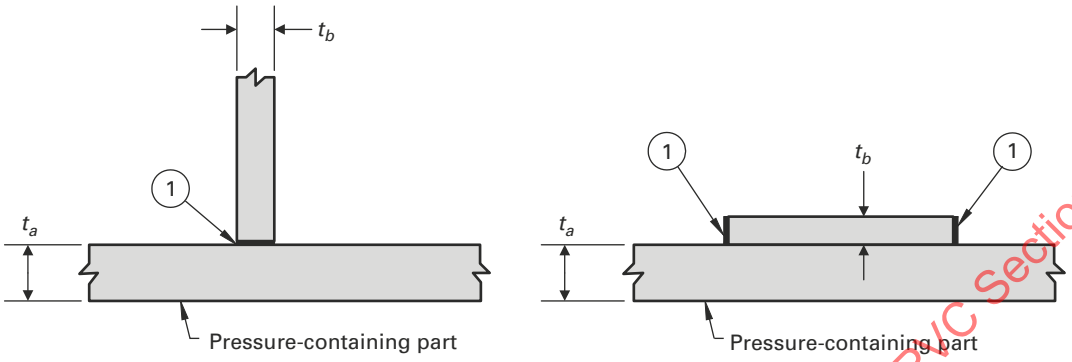
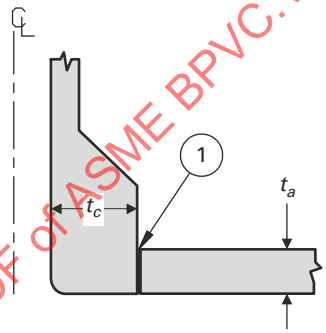
Figure 3.13
Typical Vessel Details Illustrating the Governing Thickness



t_{g1} = min. (t_a, t_b)

(a) Welded Attachments



t_{g1} = min. (t_a, t_c)

(b) Integrally Reinforced Welded Connection

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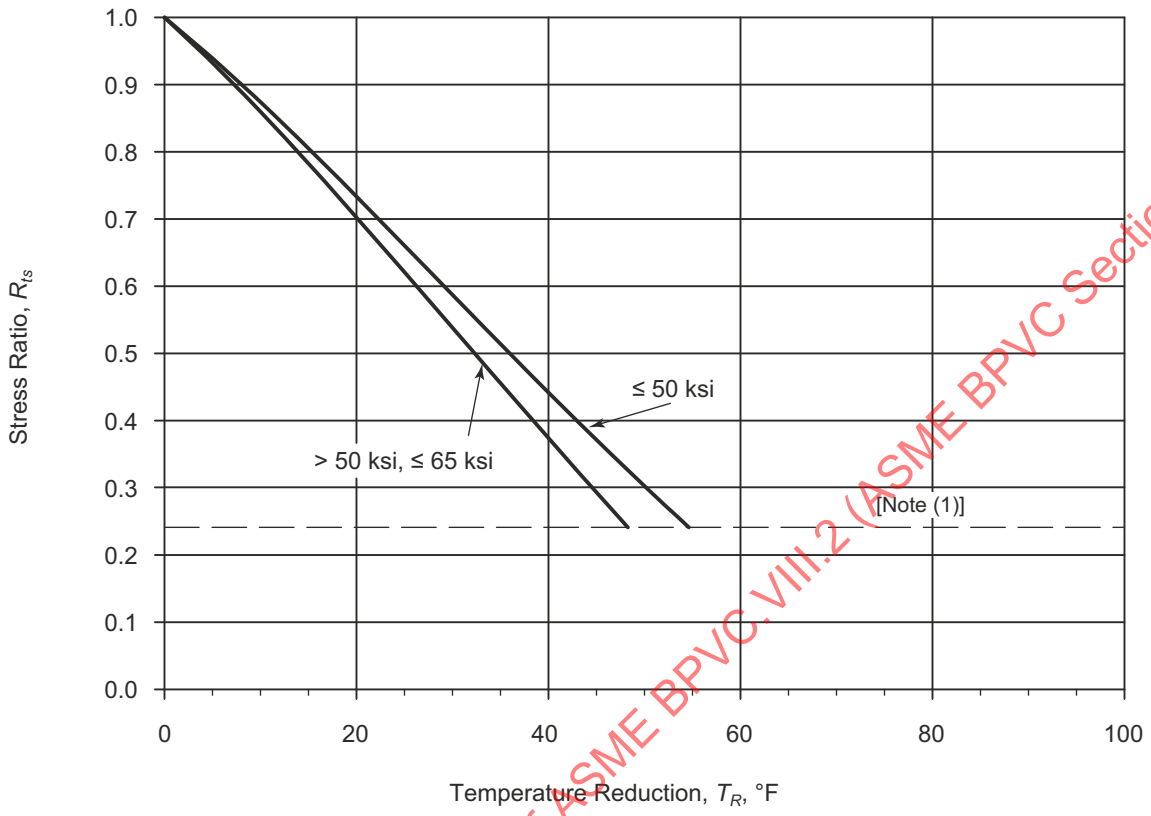
(25)

Figure 3.14
Reduction in the MDMT Without Impact Testing — Parts Not Subject to PWHT



GENERAL NOTES:
(a) Interpolation between yield strength values is permitted.
(b) The reduction in MDMT shall not exceed 55°C (100°F), except as permitted by 3.11.2.5(a), Step 5(b).
(c) Data of Figures 3.14 and 3.14M are shown in Table 3.17.

NOTE:
(1) See 3.11.2.5(a), Step 5(a) when R_{ts} is less than or equal to 0.24.

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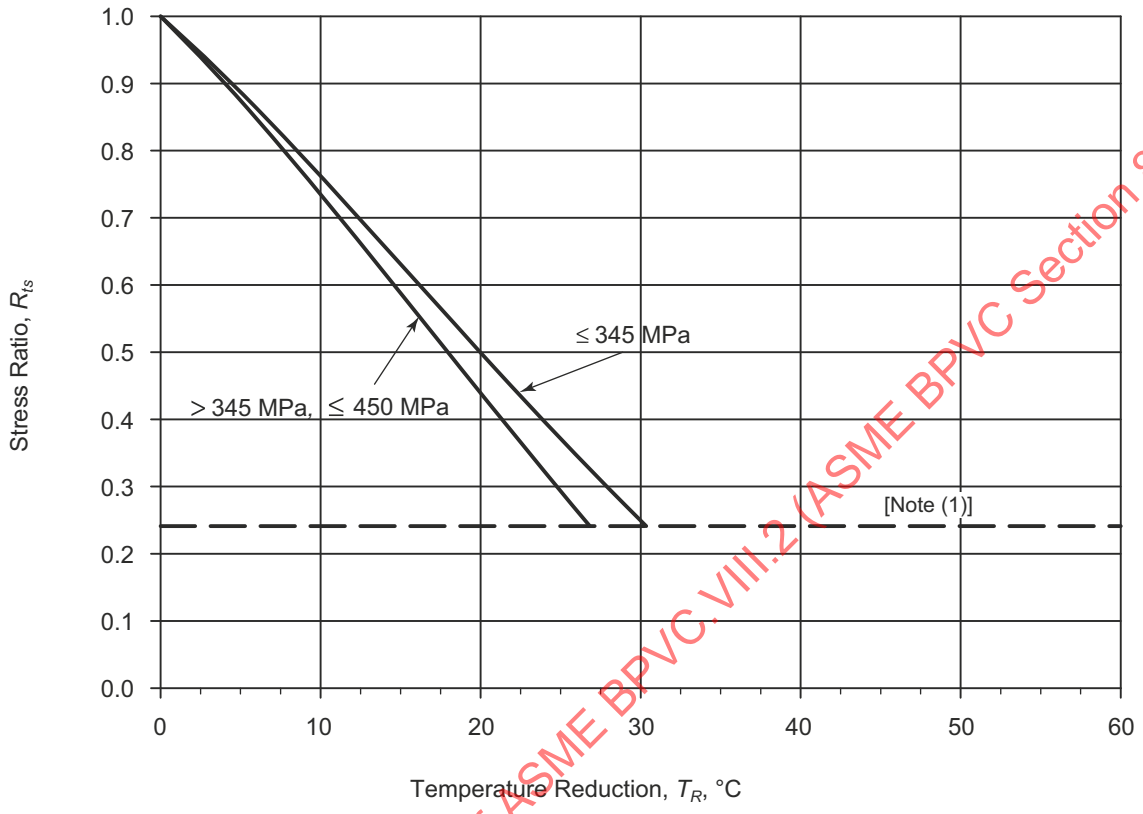
(25)

Figure 3.14M
Reduction in the MDMT Without Impact Testing — Parts Not Subject to PWHT



GENERAL NOTES:
(a) Interpolation between yield strength values is permitted.
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(c) Data of Figures 3.14 and 3.14M are shown in Table 3.17.

NOTE:
(1) See 3.11.2.5(a), Step 5(a) when R_{ts} is less than or equal to 0.24.

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