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# SECTION III

Rules for Construction of Nuclear Facility Components

# 2023 ASME Boiler and Pressure Vessel Code

An International Code

## Division 1 — Subsection NG

Core Support Structures



ASME

SETTING THE STANDARD

AN INTERNATIONAL CODE

# 2023 ASME Boiler & Pressure Vessel Code

2023 Edition July 1, 2023

# III

# RULES FOR CONSTRUCTION OF NUCLEAR FACILITY COMPONENTS

## Division 1 - Subsection NG

## Core Support Structures

ASME Boiler and Pressure Vessel Committee
on Construction of Nuclear Facility Components

The American Society of Mechanical Engineers

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# FOREWORD*

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 In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees: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, which 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. This 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.

This 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 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

* 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.

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 this Code. Requests for revisions, new rules, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action (see Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees). 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 this Section, the singular shall be interpreted as the plural, and vice versa, and the feminine, masculine, or neuter gender shall be treated as such other gender as appropriate.

The words "shall," "should," and "may" are used in this Standard 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.

# 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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(23)

## 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 e-mail 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(s), 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(s) to which the proposed case applies

*(4)* the edition(s) 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.

## 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 Interpretation Submittal Form at http://go.asme.org/InterpretationRequest. Upon submitting the form, the inquirer will receive an automatic e-mail 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.

# ORGANIZATION OF SECTION III

(23)

## 1 GENERAL

Section III consists of Division 1, Division 2, Division 3, Division 4, and Division 5. These Divisions are broken down into Subsections and are designated by capital letters preceded by the letter “N” for Division 1, by the letter “C” for Division 2, by the letter “W” for Division 3, by the letter "F" for Division 4, and by the letter “H” for Division 5. Each Subsection is published separately, with the exception of those listed for Divisions 2, 3, 4, and 5.

- Subsection NCA — General Requirements for Division 1 and Division 2
- Appendices
- Division 1
  - Subsection NB — Class 1 Components
  - Subsection NCD — Class 2 and Class 3 Components
  - Subsection NE — Class MC Components
  - Subsection NF — Supports
  - Subsection NG — Core Support Structures
- Division 2 — Code for Concrete Containments
  - Subsection CC — Concrete Containments
- Division 3 — Containment Systems for Transportation and Storage of Spent Nuclear Fuel and High-Level Radioactive Material
  - Subsection WA — General Requirements for Division 3
  - Subsection WB — Class TC Transportation Containments
  - Subsection WC — Class SC Storage Containments
  - Subsection WD — Class ISS Internal Support Structures
- Division 4 — Fusion Energy Devices
  - Subsection FA — Fusion Energy Device Facilities
  - Subsection FB — Pressure Boundary Components
- Division 5 — High Temperature Reactors
  - Subsection HA — General Requirements
    - Subpart A — Metallic Materials
    - Subpart B — Graphite Materials
    - Subpart C — Composite Materials
  - Subsection HB — Class A Metallic Pressure Boundary Components
    - Subpart A — Low Temperature Service
    - Subpart B — Elevated Temperature Service
  - Subsection HC — Class B Metallic Pressure Boundary Components
    - Subpart A — Low Temperature Service
    - Subpart B — Elevated Temperature Service
  - Subsection HF — Class A and B Metallic Supports
    - Subpart A — Low Temperature Service
  - Subsection HG — Class SM Metallic Core Support Structures
    - Subpart A — Low Temperature Service
    - Subpart B — Elevated Temperature Service
  - Subsection HH — Class SN Nonmetallic Core Components
    - Subpart A — Graphite Materials
    - Subpart B — Composite Materials

## 2 SUBSECTIONS

Subsections are divided into Articles, subarticles, paragraphs, and, where necessary, subparagraphs and subsubparagraphs.

## 3 ARTICLES

Articles are designated by the applicable letters indicated above for the Subsections followed by Arabic numbers, such as NB-1000. Where possible, Articles dealing with the same topics are given the same number in each Subsection, except NCA, in accordance with the following general scheme:

| Article Number | Title |
|---|---|
| 1000 | Introduction or Scope |
| 2000 | Material |
| 3000 | Design |
| 4000 | Fabrication and Installation |
| 5000 | Examination |
| 6000 | Testing |
| 7000 | Overpressure Protection |
| 8000 | Nameplates, Stamping With Certification Mark, and Reports |

The numbering of Articles and the material contained in the Articles may not, however, be consecutive. Due to the fact that the complete outline may cover phases not applicable to a particular Subsection or Article, the rules have been prepared with some gaps in the numbering.

## 4 SUBARTICLES

Subarticles are numbered in units of 100, such as NB-1100.

## 5 SUBSUBARTICLES

Subsubarticles are numbered in units of 10, such as NB-2130, and generally have no text. When a number such as NB-1110 is followed by text, it is considered a paragraph.

## 6 PARAGRAPHS

Paragraphs are numbered in units of 1, such as NB-2121.

## 7 SUBPARAGRAPHS

Subparagraphs, when they are *major* subdivisions of a paragraph, are designated by adding a decimal followed by one or more digits to the paragraph number, such as NB-1132.1. When they are *minor* subdivisions of a paragraph, subparagraphs may be designated by lowercase letters in parentheses, such as NB-2121(a).

## 8 SUBSUBPARAGRAPHS

Subsubparagraphs are designated by adding lowercase letters in parentheses to the *major* subparagraph numbers, such as NB-1132.1(a). When further subdivisions of *minor* subparagraphs are necessary, subsubparagraphs are designated by adding Arabic numerals in parentheses to the subparagraph designation, such as NB-2121(a)(1).

## 9 REFERENCES

References used within Section III generally fall into one of the following four categories:

*(a) References to Other Portions of Section III.* When a reference is made to another Article, subarticle, or paragraph, all numbers subsidiary to that reference shall be included. For example, reference to Article NB-3000 includes all material in Article NB-3000; reference to NB-3100 includes all material in subarticle NB-3100; reference to NB-3110 includes all paragraphs, NB-3111 through NB-3113.

*(b) References to Other Sections.* Other Sections referred to in Section III are the following:

*(1) Section II, Materials.* When a requirement for a material, or for the examination or testing of a material, is to be in accordance with a specification such as SA-105, SA-370, or SB-160, the reference is to material specifications in Section II. These references begin with the letter "S."

*(2) Section V, Nondestructive Examination.* Section V references begin with the letter "T" and relate to the nondestructive examination of material or welds.

*(3) Section IX, Welding and Brazing Qualifications.* Section IX references begin with the letter "Q" and relate to welding and brazing requirements.

*(4) Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components.* When a reference is made to inservice inspection, the rules of Section XI shall apply.

*(c) Reference to Specifications and Standards Other Than Published in Code Sections*

*(1)* Specifications for examination methods and acceptance standards to be used in connection with them are published by the American Society for Testing and Materials (ASTM). At the time of publication of Section III, some such specifications were not included in Section II of this Code. A reference to ASTM E94 refers to the specification so designated by and published by ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

*(2)* Dimensional standards covering products such as valves, flanges, and fittings are sponsored and published by The American Society of Mechanical Engineers and approved by the American National Standards Institute.* When a product is to conform to such a standard, for example ASME B16.5, the standard is approved by the American National Standards Institute. The applicable year of issue is that suffixed to its numerical designation in Table NCA-7100-1, for example ASME B16.5-2003. Standards published by The American Society of Mechanical Engineers are available from ASME (https://www.asme.org/).

*(3)* Dimensional and other types of standards covering products such as valves, flanges, and fittings are also published by the Manufacturers Standardization Society of the Valve and Fittings Industry and are known as Standard Practices. When a product is required by these rules to conform to a Standard Practice, for example MSS SP-100, the Standard Practice referred to is published by the Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. (MSS), 127 Park Street, NE, Vienna, VA 22180. The applicable year of issue of such a Standard Practice is that suffixed to its numerical designation in Table NCA-7100-1, for example MSS SP-58-2009.

*(4)* Specifications for welding and brazing materials are published by the American Welding Society (AWS), 8669 NW 36 Street, No. 130, Miami, FL 33166. Specifications of this type are incorporated in Section II and are identified by the AWS designation with the prefix "SF," for example SFA-5.1.

*(5)* Standards applicable to the design and construction of tanks and flanges are published by the American Petroleum Institute and have designations such as API-605. When documents so designated are referred to in Section III, for example API-605–1988, they are standards published by the American Petroleum Institute and are listed in Table NCA-7100-1.

*(d) References to Appendices.* Section III uses two types of appendices that are designated as either Section III Appendices or Subsection Appendices. Either of these appendices is further designated as either Mandatory or Nonmandatory for use. Mandatory Appendices are referred to in the Section III rules and contain requirements that must be followed in construction. Nonmandatory Appendices provide additional information or guidance when using Section III.

*(1)* Section III Appendices are contained in a separate book titled "Appendices." These appendices have the potential for multiple subsection applicability. Mandatory Appendices are designated by a Roman numeral followed, when appropriate, by Arabic numerals to indicate various articles, subarticles, and paragraphs of the appendix, such as II-1500 or XIII-1210. Nonmandatory Appendices are designated by a capital letter followed, when appropriate, by Arabic numerals to indicate various articles, subarticles, and paragraphs of the appendix, such as D-1200 or Y-1440.



*The American National Standards Institute (ANSI) was formerly known as the American Standards Association. Standards approved by the Association were designated by the prefix "ASA" followed by the number of the standard and the year of publication. More recently, the American National Standards Institute was known as the United States of America Standards Institute. Standards were designated by the prefix "USAS" followed by the number of the standard and the year of publication. While the letters of the prefix have changed with the name of the organization, the numbers of the standards have remained unchanged.

*(2)* Subsection Appendices are specifically applicable to just one subsection and are contained within that subsection. Subsection-specific mandatory and nonmandatory appendices are numbered in the same manner as Section III Appendices, but with a subsection identifier (e.g., NF, NH, D2, etc.) preceding either the Roman numeral or the capital letter for a unique designation. For example, NF-II-1100 or NF-A-1200 would be part of a Subsection NF mandatory or nonmandatory appendix, respectively. For Subsection CC, D2-IV-1120 or D2-D-1330 would be part of a Subsection CC mandatory or nonmandatory appendix, respectively.

*(3)* It is the intent of this Section that the information provided in both Mandatory and Nonmandatory Appendices may be used to meet the rules of any Division or Subsection. In case of conflict between Appendix rules and Division/Subsection rules, the requirements contained in the Division/Subsection shall govern. Additional guidance on Appendix usage is provided in the front matter of Section III Appendices.

## SUMMARY OF CHANGES

Changes listed below are identified on the pages by a margin note, **(23)**, placed next to the affected area. In addition, gender pronouns have been eliminated throughout this Subsection.

| *Page* | *Location* | *Change* |
|---|---|---|
| v | List of Sections | (1) Under Section III, Division 4 added<br>(2) Title of Section XI and subtitle of Section XI, Division 2 revised<br>(3) Information on interpretations and Code cases moved to "Correspondence With the Committee" |
| ix | Personnel | Updated |
| xxxi | Correspondence With the Committee | Added (replaces "Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees") |
| xxxiii | Organization of Section III | In para. 1, Division 4 added |
| xxxviii | Cross-Referencing in the ASME BPVC | Updated |
| 5 | NG-2130 | Cross-references updated |
| 5 | NG-2160 | Last sentence added |
| 8 | NG-2321.2 | Revised |
| 9 | NG-2332 | In subpara. (b)(1), reference to endnote 8 added |
| 23 | NG-2610 | Revised |
| 24 | NG-3112.1 | Subparagraph (a) revised |
| 24 | NG-3112.3 | First paragraph revised |
| 25 | NG-3122 | NG-3122.1, NG-3122.3, and NG-31.22.4 revised |
| 28 | NG-3200 | (1) Title of 3210 revised<br>(2) NG-3211 merged with NG-3210 and revised<br>(3) NG-3212 through NG-3235 and related figures and tables deleted |
| 29 | NG-3352 | Revised |
| 29 | NG-3352.2 | Revised |
| 39 | NG-4413 | Added |
| 40 | NG-4422 | Revised |
| 40 | NG-4423 | Revised |
| 41 | Figure NG-4427-1 | Illustration (c-1) revised |
| 42 | NG-4451 | Revised |
| 44 | Table NG-4622.1-1 | Column heads revised |
| 43 | NG-4622.3 | Revised |
| 46 | Table NG-4622.7(b)-1 | For "9A Gr. 1" and "9B Gr. 1" type of weld revised |
| 50 | NG-5321 | In subpara. (d), first line revised |
| 52 | NG-5510 | Cross-references updated |
| 53 | NG-5540 | Added |

(23)

# 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 crossreferences 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).

# ARTICLE NG-1000
# INTRODUCTION

## NG-1100 SCOPE

### NG-1110 ASPECTS OF CONSTRUCTION COVERED BY THESE RULES

Subsection NG establishes rules for materials, design, fabrication, examination, and preparation of reports required in the manufacture and installation of core support structures.[1, 2]

### NG-1120 DEFINITION OF STRUCTURES AND APPLICATION OF THESE RULES TO THEM

#### NG-1121 Core Support Structures

Core support structures shall be constructed to the rules of this Subsection. Core support structures are those structures or parts of structures which are designed to provide direct support or restraint of the core (fuel and blanket assemblies) within the reactor pressure vessel. Structures which support or restrain the core only after the postulated failure of core support structures are considered to be internal structures (see NG-1122).

#### NG-1122 Internal Structures

*(a)* Internal structures are *all* structures within the reactor pressure vessel other than core support structures, fuel[3] and blanket assemblies, control assemblies, and instrumentation.

*(b)* The rules of this Subsection apply to internal structures as defined in (a) above, only when so stipulated by the Certificate Holder manufacturing core supports, hereafter referred to in this Subsection as Certificate Holder.

*(c)* The Certificate Holder shall certify[2] that the construction of all internal structures is such as not to affect adversely the integrity of the core support structure.

#### NG-1123 Temporary Attachments

A temporary attachment is an element in contact with or connected to the core support structure, which is removed prior to operation. Temporary attachments include items such as alignment lug tie straps and braces.

### NG-1130 BOUNDARIES OF JURISDICTION APPLICABLE TO THIS SUBSECTION

#### NG-1131 Boundary Between Core Support Structure and Reactor Pressure Vessel

The jurisdictional boundary between a core support structure and the reactor pressure vessel shall be the surface of the core support structure. The first connecting weld of a core support structure to the reactor pressure vessel shall be considered part of the reactor pressure vessel unless the weld is more than $2t$ from the pressure-retaining portion of the reactor pressure vessel, where $t$ is the nominal thickness of the pressure-retaining material. Beyond the first connecting weld to the reactor pressure vessel, or beyond $2t$ from the pressure-retaining portion of the reactor pressure vessel, the first weld shall be considered part of the core support structure, unless otherwise specified in the Design Specification. Mechanical fasteners used to connect a core support structure to the reactor pressure vessel shall meet the requirements of this Subsection. Figure NG-1131-1 is provided as an aid in defining the boundary and construction requirements of this Subsection.

#### NG-1132 Boundary Between Core Support Structure and Internal Structure

*(a)* Internal structures may bear on or may be welded, cast, or fastened to core support structures.

*(b)* The jurisdictional boundary between a core support structure and an internal structure is the surface of the core support structure. The means by which the internal structure is connected to the core support structure shall be considered as follows:

*(1)* Attachment welds shall be considered as part of the core support structure.

*(2)* Mechanical connections (such as fasteners or pins) shall be considered as part of the internal structure.

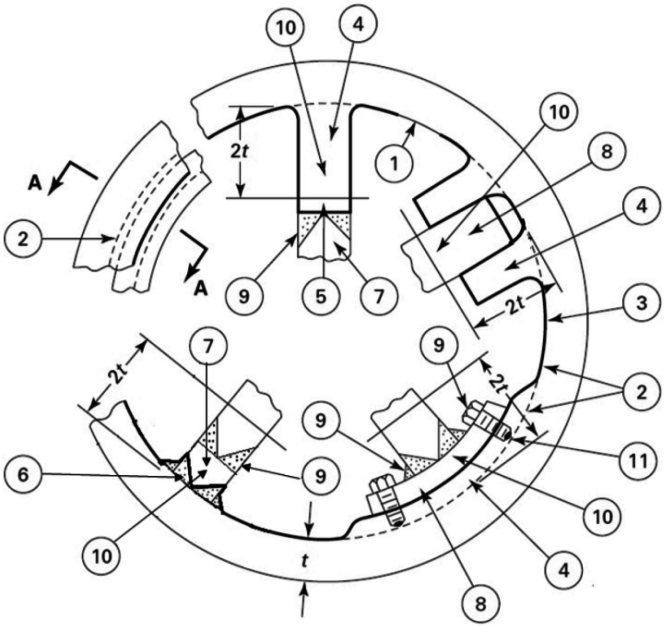
*(c)* One or more portions of a casting may be classified as core support structures and different portions of the same casting may be classified as internal structures. The portions of the casting so classified shall be defined by the Design Specification or on the drawing. The entire casting (core support and internal structural portions) shall meet the material property requirements of Article NG-2000 with the additional nondestructive examinations of the

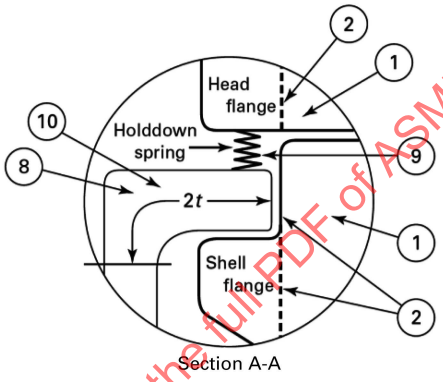
internal structure portion sufficient to meet the requirement of NG-1122(c).

### NG-1133 Boundary Between Core Support Structure and Temporary Attachment

The jurisdictional boundary between a core support structure and a temporary attachment shall be the surface of the core support structure.

**Figure NG-1131-1**
**Jurisdictional Boundary Between Core Support Structure and Reactor Pressure Vessel**




(1) Reactor pressure vessel conforms to Subsection NB.

(2) Pressure-retaining portion of the reactor pressure vessel.

(3) Jurisdictional boundary (heavy line).

(4) Cast or forged attachment or weld buildup shall conform to Subsection NB.

(5) Beyond 2*t* from the pressure-retaining portion of the reactor pressure vessel, the design rules of Article NG-3000 may be used as a substitute for the design rules of Article NB-3000.

(6) At or within 2*t* from the pressure-retaining portion of the reactor pressure vessel, the first connecting weld shall conform to Subsection NB.

(7) Beyond 2*t* from the pressure-retaining portion of the reactor pressure vessel or beyond the first connecting weld, the attachment shall conform to Subsection NG [see Note (1)].

(8) Bearing, clamped, or fastened attachment shall conform to Subsection NG [see Note (1)].

(9) Attachment connection shall conform to Subsection NG [see Note (1)].

(10) At or within 2*t* from the pressure-retaining portion of the component, the interaction effects of the attachment on the reactor pressure vessel shall be considered in accordance with NB-3135.

(11) Drilled holes within the jurisdictional boundary shall conform to Subsection NB.

GENERAL NOTE: These sketches are intended to show jurisdictional concepts and should not be considered as recommended configurations.

NOTE: (1) If the attachment is an internal structure (see NG-1122), material, design, and connections, as appropriate, are outside Code jurisdiction except when the core support structure Design Specification requires the internal structure to conform to Subsection NG.

# ARTICLE NG-2000
# MATERIAL

## NG-2100 GENERAL REQUIREMENTS FOR MATERIAL

### NG-2110 SCOPE OF PRINCIPAL TERMS EMPLOYED

*(a)* The term *material* as used in this Subsection is defined in NCA-1220. The term *Material Organization* is defined in Article NCA-9000.

*(b)* The requirements of this Article make reference to the term *thickness*. For the purpose intended, the following definitions of nominal thickness apply:

*(1) plate*: the thickness is the dimension of the short transverse direction.

*(2) forgings*: the thickness is the dimension defined as follows:

*(-a) hollow forgings*: the nominal thickness is measured between the inside and outside surfaces (radial thickness).

*(-b) disk forgings* (axial length less than the outside diameter): the nominal thickness is the axial length.

*(-c) flat ring forgings* (axial length less than the radial thickness): for axial length ≤2 in. (50 mm), the axial length is the nominal thickness; for axial length >2 in. (50 mm), the radial thickness is the nominal thickness.

*(-d) rectangular solid forgings*: the least rectangular dimension is the nominal thickness.

*(3) castings*: thickness, *t*, is defined as the largest nominal thickness of the load carrying portion of the casting.

### NG-2120 MATERIAL FOR CORE SUPPORT STRUCTURES

#### NG-2121 Permitted Material Specifications

*(a)* Core support structural material, and material welded thereto, and threaded structural fasteners, with the exception of welding material (see NG-2430), hard surfacing material (Section IX, QW-251.4), cladding which is 10% or less of the thickness of the base material (see NG-3122), or the material excluded by NG-4430, shall conform to the requirements of the specifications for material given in Section II, Part D, Subpart 1, Tables 2A and 2B, including all applicable notes in the table, and to all of the special requirements of this Article which apply to the product form in which the material is used.

*(b)* The requirements of this Article apply to the internal structures (see NG-1122) only as specifically stipulated by the Certificate Holder; however, the Certificate Holder shall certify that the material used for the internal structures shall not adversely affect the integrity of the core support structure.

*(c)* Welding material used in manufacture of items shall comply with an SFA Specification in Section II, Part C, except as otherwise permitted in Section IX, and shall also comply with the applicable requirements of this Article. The requirements of this Article do not apply to materials used as backing rings or backing strips in welded joints.

#### NG-2122 Special Requirements Conflicting With Permitted Material Specifications

Special requirements stipulated in this Article shall apply in lieu of the requirements of the material specification wherever the special requirements conflict with the material specification requirements (NCA-4256). Where the special requirements include an examination, test, or treatment which is also required by the material specification, the examination, test, or treatment need be performed only once. Required nondestructive examinations shall be performed as specified for each product form in NG-2500. Any examination, repair, test, or treatment required by the material specification or this Article may be performed by the Material Organization or the Certificate Holder as provided in NG-4121.1. Any hydrostatic or pneumatic pressure test required by a material specification need not be performed provided the material is not used in a pressure-retaining function.

*(a)* The stress rupture test of SA-453 and SA-638 for Grade 660 (UNS S66286) is not required for design temperatures of 800°F (427°C) and below.

#### NG-2124 Size Ranges

Material outside the limits of size or thickness given in any specification in Section II may be used if the material is in compliance with the other requirements of the specification and no size limitation is given in the rules for construction. In those specifications in which chemical composition, mechanical properties, or both are indicated to vary with size or thickness, any material outside the

specification range shall be required to conform to the composition and mechanical properties shown for the nearest specified range (NCA-4256).

(23) **NG-2130 CERTIFICATION OF MATERIAL**

All material used in the construction or installation of core support structures shall be certified as required in NCA-1225 and NCA-1224. Certified Material Test Reports are required for core support material except as provided by NCA-1224. A Certificate of Compliance may be provided in lieu of Certified Material Test Reports for all other material. Copies of all Certified Material Test Reports and Certificates of Compliance applicable to material used in a core support structure shall be furnished with the material.

**NG-2140 WELDING MATERIAL**

For the requirements governing the material to be used for welding, see NG-2400.

**NG-2150 MATERIAL IDENTIFICATION**

The identification of material for core support structures shall meet the requirements of NCA-4256. Material for small items shall be controlled during manufacture of the core support structures so that they are identifiable as acceptable material at all times. Welding material shall be controlled during the repair of material and the manufacture and installation of core support structures so that they are identifiable as acceptable material until the material is actually consumed in the process (see NG-4122).

(23) **NG-2160 DETERIORATION OF MATERIAL IN SERVICE**

Consideration of deterioration of material caused by service is generally outside the scope of this Subsection. It is the responsibility of the Owner to select material suitable for the conditions stated in the Design Specifications (NCA-3250), with specific attention being given to the effects of service conditions upon the properties of the material. Special consideration shall be given to the influences of weld residual stresses on in-service material degradation such as stress corrosion cracking.

**NG-2170 HEAT TREATMENT TO ENHANCE IMPACT PROPERTIES**

Carbon steels, low alloy steels, and high alloy chromium (Series 4XX) steels may be heat-treated by quenching and tempering to enhance their impact properties. Postweld heat treatment of the component at a temperature of not less than 1,100°F (595°C) may be considered to be the tempering phase of the heat treatment.

**NG-2180 PROCEDURES FOR HEAT TREATMENT OF MATERIAL**

When heat treating temperature or time is required by the material specification and the rules of this Subsection, the heat treating shall be performed in temperature-surveyed and -calibrated furnaces or the heat treating shall be controlled by measurement of material temperature by thermocouples in contact with the material or attached to blocks in contact with the material or by calibrated pyrometric instruments. Heat treating shall be performed under furnace loading conditions such that the heat treatment is in accordance with the material specification and the rules of this Subsection.

**NG-2190 TEMPORARY ATTACHMENT MATERIAL**

Material used for temporary attachments need not comply with Article NG-2000 and may be welded to the core support structure provided the requirements of NG-4430 are met.

## NG-2200 MATERIAL TEST COUPONS AND SPECIMENS FOR FERRITIC STEEL MATERIAL

**NG-2210 HEAT TREATMENT REQUIREMENTS**

**NG-2211 Test Coupon Heat Treatment for Ferritic Material**[4]

Where ferritic steel material is subjected to heat treatment during construction, the material used for the tensile and impact test specimens shall be heat-treated in the same manner as the core support structures, except that test coupons and specimens for P-No. 1 Groups Nos. 1 and 2 material with a nominal thickness of 2 in. (50 mm) or less are not required to be so heat-treated. The Certificate Holder shall provide the Material Organization with the temperature and heating and cooling rate to be used. In the case of postweld heat treatment, the total time at temperature or temperatures for the test material shall be at least 80% of the total time at temperature or temperatures during actual postweld heat treatment of the material and the total time at temperature or temperatures for the test material, coupon, or specimen may be performed in a single cycle.

**NG-2212 Test Coupon Heat Treatment for Quenched and Tempered Material**

**NG-2212.1 Cooling Rates.** Where ferritic steel material is subjected to quenching from the austenitizing temperature, the test coupons representing those materials shall be cooled at a rate similar to and no faster than the main body of the material except in the case of certain forgings and castings (see NG-2223.3 and NG-2226.4). This rule shall apply for coupons taken directly from the material

as well as for separate test coupons representing the material, and one of the general procedures described in NG-2212.2 or one of the specific procedures described in NG-2220 shall be used for each product form.

**NG-2212.2 General Procedures.** One of the general procedures stipulated in (a) through (c) below may be applied to quenched and tempered material or test coupons representing the material, provided the specimens are taken relative to the surface of the product in accordance with NG-2220. Further specific details of the methods to be used shall be the obligation of the Material Organization and the Certificate Holder.

*(a)* Any procedure may be used which can be demonstrated to produce a cooling rate in the test material that matches the cooling rate of the main body of the product at the region midway between midthickness and the surface ($\frac{1}{4}t$) and no nearer any heat-treated edge than a distance equal to the nominal thickness $t$ being quenched within 25°F (14°C) and 20 sec at all temperatures after cooling begins from the austenitizing temperature.

*(b)* If cooling rate data for the material and cooling rate control devices for the test specimens are available, the test specimens may be heat-treated in the device to represent the material provided that the provisions of (a) above are met.

*(c)* When any of the specific procedures described in NG-2220 are used, faster cooling rates at the edges may be compensated for by

*(1)* taking the test specimens at least $t$ from a quenched edge where $t$ equals the material thickness

*(2)* attaching a steel pad at least $t$ wide by a partial penetration weld, which completely seals the buffered surface, to the edge where specimens are to be removed

*(3)* using thermal barriers or insulation at the edge where specimens are to be removed

It shall be demonstrated (and this information shall be included in the Certified Material Test Report) that the cooling rates are equivalent to (a) or (b) above.

## NG-2220 PROCEDURE FOR OBTAINING TEST COUPONS AND SPECIMENS FOR QUENCHED AND TEMPERED MATERIAL

### NG-2221 General Requirements

The procedure for obtaining test coupons and specimens for quenched and tempered material is related to the product form. Coupon and specimen location and the number of tension test specimens shall be in accordance with the material specifications, except as required by this subarticle. References to dimensions signify nominal values.

### NG-2222 Plates

**NG-2222.1 Number of Tension Test Coupons.** The number of tension test coupons required shall be in accordance with the material specification and SA-20, except that from carbon steel plates weighing 42,000 lb (19 000 kg) and over and alloy steel plates weighing 40,000 lb (18 000 kg) and over, two tension test coupons shall be taken, one representing the top end of the plate and one representing the bottom end of the plate.

**NG-2222.2 Orientation and Location of Coupons.** Coupons shall be taken so that specimens shall have their longitudinal axes at least $\frac{1}{4}t$ from a rolled surface and with the midlength of the specimen at least $t$ from any heat-treated edge, where $t$ is the nominal thickness of the material.

**NG-2222.3 Requirements for Separate Test Coupons.** Where a separate test coupon is used to represent the core support structure material, it shall be of sufficient size to ensure that the cooling rate of the region from which the test coupons are removed represents the cooling rate of the material at least $\frac{1}{4}t$ deep and $t$ from any edge of the product. Unless cooling rates applicable to the bulk pieces or product are simulated in accordance with NG-2212.2(b), the dimensions of the coupon shall be not less than $3t \times 3t \times t$, where $t$ is the nominal material thickness.

### NG-2223 Forgings

**NG-2223.1 Location of Coupons.** Coupons shall be taken so that specimens shall have their longitudinal axes at least $\frac{1}{4}t$ from any surface and with the midlength of the specimens at least $t$ from any second surface, where $t$ is the maximum heat-treated thickness. A thermal buffer as described in NG-2212.2(c) may be used to achieve these conditions, unless cooling rates applicable to the bulk forgings are simulated as otherwise provided in NG-2212.2.

**NG-2223.2 Very Thick and Complex Forgings.** Test coupons for forgings which are both very thick and complex, such as contour nozzles, flanges, nozzles, and other complex forgings that are contour shaped or machined to essentially the finished product configuration prior to heat treatment, may be removed from prolongations or other stock provided on the product. The Certificate Holder shall specify the surfaces of the finished product subjected to high tensile stresses in service. The coupons shall be taken so that specimens shall have their longitudinal axes at a distance below the nearest heat-treated surface, equivalent at least to the greatest distance that the indicated high tensile stress surface will be from the nearest surface during heat treatment, and with the midlength of the specimens a minimum of twice this distance from a second heat-treated surface.

In any case, the longitudinal axes of the specimens shall not be nearer than $^{3}/_{4}$ in. (19 mm) to any heat-treated surface and the midlength of the specimens shall be at least $1^{1}/_{2}$ in. (38 mm) from any second heat-treated surface.

**NG-2223.3 Coupons From Separately Produced Test Forgings.** Test coupons representing forgings from one heat and one heat treatment lot may be taken from a separately forged piece under the conditions given in the following:

*(a)* 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 forging it represents.

*(b)* The separate test forging shall be heat-treated in the same furnace charge and under the same conditions as the production forging.

*(c)* The separate test forging shall be of the same nominal thickness as the production forging.

*(d)* Test coupons for simple forgings shall be taken so that specimens shall have their longitudinal axes at the region midway between midthickness and the surface and with the midlength of the specimens no nearer any heat-treated edge than a distance equal to the forging thickness except when the thickness-to-length ratio of the production forging does not permit, in which case a production forging shall be used as the test forging and the midlength of the specimens shall be at the midlength of the test forging.

*(e)* Test coupons for complex forgings shall be taken in accordance with NG-2223.2.

## NG-2224 Location of Coupons

*(a) Bars.* Coupons shall be taken so that specimens shall have their longitudinal axes at least $^{1}/_{4}t$ from the outside or rolled surface and with the midlength of the specimens at least $t$ from a heat-treated end, where $t$ is either the bar diameter or thickness.

*(b) Threaded Structural Fastener Material.* For threaded structural fastener material, the coupons shall be taken in conformance with the applicable material specification and with the midlength of the specimen at least one diameter or thickness from a heat-treated end. When the threaded structural fasteners, including studs and nuts, are not of sufficient length, the midlength of the specimen shall be at the midlength of the threaded structural fasteners. The threaded structural fasteners, including studs and nuts, selected to provide test coupon material shall be identical with respect to the quenched contour and size except for length, which shall equal or exceed the length of the represented threaded structural fasteners.

## NG-2225 Tubular Products and Fittings

**NG-2225.1 Location of Coupons.** Coupons shall be taken so that specimens shall have their longitudinal axes at least $^{1}/_{4}t$ from the inside or outside surface and with the midlength of the specimens at least $t$ from a heat-treated end, where $t$ is the nominal wall thickness of the tubular product.

**NG-2225.2 Separately Produced Coupons Representing Fittings.** Separately produced test coupons representing fittings may be used. When separately produced coupons are used, the requirements of NG-2223.3 shall be met.

## NG-2226 Castings

**NG-2226.1 Castings With 2 in. (50 mm) Maximum Thickness and Less.** For castings with a maximum thickness of 2 in. (50 mm) and less, the specimens shall be taken from either the standard separately cast coupons or the casting, in accordance with the material specification.

**NG-2226.2 Castings With Thicknesses Exceeding 2 in. (50 mm) Maximum Thickness.** For castings exceeding a thickness of 2 in. (50 mm), the coupons shall be taken from the casting (or an extension of it) so that specimens shall have their longitudinal axes at least $^{1}/_{4}t$ of the maximum heat-treated thickness from any surface and with the midlength of the specimens at least $t$ from any second surface. A thermal buffer may be used [see NG-2212.2(c)].

**NG-2226.3 Separately Cast Test Coupons for Castings With Thicknesses Exceeding 2 in. (50 mm).** In lieu of the requirements of NG-2226.2, separately cast test coupons may be used under the following conditions:

*(a)* The separate test coupon representing castings from one heat and one heat treatment lot shall be of the same heat of material and shall be subjected to substantially the same foundry practices as the production casting it represents.

*(b)* 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 the bulk castings are simulated in accordance with NG-2212.2.

*(c)* The separate test coupon shall be not less than $3t \times 3t \times t$, where $t$ equals the nominal thickness of the casting. Test specimens shall be taken with their longitudinal axes at the region midway between midthickness and the surface and with the midlength of the specimens no nearer any heat-treated edge than a distance equal to the casting thickness.

**NG-2226.4 Castings Machined or Cast to Finished Configuration Before Heat Treatment.** In lieu of the requirements of NG-2226.1, NG-2226.2, or NG-2226.3, test coupons may be removed from prolongations or

other stock provided on the product. The coupons shall be taken so that specimens shall have their longitudinal axes at a distance below the nearest heat-treated surface equivalent at least to the greatest distance that the indicated high tensile stress surface will be from the nearest outside surface during heat treatment and with the midlength of the specimens a minimum of twice this distance from a second heat-treated surface. In any case, the longitudinal axes of the specimens shall be at least $^{3}/_{4}$ in. (19 mm) from any heat-treated surface and the midlength of the specimens shall be at least $1^{1}/_{2}$ in. (38 mm) from any second heat-treated surface. The Certificate Holder shall specify the surfaces of the finished product subjected to high tensile stresses in service.

# NG-2300 FRACTURE TOUGHNESS REQUIREMENTS FOR MATERIAL

## NG-2310 MATERIAL TO BE IMPACT TESTED

### NG-2311 Components for Which Impact Testing of Material Is Required

*(a)* When the Design Specifications for core support structures require impact testing[5] they shall be impact tested in accordance with the requirements of NG-2300, except that the following materials are not to be impact tested as a requirement of this Subsection:

*(1)* material with a nominal section thickness of $^{5}/_{8}$ in. (16 mm) and less

*(2)* threaded structural fasteners, including studs and nuts, with a nominal size of 1 in. (25 mm) and less

*(3)* bars with a nominal cross-sectional area of 1 in.$^2$ (650 mm$^2$) and less

*(4)* all thicknesses of materials for pipe, tube, and fittings with an NPS 6 (DN 150) diameter and smaller

*(5)* austenitic stainless steels, including precipitation-hardened austenitic Grade 660 (UNS S66286)

*(6)* nonferrous material

*(b)* Drop weight tests are not required for martensitic high alloy chromium (Series 4XX) steels and precipitation-hardening steels listed in Section II, Part D, Subpart 1, Tables 2A and 2B. The other requirements of NG-2331 and NG-2332 apply for these steels. For nominal wall thickness greater than 2 in. (50 mm), the required $C_v$ value shall be 40 mils (1.00 mm) lateral expansion.

## NG-2320 IMPACT TEST PROCEDURES

### NG-2321 Types of Tests

**NG-2321.1 Drop Weight Tests.** The drop weight test, when required, shall be performed in accordance with ASTM E208. Specimen types P-1, P-2, or P-3 may be used. The orientations and locations of all test specimens and the results of all tests performed to meet the requirements of NG-2330 shall be reported in the Certified Material Test Report.

**NG-2321.2 Charpy V-Notch Tests.** The Charpy V-notch test ($C_v$), when required, shall be performed in accordance with SA-370. Specimens shall be in accordance with SA-370, Figure 11, Type A. A test shall consist of a set of three full-size 10 mm × 10 mm specimens and meet the requirements of NG-2330. When the material being tested is expected to exceed 80% of the testing machine's full-scale capacity, standard subsize specimens may be used as permitted in SA-370. When subsize specimens are used, the average lateral expansion and absorbed energy results shall be a minimum of 50 mils (1.27 mm) and 75 ft-lb (100 J), respectively. The test location, orientation, size, test temperature, lateral expansion, and absorbed energy shall be reported in the Certified Material Test Report. (23)

### NG-2322 Test Specimens

**NG-2322.1 Location of Test Specimens.** Impact test specimens for quenched and tempered material shall be removed from the locations in each product form specified in NG-2220 for tensile test specimens. For material in other heat-treated conditions, impact test specimens shall be removed from the locations specified for tensile specimens in the material specification. For all other material, the number of tests shall be in accordance with NG-2340. For threaded structural fasteners, the $C_v$ impact test specimens shall be taken with the longitudinal axis of the specimen located at least one-half radius or 1 in. (25 mm) below the surface plus the machining allowance per side, whichever is less. The fracture plane of the specimens shall be at least one diameter or thickness from the heat-treated end. When the threaded structural fasteners, including studs and nuts, are not of sufficient length, the midlength of the specimen shall be at the midlength of the threaded structural fasteners. The threaded structural fasteners, including studs and nuts, selected to provide test coupon material shall be identical with respect to the quenched contour and size except for length, which shall equal or exceed the length of the represented threaded structural fasteners.

**NG-2322.2 Orientation of Impact Test Specimens.**

*(a)* Specimens for Charpy V-notch tests shall be oriented as follows:

*(1)* Specimens for forgings, other than threaded structural fasteners and bars, shall be oriented in a direction normal to the principal direction in which the material was worked. Specimens are neither required nor prohibited from the thickness direction.

*(2)* Specimens from material for pipe, tube, and fittings, except for those made from plate, shall be oriented in the axial direction.

**Table NG-2331(a)-1**
**Required $C_v$ Values for Core Structure Material With 2 in. (50 mm) Maximum Thickness (Other Than Threaded Structural Fasteners)**

| Nominal Wall Thickness, in. (mm) | Lateral Expansion, mils (mm) |
|---|---|
| 5/8 (16) or less | No test required |
| Over 5/8 to 3/4 (16 to 19), incl. | 20 (0.50) |
| Over 3/4 to 1 1/2 (19 to 38), incl. | 25 (0.64) |
| Over 1 1/2 to 2 (38 to 50), incl. | 40 (1.00) |

*(3)* Specimens from threaded structural fastener material and bars shall be oriented in the axial direction.

*(4)* Specimens for all plate material, including those used for pipe, tube, and fittings, shall be oriented in a direction normal to the principal rolling direction, other than thickness direction.

*(5)* Specimens for cast material shall have their axes oriented the same as the axes of the tensile specimens (see NG-2226).

*(6)* In cases (1) through (5) above, the length of the notch of the $C_v$ specimen shall be normal to the surface of the material.

*(b)* Specimens for drop weight tests may have their axes oriented in any direction. The orientation used shall be reported in the Certified Material Test Report.

## NG-2330 TEST REQUIREMENTS AND ACCEPTANCE STANDARDS[6]

### NG-2331 Material for Core Support Structures Not Exceeding 2 in. (50 mm) Maximum Thickness

Material for core support structures (other than threaded structural fasteners) with nominal thickness 2 in. (50 mm) and less shall be tested as required in the following:

*(a)* Test three $C_v$ specimens at a temperature lower than or equal to the lowest service temperature.[7] All three specimens shall meet the requirements of Table NG-2331(a)-1.

*(b)* Apply the procedures of (a) above to

*(1)* base material,[8]

*(2)* the base material, the heat-affected zone, and weld metal from the weld procedure qualification tests in accordance with NG-4330, and

*(3)* the weld metal of NG-2431.

(23) ### NG-2332 Material With Thickness Exceeding 2 in. (50 mm)

Material for core support structures (other than threaded structural fasteners) with nominal wall thickness over 2 in. (50 mm) shall meet the following requirements:

*(a)* Establish a reference temperature $RT_{NDT}$; this shall be done as required in (1) through (5) below.

*(1)* Determine a temperature $T_{NDT}$ which is at or above the nil-ductility transition temperature by drop weight tests.

*(2)* At a temperature not greater than $[T_{NDT} + 60°F (33°C)]$, each specimen of the $C_v$ test (see NG-2321.2) shall exhibit at least 35 mils (0.89 mm) lateral expansion and not less than 50 ft-lb (68 J) absorbed energy. Retesting in accordance with NG-2350 is permitted. When these requirements are met, $T_{NDT}$ is the reference temperature $RT_{NDT}$.

*(3)* In the event that the requirements of (2) are not met, conduct additional $C_v$ tests in groups of three specimens (see NG-2321.2) to determine the temperature $T_{C_v}$ at which they are met. In this case, the reference temperature $RT_{NDT} = T_{C_v} - 60°F (33°C)$. Thus, the reference temperature $RT_{NDT}$ is the higher of $T_{NDT}$ or $[T_{C_v} - 60°F (33°C)]$.

*(4)* When a $C_v$ test has not been performed at $[T_{NDT} + 60°F (33°C)]$ or when the $C_v$ test at $[T_{NDT} + 60°F (33°C)]$ does not exhibit a minimum of 50 ft-lb (68 J) energy absorption and 35 mils (0.89 mm) lateral expansion, a temperature representing a minimum of 50 ft-lb (68 J) energy absorption and 35 mils (0.89 mm) lateral expansion may be obtained from a full $C_v$ impact curve developed from the minimum data points of all the $C_v$ tests performed.

*(5)* The lowest service temperature shall be not lower than $RT_{NDT} + 100°F (55°C)$ unless a lower temperature is justified by using methods similar to those contained in Section III Appendices, Nonmandatory Appendix G, Article G-2000.

*(b)* Apply the procedures of (a) above to

*(1)* the base material[8]

*(2)* the base material, the heat-affected zone, and weld metal from the weld procedure qualification tests in accordance with NG-4330

*(3)* the weld metal of NG-2431

*(c)* Product forms having dimensions which prohibit obtaining drop weight test specimens shall be tested in accordance with NG-2331.

*(d)* Consideration shall be given to the effects of irradiation on material toughness properties (such as core beltline region of reactor). The Design Specifications shall include additional requirements, as necessary, to assure adequate fracture toughness for the service lifetime of the core support structures. The toughness properties may be verified in service periodically by a material surveillance program using the methods of ASTM E185 and the material conditions monitored by the in-service inspection requirements of Section XI.

### NG-2333 Threaded Structural Fasteners

For threaded structural fastener material, including studs and nuts, test three $C_v$ specimens at a temperature no higher than the preload temperature or the lowest

**Table NG-2333-1**
**Required $C_v$ Values for Threaded Structural Fastener Material**

| Nominal Diameter, in. (mm) | Lateral Expansion, mils (mm) | Absorbed Energy, ft-lb (J) |
|---|---|---|
| 1 (25) or less | No test required | No test required |
| 1 (25) through 4 (100) | 25 (0.64) | No requirements |
| Over 4 (100) | 25 (0.64) | 45 (61) |

service temperature, whichever is the lesser. All three specimens shall meet the requirements of Table NG-2333-1.

## NG-2340 NUMBER OF IMPACT TESTS REQUIRED

### NG-2341 Plates

One test shall be made from each plate as heat-treated. Where plates are furnished in the nonheat-treated condition and qualified by heat-treated test specimens, one test shall be made for each plate as-rolled. The term *as-rolled* refers to the plate rolled from a slab or directly from an ingot, not to its heat-treated condition.

### NG-2342 Forgings and Castings

*(a)* Where the weight of an individual forging or casting is less than 1,000 lb (450 kg), one test shall be made to represent each heat in each heat treatment lot.

*(b)* When heat treatment is performed in a continuous type furnace with suitable temperature controls and equipped with recording pyrometers so that complete heat treatment records are available, a heat treatment charge shall be considered as the lesser of a continuous run not exceeding 8 hr duration or a total weight, so treated, not exceeding 2,000 lb (900 kg).

*(c)* One test shall be made for each forging or casting of 1,000 lb to 10,000 lb (450 kg to 4 500 kg) in weight.

*(d)* As an alternative to (c) above, a separate test forging or casting may be used to represent forgings or castings of different sizes in one heat and heat treat lot, provided the test piece is a representation of the greatest thickness in the heat treat lot. In addition, test forgings shall have been subjected to substantially the same reduction and working as the forgings represented.

*(e)* Forgings or castings larger than 10,000 lb (4 500 kg) shall have two tests per part for Charpy V-notch and one test for drop weights. The location of drop weight or $C_v$ impact test specimens shall be selected so that an equal number of specimens is obtained from positions in the forging or casting 180 deg apart.

*(f)* As an alternative to (e) for static castings, a separately cast test coupon (see NG-2226.3) may be used; one test shall be made for Charpy V-notch and one test for drop weight.

### NG-2343 Bars

One test shall be made for each diameter or size having a nominal cross-sectional area greater than 1 $in.^2$ in each lot, where a lot is defined as one heat of material heat-treated in one charge or as one continuous operation, not to exceed 6,000 lb (2 700 kg).

### NG-2344 Tubular Products and Fittings

On products which are seamless or welded without filler metal, one test shall be made from each lot. On products which are welded with filler metal, one additional test with the specimens taken from the weld area shall also be made on each lot. A lot shall be defined as stated in the applicable material specification but in no case shall a lot consist of products from more than one heat of material and of more than one diameter, with the nominal thickness of any product included not exceeding that to be impact tested by more than ¼ in. (6 mm); such a lot shall be in a single heat treatment load or in the same continuous run in a continuous furnace controlled within a 50°F (28°C) range and equipped with recording pyrometers.

### NG-2345 Threaded Structural Fastener Material

One test shall be made for each lot of material where a lot is defined as one heat of material heat-treated in one charge or as one continuous operation, not to exceed in weight the following:

| Diameter | Weight |
|---|---|
| 1¾ in. (45 mm) and less | 1,500 lb (700 kg) |
| Over 1¾ in. to 2½ in. (45 mm to 64 mm) | 3,000 lb (1 350 kg) |
| Over 2½ in. to 5 in. (64 mm to 125 mm) | 6,000 lb (2 700 kg) |
| Over 5 in. (125 mm) | 10,000 lb (4 500 kg) |

### NG-2346 Test Definition

Unless otherwise stated in NG-2341 through NG-2345, the term *one test* is defined to include the combination of the drop weight test and the $C_v$ test when $RT_{NDT}$ is required (see NG-2332) and only the $C_v$ test when determination of $RT_{NDT}$ is not required (see NG-2331).

## NG-2350 RETESTS

*(a)* For $C_v$ tests required by NG-2330, one retest at the same temperature may be conducted, provided

*(1)* the average value of the test results meets the minimum requirements

*(2)* not more than one specimen per test is below the minimum requirements

*(3)* the specimen not meeting the minimum requirements is not lower than 10 ft-lb (13.6 J) or 5 mils (0.13 mm) below the specified requirements

*(b)* A retest consists of two additional specimens taken as near as practicable to the failed specimens. For acceptance of the retest, both specimens shall meet the minimum requirements.

### NG-2360 CALIBRATION OF INSTRUMENTS AND EQUIPMENT

Calibration of temperature instruments and $C_v$ impact test machines used in impact testing shall be performed at the frequency specified in the following:

*(a)* Temperature instruments used to control test temperature of specimens shall be calibrated and the results recorded to meet the requirements of NCA-4258.2 at least once in each 3-month interval.

*(b)* $C_v$ test machines shall be calibrated and the results recorded to meet the requirements of NCA-4258.2. The calibrations shall be performed using the frequency and methods outlined in ASTM E23 and employing standard specimens obtained from the National Institute of Standards and Technology, or any supplier of subcontracted calibration services accredited in accordance with the requirements of NCA-3126 and NCA-4255.3(c).

## NG-2400 WELDING MATERIAL

### NG-2410 GENERAL REQUIREMENTS

*(a)* All welding material used in the construction and repair of components or material, except welding material used for hard surfacing, shall conform to the requirements of the material specification or to the requirements for other welding material as permitted in Section IX. In addition, welding material shall conform to the requirements stated in this subarticle and to the rules covering identification in NG-2150.

*(b)* The Certificate Holder shall provide the organization performing the testing with the following information, as applicable:

*(1)* welding process

*(2)* SFA Specification and classification

*(3)* other identification if no SFA Specification applies

*(4)* minimum tensile strength [see NG-2431.1(e)] in either the as-welded or heat-treated condition or both [see NG-2431.1(c)]

*(5)* drop weight test for material as-welded or heat-treated or both (see NG-2332)

*(6)* Charpy V-notch test for material as-welded or heat-treated or both (see NG-2331); the test temperature, and the lateral expansion or the absorbed energy, shall be provided

*(7)* the preheat and interpass temperatures to be used during welding of the test coupon [see NG-2431.1(c)]

*(8)* postweld heat treatment time, temperature range, and maximum cooling rate, if the production weld will be heat-treated [see NG-2431.1(c)]

*(9)* elements for which chemical analysis is required per the SFA Specification or WPS, and NG-2432

*(10)* minimum delta ferrite (see NG-2433)

### NG-2420 REQUIRED TESTS

The required tests shall be conducted for each lot of covered, flux-cored, or fabricated electrodes; for each heat of bare electrodes, rod, or wire for use with the OFW, GMAW, GTAW, PAW, and EGW (electrogas welding) processes (Section IX, QG-109); for each heat of consumable inserts; for each combination of heat of bare electrodes and lot of submerged arc flux; for each combination of lot of fabricated electrodes and lot of submerged arc flux; for each combination of heat of bare electrodes or lot of fabricated electrodes, and dry blend of supplementary powdered filler metal, and lot of submerged arc flux; or for each combination of heat of bare electrodes and lot of electroslag flux. The definitions in SFA-5.01 and the Lot Classes specified in (a) through (e) below shall apply.

*(a)* each Lot Class C3 of covered electrodes.

*(b)* each Lot Class T2 of tubular-cored electrodes and rods (flux cored or fabricated).

*(c)* each Lot Class S2 of fully metallic solid welding consumables (bare electrode, rod, wire, consumable insert, or powdered filler metal).

*(d)* each Lot Class S2 of fully metallic solid welding electrodes or each Lot Class T2 of tubular-cored (fabricated) electrodes and each Lot Class F2 of submerged arc or electroslag welding flux.

*(e)* each Lot Class S2 of fully metallic solid welding electrodes or each Lot Class T2 of tubular-cored (fabricated) electrodes and each Lot Class F2 of submerged arc or electroslag welding flux and each Lot Class S2 of supplementary powdered filler metal. The chemical analysis range of the supplemental powdered filler metal shall be the same as that of the welding electrode, and the ratio of powder to electrode used to make the test coupon shall be the maximum permitted for production welding.

In all cases, when filler metal of controlled chemical composition (as opposed to heat control) is used, each container of welding consumable shall be coded for identification and shall be traceable to the production period, the shift, the manufacturing line, and the analysis of the steel rod or strip. Carbon, manganese, silicon, and other intentionally added elements shall be identified to ensure that the material conforms to the SFA or user's material specification. The use of controlled chemical composition is only permitted for carbon and low alloy steel consumables. Tests performed on welding material in the qualification of weld procedures will satisfy the testing requirements for the lot, heat, or combination of heat and batch of welding material used, provided the tests required by Article NG-4000 and this subarticle are made and the results conform to the requirements of this Article.

## NG-2430 WELD METAL TESTS

### NG-2431 Mechanical Properties Test

Tensile and impact tests shall be made, in accordance with this paragraph, of welding material used to join P-Nos. 1, 3 through 7, 9, and 11 base materials in any combination, with the following exceptions:

*(a)* austenitic stainless steel and nonferrous welding material used to join the listed P-Numbers

*(b)* consumable inserts (backing filler material)

*(c)* welding material used for GTAW root deposits with a maximum of two layers

*(d)* welding material to be used for the welding of base material exempted from impact testing by NG-2300 shall likewise be exempted from the impact testing required by this paragraph

**NG-2431.1 General Test Requirements.** The welding test coupon shall be made in accordance with (a) through (f) below using each process with which the weld material will be used in production welding.

*(a)* Test coupons shall be of sufficient size and thickness such that the test specimens required herein can be removed.

*(b)* The weld metal to be tested for all processes except electroslag welding shall be deposited in such a manner as to eliminate substantially the influence of the base material on the results of the tests. Weld metal to be used with the electroslag process shall be deposited in such a manner as to conform to one of the applicable Welding Procedure Specifications (WPS) for production welding. The base material shall conform with the requirements of Section IX, QW-403.1 or QW-403.4, as applicable.

*(c)* The welding of the test coupon shall be performed within the range of preheat and interpass temperatures which will be used in production welding. Coupons shall be tested in the as-welded condition or they shall be tested in the applicable postweld heat-treated condition when the production welds are to be postweld heat-treated. The postweld heat treatment holding time[4] shall be at least 80% of the maximum time to be applied to the weld metal in production application. The total time for postweld heat treatment of the test coupon may be applied in one heating cycle. The cooling rate from the postweld heat treatment temperature shall be of the same order as that applicable to the weld metal in the component. In addition, weld coupons for weld metal to be used with the electroslag process that are tested in the as-welded condition, or following a postweld heat treatment within the holding temperature ranges of Table NG-4622.1-1 or Table NG-4622.4(c)-1, shall have a thickness within the range of 0.5 to 1.1 times the thickness of the welds to be made in production. Electroslag weld coupons to be tested following a postweld heat treatment which will include heating the coupon to a temperature above the "Holding Temperature Range" of Table NG-4622.1-1 for the type of material being tested shall have a thickness within the range of 0.9 to 1.1 times the thickness of the welds to be made in production.

*(d)* The tensile specimens, and the $C_v$ impact specimens where required, shall be located and prepared in accordance with the requirements of SFA-5.1, or the applicable SFA Specification. Drop weight impact test specimens, where required, shall be oriented so that the longitudinal axis is transverse to the weld with the notch in the weld face or in a plane parallel to the weld face. For impact specimen preparation and testing, the applicable parts of NG-2321.1 and NG-2321.2 shall apply. The longitudinal axis of the specimen shall be at a minimum depth of $\frac{1}{4}t$ from a surface, where $t$ is the thickness of the test weld.

*(e)* One all weld metal tensile specimen shall be tested and shall meet the specified minimum tensile strength requirements of the base material specification. When base materials of different specifications are to be welded, the tensile strength requirements shall conform to the specified minimum tensile strength requirements of either of the base material specifications.

*(f)* Impact specimens of the weld metal shall be tested where impact tests are required for either of the base materials of the production weld. The weld metal shall conform to the requirements of NG-2330 applicable to the base material. Where different requirements exist for the two base materials, the weld metal may conform to either of the two requirements.

**NG-2431.2 Standard Test Requirements.** In lieu of the use of the General Test Requirements specified in NG-2431.1, tensile and impact tests may be made in accordance with this subparagraph where they are required for mild and low alloy steel covered electrodes. The material combinations to require weld material testing, as listed in NG-2431, shall apply for this Standard Test Requirements option. The limitations and testing under this Standard Test option shall be in accordance with the following:

*(a)* Testing to the requirements of this subparagraph shall be limited to electrode classifications included in Specification SFA-5.1 or SFA-5.5.

*(b)* The test assembly required by SFA-5.1 or SFA-5.5, as applicable, shall be used for test coupon preparation, except that it shall be increased in size to obtain the number of $C_v$ specimens and the drop weight test specimens required by NG-2330, where applicable.

*(c)* The welding of the test coupon shall conform to the requirements of the SFA Specification for the classification of electrode being tested. Coupons shall be tested in the as-welded condition and also in the postweld heat-treated condition. The postweld heat treatment temperatures shall be in accordance with Table NG-4622.1-1 for the applicable P-Number equivalent. The time at postweld heat treatment temperature shall be 8 hr (this qualifies postweld heat treatments of 10 hr or less). Where the postweld heat treatment of the production weld exceeds 10 hr or the

**Table NG-2432.1-1**
**Sampling of Welding Materials for Chemical Analysis**

| Welding Material | GTAW/PAW | GMAW | All Other Processes |
|---|---|---|---|
| A-No. 8 filler metal | Filler metal or weld deposit | Weld deposit | Weld deposit |
| All other filler metal | Filler metal or weld deposit | Filler metal or weld deposit | Weld deposit |

PWHT temperature is other than that required above, the general test of NG-2431.1 shall be used.

*(d)* The tensile and $C_v$ specimens shall be located and prepared in accordance with the requirements of SFA-5.1 or SFA-5.5, as applicable. Drop weight impact test specimens, where required, shall be located and oriented as specified in NG-2431.1(d).

*(e)* One all weld metal tensile specimen shall be tested and shall meet the specified minimum tensile strength requirement of the SFA Specification for the applicable electrode classification.

*(f)* The requirements of NG-2431.1(f) shall be applicable to the impact testing of this option.

## NG-2432 Chemical Analysis Test

Chemical analysis of filler metal or weld deposits shall be made in accordance with NG-2420 and as required by the following subparagraphs.

**NG-2432.1 Test Method.** The chemical analysis test shall be performed in accordance with this subparagraph and Table NG-2432.1-1, and the results shall conform to NG-2432.2.

*(a)* A-No. 8 welding material to be used with GTAW and PAW processes and any other welding material to be used with any GTAW, PAW, or GMAW process shall have chemical analysis performed either on the filler metal or on a weld deposit made with the filler metal in accordance with (c) or (d) below.

*(b)* A-No. 8 welding material to be used with other than the GTAW and PAW processes and other welding material to be used with other than the GTAW, PAW, or GMAW process shall have chemical analysis performed on a weld deposit of the material or combination of materials being certified in accordance with (c) or (d) below. The removal of chemical analysis samples shall be from an undiluted weld deposit made in accordance with (c) below. As an alternative, the deposit shall be made in accordance with (d) below for material that will be used for corrosion resistant overlay cladding. Where the Welding Procedure Specification or the welding material specification specifies percentage composition limits for analysis, it shall state that the specified limits apply for either the filler metal analysis or the undiluted weld deposit analysis or for *in situ* cladding deposit analysis in conformance with the above required certification testing.

*(c)* The preparation of samples for chemical analysis of undiluted weld deposits shall comply with the method given in the applicable SFA Specification. Where a weld deposit method is not provided by the SFA Specification, the sample shall be removed from a weld pad, groove, or other test weld[9] made using the welding process that will be followed when the welding material or combination of welding materials being certified is consumed. The weld for A-No. 8 material to be used with the GMAW or EGW process shall be made using the shielding gas composition specified in the Welding Procedure Specifications that will be followed when the material is consumed. The test sample for ESW shall be removed from the weld metal of the Mechanical Properties Test coupon. Where a chemical analysis is required for a welding material which does not have a Mechanical Properties Test requirement, a chemical analysis test coupon shall be prepared as required by NG-2431.1(c), except that heat treatment of the coupon is not required and the weld coupon thickness requirements of NG-2431.1(c) do not apply.

*(d)* The alternative method provided in (b) above for the preparation of samples for chemical analysis of welding material to be used for corrosion-resistant overlay cladding shall require a test weld made in accordance with the essential variables of the Welding Procedure Specification that will be followed when the welding material is consumed. The test weld shall be made in conformance with the requirements of Section IX, QW-214.1. The removal of chemical analysis samples shall conform with QW-453 for the minimum thickness for which the Welding Procedure Specification is qualified.

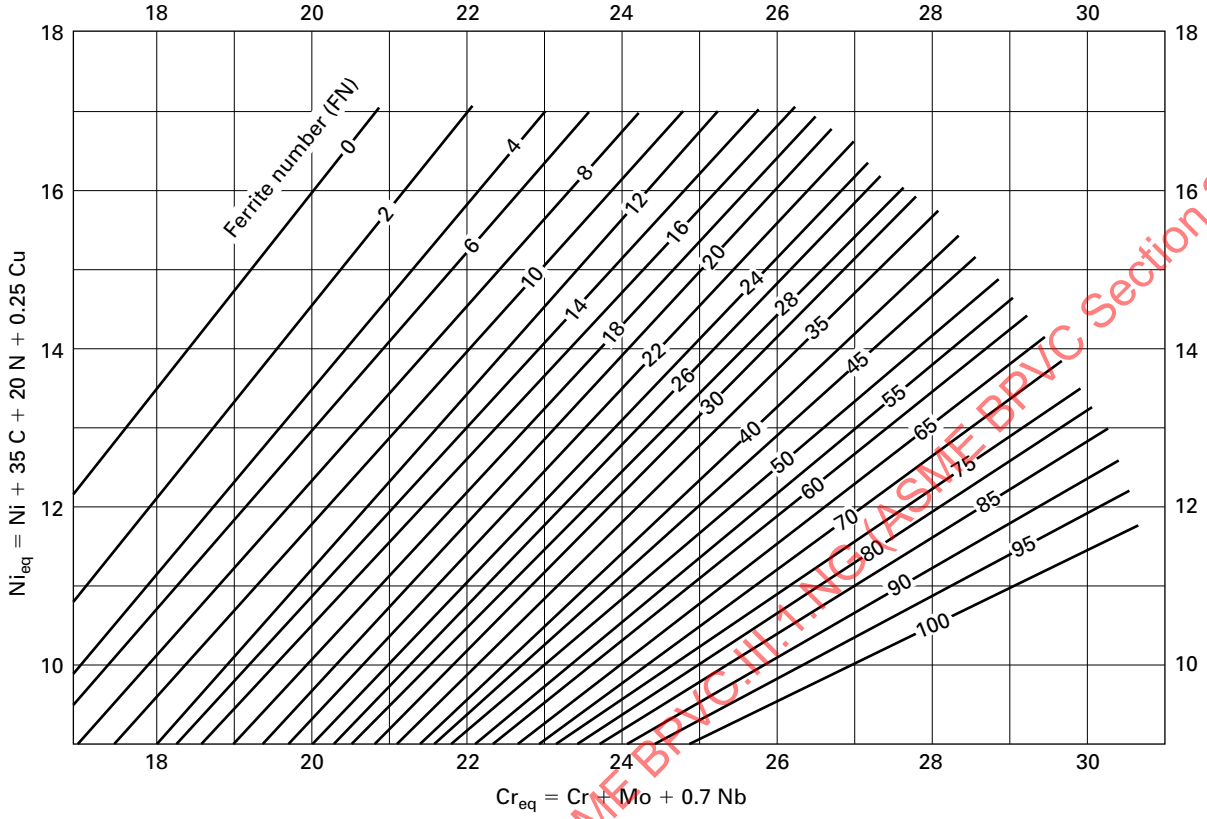
**NG-2432.2 Requirements for Chemical Analysis.** The chemical elements to be determined, the composition requirements of the weld metal, and the recording of results of the chemical analysis shall be in accordance with the following:

*(a)* All welding material shall be analyzed for the elements listed in Table NG-2432.2-1 and for other elements specified either in the welding material specification referenced by the Welding Procedure Specification or in the Welding Procedure Specification.

**Table NG-2432.2-1**
**Welding Material Chemical Analysis**

| Materials | Elements |
|---|---|
| Carbon and low alloy materials | C, Cr, Mo, Ni, Mn, Si, P, S, V, Cu |
| Chromium and Cr-Ni stainless material | C, Cr, Mo, Ni, Mn, Si, P, S, V, Cb + Ta, Ti, Cu |
| Nickel and Ni-alloy materials | C, Cr, Mo, Ni, Mn, Si, S, Cb + Ta, Cu, Fe, Co |

**Figure NG-2433.1-1**
**Weld Metal Delta Ferrite Content**




GENERAL NOTES:
(a) The actual nitrogen content is preferred. If this is not available, the following applicable nitrogen value shall be used:
*(1)* GMAW welds, 0.08%, except that when self-shielding, flux-cored electrodes are used, 0.12%
*(2)* Welds made using other processes, 0.06%.
(b) This diagram is identical to the WRC-1992 Diagram, except that the solidification mode lines have been removed for ease of use.

*(b)* The chemical composition of the weld metal or filler metal shall conform to the welding material specification for elements having specified percentage composition limits. Where the Welding Procedure Specification contains a modification of the composition limits of SFA or other referenced welding material specifications, or provides limits for additional elements, these composition limits of the Welding Procedure Specification shall apply for acceptability.

*(c)* The results of the chemical analysis shall be reported in accordance with NCA-3862.1. Elements listed in Table NG-2432.2-1 but not specified in the welding material specification shall be reported for information only.

## NG-2433 Delta Ferrite Determination

A determination of delta ferrite shall be performed on A-No. 8 weld material (Section IX, Table QW-442) backing filler metal (consumable inserts); bare electrode, rod, or wire filler metal; or weld metal, except that delta ferrite determinations are not required for SFA-5.4, Type 16-8-2, or A-No. 8 weld filler metal to be used for weld metal cladding.

**NG-2433.1 Method.** Delta ferrite determinations of welding material, including consumable insert material, shall be made using a magnetic measuring instrument and weld deposits made in accordance with (b) below. Alternatively, the delta ferrite determinations for welding materials may be performed by the use of chemical analysis of NG-2432 in conjunction with Figure NG-2433.1-1.

*(a)* Calibration of magnetic instruments shall conform to AWS A4.2.

*(b)* The weld deposit for magnetic delta ferrite determination shall be made in accordance with NG-2432.1(c).

*(c)* A minimum of six ferrite readings shall be taken on the surface of the weld deposit. The readings obtained shall be averaged to a single Ferrite Number (FN).

**NG-2433.2 Acceptance Standards.** The minimum acceptable delta ferrite shall be 5FN. The results of the delta ferrite determination shall be included in the Certified Material Test Report of NG-2130 or NG-4120.

## NG-2440 STORAGE AND HANDLING OF WELDING MATERIAL

Suitable storage and handling of electrodes, flux, and other welding material shall be maintained. Precautions shall be taken to minimize absorption of moisture by fluxes and cored, fabricated, and coated electrodes.

# NG-2500 EXAMINATION AND REPAIR OF CORE SUPPORT STRUCTURE MATERIAL

## NG-2510 EXAMINATION OF CORE SUPPORT STRUCTURE MATERIAL

Material for core support structures shall be examined by nondestructive methods applicable to the material and product form as required by the rules of this subarticle.

## NG-2520 EXAMINATION AFTER QUENCHING AND TEMPERING

Ferritic steel products that have their properties enhanced by quenching and tempering shall be examined by the methods specified in this subarticle for each product form after the quenching and tempering phase of the heat treatment.

## NG-2530 EXAMINATION AND REPAIR OF PLATE

### NG-2531 Required Examination

All plates for core support structures greater than $^{3}/_{4}$ in. (19 mm) thickness shall be examined by the straight beam ultrasonic method in accordance with NG-2532.1.

### NG-2532 Examination Procedures

**NG-2532.1 Straight Beam Examination.** The requirements for straight beam examination shall be in accordance with SA-578, as shown in Section V, except that the extent of examination and the acceptance standards to be applied are given in the following:

*(a) Extent of Examination*. 100% of one major plate surface shall be covered by moving the search unit in parallel paths with not less than a 10% overlap.

*(b) Acceptance Standards*

*(1)* Any area where one or more imperfections produce a continuous total loss of back reflection accompanied by continuous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. (75 mm) or one-half of the plate thickness, whichever is greater, is unacceptable.

*(2)* In addition, two or more imperfections smaller than described in (1) above shall be unacceptable unless separated by a minimum distance equal to the greatest diameter of the larger imperfection, or unless they may be collectively encompassed by the circle described in (1) above.

**NG-2532.2 Angle Beam Examination.** The requirements for angle beam examination shall be in accordance with SA-577, Specification for Ultrasonic Shear Wave Inspection of Steel Plates, as shown in Section V, as supplemented by this subparagraph. The calibration notch, extent of examination, and the acceptance standards to be applied are given in the following:

*(a) Calibration*. Angle beam examination shall be calibrated from a notch.

*(b) Extent of Examination*. 100% of one major plate surface shall be covered by moving the search unit in parallel paths with not less than 10% overlap.

*(c) Acceptance Standards*. Material which shows one or more imperfections which produce indications exceeding in amplitude the indication from the calibration notch is unacceptable.

### NG-2537 Time of Examination

Acceptance examinations shall be performed at the time of manufacture as required in the following:

*(a) Ultrasonic examination* shall be performed after rolling to size and after heat treatment, except postweld heat treatment.

*(b) Radiographic examination* of repair welds, when required, may be performed prior to any required postweld heat treatment.

*(c) Magnetic particle or liquid penetrant examination of repair welds* in ferritic material shall be performed after final heat treatment, except that the examination may be performed prior to postweld heat treatment of P-No. 1 material 2 in. (50 mm) and less nominal thickness. All repair welds in austenitic and nonferrous material may be liquid penetrant examined prior to any required postweld heat treatment.

### NG-2538 Elimination of Surface Defects

Surface defects shall be removed by grinding or machining, provided the following requirements are met:

*(a)* The depression, after defect elimination, is blended uniformly into the surrounding surface with not less than a 3:1 taper.

*(b)* After defect elimination, the area is examined by the magnetic particle method in accordance with NG-2545 or the liquid penetrant method in accordance with NG-2546 to assure that the defect has been removed or reduced to an imperfection of an acceptable size.

*(c)* Areas ground to remove oxide scale or other mechanically caused impressions for appearance or to facilitate proper ultrasonic testing need not be examined by the magnetic particle or liquid penetrant test method.

*(d)* If the elimination of the defect reduces the thickness of the section below the minimum required to satisfy the rules of Article NG-3000, the product shall be repaired in accordance with NG-2539.

## NG-2539 Repair by Welding

Material from which defects have been removed may be repaired by welding, provided the requirements of the following subparagraphs are met. Prior approval of the Certificate Holder shall be obtained for any repair of plates to be used in the manufacture of core support structures.

**NG-2539.1 Defect Removal.** The defect shall be removed or reduced to an imperfection of an acceptable size by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair (see NG-4211.1).

**NG-2539.2 Qualification of Welding Procedures and Welders.** The welding procedure and welders or welding operators shall be qualified in accordance with Article NG-4000 and Section IX.

**NG-2539.3 Blending of Repaired Areas.** After repair, the surface shall be blended uniformly into the surrounding surface.

**NG-2539.4 Examination of Repair Welds.** Each repair weld shall be examined by the magnetic particle method (see NG-2545) or by the liquid penetrant method (see NG-2546). In addition, when the depth of the repair cavity exceeds the lesser of $^{3}/_{8}$ in. (10 mm) or 10% of the section thickness, the repair weld shall be radiographed in accordance with Article NG-5000 and to the acceptance standards of NG-5320 or shall be ultrasonically examined after repair in accordance with NG-2532.2 or NG-2532.1.

**NG-2539.5 Heat Treatment After Repairs.** The product shall be heat-treated after repair in accordance with the heat treatment requirements of NG-4620.

**NG-2539.6 Material Report Describing Defects and Repairs.** Each defect repair exceeding in depth the lesser of $^{3}/_{8}$ in. (10 mm) or 10% of the section thickness and, in addition, all repair welds exceeding an accumulated area of 20% of the area of the part or 15 in.$^2$ (9700 mm$^2$), whichever is less, shall be described in the Certified Material Test Report. The Certified Material Test Report for each piece shall include a chart which shows the location and size of the prepared cavity, the welding material identification, the welding procedure, the heat treatment, and the examination results, including radiographs.

## NG-2540 EXAMINATION AND REPAIR OF FORGINGS AND BARS

### NG-2541 Required Examinations

*(a)* Forgings and bars except as noted in NG-2551 shall be examined by the ultrasonic method in accordance with NG-2542, except that forgings or sections of forgings which have coarse grains or configurations which do not yield meaningful examination results by ultrasonic methods shall be examined by radiographic methods in accordance with Section V, Article 2, and the acceptance standards of NG-5320. In addition, selected surfaces, as designated by the Certificate Holder, shall be liquid penetrant examined in accordance with NG-2546 or magnetic particle examined in accordance with NG-2545.

*(b)* Forged flanges and fittings, such as elbows, tees, and couplings, shall be examined in accordance with the requirements of NG-2550.

*(c)* Bar material used for threaded structural fasteners shall be examined in accordance with NG-2580.

### NG-2542 Ultrasonic Examination

**NG-2542.1 Examination Procedure.** All forgings in the rough forged or finished condition, and bars, shall be examined in accordance with one of the following specifications: SA-745, Standard Practice for Ultrasonic Examination of Austenitic Steel Forgings; or SA-388, Recommended Practice for Ultrasonic Testing and Inspection of Heavy Steel Forgings, as shown in Section V, Article 23. Contact, immersion, or water column coupling is permissible. The following techniques are required, as applicable:

*(a)* All forgings and bars shall be examined by the ultrasonic method using the straight beam technique.

*(b)* Ring forgings and other hollow forgings shall, in addition, be examined using the angle beam technique in two circumferential directions, unless wall thickness or geometric configuration makes angle beam examination impractical.

*(c)* Forgings may be examined by the use of alternative ultrasonic methods which utilize distance amplitude corrections provided the acceptance standards are shown to be equivalent to those listed in NG-2542.2.

**NG-2542.2 Acceptance Standards.**

*(a) Straight Beam General Rule.* A forging shall be unacceptable if the results of straight beam examinations show one or more reflectors which produce indications accompanied by a complete loss of back reflection not associated with or attributable to geometric configurations. Complete loss of back reflection is assumed when the back reflection falls below 5% of full calibration screen height.

*(b) Angle Beam Rule.* A forging shall be unacceptable if the results of angle beam examinations show one or more reflectors which produce indications exceeding in amplitude the indication from the appropriate calibration notches.

## NG-2545 Magnetic Particle Examination

**NG-2545.1 Examination Procedure.** The procedure for magnetic particle examination shall be in accordance with the methods of Section V, Article 7.

**NG-2545.2 Evaluation of Indications.**

*(a)* Mechanical discontinuities at the surface are revealed by the retention of the examination medium. All indications are not necessarily defects, however, since certain metallurgical discontinuities and magnetic permeability variations may produce similar indications which are not relevant.

*(b)* Any indication in excess of the NG-2545.3 acceptance standards which is believed to be nonrelevant shall be reexamined by the same or other nondestructive examination methods to verify whether or not actual defects are present. Surface conditioning may precede the reexamination. Nonrelevant indications which would mask defects are unacceptable.

*(c)* Relevant indications are indications which result from imperfections. Linear indications are indications in which the length is more than three times the width. Rounded indications are indications which are circular or elliptical with the length equal to or less than three times the width.

**NG-2545.3 Acceptance Standards.**

*(a)* Only imperfections producing indications with major dimensions greater than $^{1}/_{16}$ in. (1.5 mm) shall be considered relevant imperfections.

*(b)* Imperfections producing the following relevant indications are unacceptable:

*(1)* any linear indications greater than $^{1}/_{16}$ in. (1.5 mm) long for material less than $^{5}/_{8}$ in. (16 mm) thick, greater than $^{1}/_{8}$ in. (3 mm) long for material from $^{5}/_{8}$ in. (16 mm) thick to under 2 in. (50 mm) thick, and $^{3}/_{16}$ in. (5 mm) long for material 2 in. (50 mm) thick and greater

*(2)* rounded indications with dimensions greater than $^{1}/_{8}$ in. (3 mm) for thicknesses less than $^{5}/_{8}$ in. (16 mm) and greater than $^{3}/_{16}$ in. (5 mm) for thicknesses $^{5}/_{8}$ in. (16 mm) and greater

*(3)* four or more relevant indications in a line separated by $^{1}/_{16}$ in. (1.5 mm) or less edge to edge

*(4)* ten or more relevant indications in any 6 in.$^2$ (4 000 mm$^2$) of area whose major dimension is no more than 6 in. (150 mm) with the dimensions taken in the most unfavorable location relative to the indications being evaluated

## NG-2546 Liquid Penetrant Examination

**NG-2546.1 Examination Procedure.** The procedure for liquid penetrant examination shall be in accordance with the methods of Section V, Article 6.

**NG-2546.2 Evaluation of Indications.**

*(a)* Mechanical discontinuities at the surface are revealed by bleeding out of the penetrant; however, localized surface discontinuities such as may occur from machining marks or surface conditions may produce similar indications which are not relevant.

*(b)* Any indication in excess of the NG-2546.3 acceptance standards that is believed to be nonrelevant shall be reexamined to verify whether or not actual defects are present. Surface conditioning may precede the reexamination. Nonrelevant indications and broad areas of pigmentation which would mask defects are unacceptable.

*(c)* Relevant indications are indications which result from imperfections. Linear indications are indications in which the length is more than three times the width. Rounded indications are indications which are circular or elliptical with the length equal to or less than three times the width.

**NG-2546.3 Acceptance Standards.**

*(a)* Only imperfections producing indications with major dimensions greater than $^{1}/_{16}$ in. (1.5 mm) shall be considered relevant imperfections.

*(b)* Imperfections producing the following relevant indications are unacceptable:

*(1)* any linear indications greater than $^{1}/_{16}$ in. (1.5 mm) long for material less than $^{5}/_{8}$ in. (16 mm) thick, greater than $^{1}/_{8}$ in. (3 mm) long for material from $^{5}/_{8}$ in. (16 mm) thick to under 2 in. (50 mm) thick, and $^{3}/_{16}$ in. (5 mm) long for materials 2 in. (50 mm) thick and greater

*(2)* rounded indications with dimensions greater than $^{1}/_{8}$ in. (3 mm) for thicknesses less than $^{5}/_{8}$ in. (16 mm) and greater than $^{3}/_{16}$ in. (5 mm) for thicknesses $^{5}/_{8}$ in. (16 mm) and greater

*(3)* four or more relevant indications in a line separated by $^{1}/_{16}$ in. (1.6 mm) or less edge to edge

*(4)* ten or more relevant indications in any 6 in.$^2$ (4 000 mm$^2$) of area whose major dimension is no more than 6 in. (150 mm) with the dimensions taken in the most unfavorable location relative to the indications being evaluated

## NG-2547 Time of Examination

Acceptance examinations, including those for repair welds, shall be performed at the time of manufacture as required in the following:

*(a)* Ultrasonic examination may be performed at any time after forging, and the maximum practical volume shall be examined after final heat treatment, excluding postweld heat treatment.

*(b)* Radiographic examination of repair welds, if required, may be performed prior to any required postweld heat treatment.

### NG-2548 Elimination of Surface Defects

Elimination of surface defects shall be made in accordance with NG-2538.

### NG-2549 Repair by Welding

Repair by welding shall be in accordance with NG-2539, except that

*(a)* the depth of repair that is permitted is not limited, and

*(b)* for ferritic steel forgings, the completed repair may be examined by the ultrasonic methods in accordance with the requirements of NG-2542 in lieu of radiography.

## NG-2550 EXAMINATION AND REPAIR OF SEAMLESS AND WELDED TUBULAR PRODUCTS AND FITTINGS

### NG-2551 Required Examination

*(a)* The examination performed shall be practical and yield meaningful pertinent information for the product form being examined. Certain examination methods are ineffective for some material conditions and product configuration. Some examples are

*(1)* it may not be practical or meaningful to examine irregular shapes such as welding flanges and fittings by ultrasonic methods

*(2)* ultrasonic examination employing special techniques is required on coarse-grained austenitic stainless steel or coarse-grained, nickel-base alloy materials

*(b)* Welded tubular products and fittings, including flanges and fittings, made from plate material greater than $^{3}/_{4}$ in. (19 mm) in thickness shall be ultrasonically or radiographically examined in accordance with NG-2552 or NG-2553.

*(c)* All welds in welded tubular products and fittings, including flanges and fittings, shall be ultrasonically or radiographically examined in accordance with NG-2552 or NG-2553. In addition, all welds shall be magnetic particle or liquid penetrant examined on all accessible surfaces in accordance with NG-2555 or NG-2556.

*(d)* Wrought seamless tubular products and fittings, including flanges and fittings machined from forgings and bars, greater than $^{3}/_{8}$ in. (10 mm) thickness shall be ultrasonically or radiographically examined in accordance with NG-2552 or NG-2553.

### NG-2552 Ultrasonic Examination

**NG-2552.1 Examination Procedure.** The procedure for ultrasonic examination shall provide a sensitivity which will consistently detect defects that produce indications equal to and greater than the indication produced by standard defects included in the reference specimen specified in NG-2552.2. Products with defects that produce indications in excess of the indications produced by the standard defects in the reference specimens are unacceptable unless the defects are eliminated or repaired in accordance with NG-2558 or NG-2559, as applicable.

**NG-2552.2 Reference Specimens.**

*(a)* The reference specimen shall be of the same nominal diameter and thickness and of the same nominal composition and heat-treated condition as the product which is being examined. The standard defects shall be axial notches or grooves on the outside and the inside surfaces of the reference specimen and shall have a length of approximately 1 in. (25 mm) or less, a width not to exceed $^{1}/_{16}$ in. (1.5 mm), and a depth not greater than the larger of 0.004 in. (0.10 mm) or 5% of the nominal wall thickness. The reference specimen may be the product being examined.

*(b)* The reference specimen shall be long enough to simulate the handling of the product being examined through the examination equipment. When more than one standard defect is placed in a reference specimen, the defects shall be located so that indications from each defect are separate and distinct without mutual interference or amplification.

**NG-2552.3 Checking and Calibration of Equipment.** The proper functioning of the examination equipment shall be checked and the equipment shall be calibrated by the use of the reference specimens, as a minimum

*(a)* at the beginning of each production run of a given size and thickness of a given material

*(b)* after each 4 hr or less during the production run

*(c)* at the end of the production run

*(d)* at any time that malfunctioning is suspected

If during any check it is determined that the testing equipment is not functioning properly, all of the product that has been tested since the last valid equipment calibration shall be reexamined.

### NG-2553 Radiographic Examination

The radiographic examination shall be performed in accordance with Section V, Article 2, as modified by NG-5111, using the acceptance requirements of NG-5320.

### NG-2555 Magnetic Particle Examination

The magnetic particle examination shall be performed in accordance with the requirements of NG-2545.

### NG-2556 Liquid Penetrant Examination

The liquid penetrant examination shall be performed in accordance with the requirements of NG-2546.

### NG-2557 Time of Examination

Time of acceptance examination, including that of repair welds, shall be in accordance with NG-2537.

### NG-2558 Elimination of Surface Defects

Surface defects shall be removed by grinding or machining provided the following requirements are met:

*(a)* The depression, after defect elimination, is blended uniformly into the surrounding surface.

*(b)* After defect elimination, the area is reexamined by the method which originally disclosed the defect to assure that the defect has been removed or reduced to an imperfection of acceptable size.

*(c)* If the elimination of the defect reduces the thickness of the section below the minimum required to satisfy the rules of Article NG-3000, the product shall be repaired in accordance with NG-2559.

### NG-2559 Repair by Welding

Repair welding of base material defects shall be in accordance with NG-2539. Repair welding of seam defects shall be made in accordance with NG-4450.

## NG-2570 EXAMINATION AND REPAIR OF STATICALLY AND CENTRIFUGALLY CAST PRODUCTS

### NG-2571 Required Examinations

**NG-2571.1 General Requirements.** The portion of castings, as specified by the Design Specifications or drawings, used for core support structures shall be examined over the maximum feasible volume by radiographic methods, or ultrasonic methods, or a combination of both methods. Castings or sections of castings which have coarse grains or configurations which do not yield meaningful examination results by ultrasonic methods shall be examined by radiographic methods. In addition, the portion of castings used for core support structures shall be examined on accessible surfaces by either magnetic particle or liquid penetrant methods. Accessible machined surfaces, except threaded surfaces, of a cast product shall be examined by either liquid penetrant or magnetic particle methods after machining.

**NG-2571.2 Alternative General Requirements.** The portion of castings 2 in. (50 mm) thick and less, which are specified by the Design Specifications or drawings to be used for core support structures, may be utilized when the following requirements are met:

*(a)* The design stress intensity values in Section II, Part D, Subpart 1, Tables 2A and 2B are reduced by applying a quality factor of 0.75.

*(b)* A fatigue strength reduction factor of 2.0 is applied to the allowable $S_a$ values when peak stresses are considered.

*(c)* The portions of castings used as core support structures are magnetic particle or liquid penetrant examined per NG-2575 or NG-2576 on all accessible as-cast or, if machined, machine-finished surfaces. The acceptance criteria of NG-2575 or NG-2576 shall be utilized except that no linear indications greater than $^1/_{16}$ in. (1.5 mm) are permitted.

*(d)* Five pilot castings[10] made from a new or altered design of a production run[11] shall be radiographically examined over the maximum feasible volume to the requirements of NG-2573.1. If all five pilot castings meet the radiographic acceptance criteria, a production run may be poured. The production run shall be examined using either of the sampling plans specified in (1) or (2) below. The five pilot castings, having passed examination, are not to be included in the following sampling examination programs:

*(1)* The production run shall be considered a single lot. Twenty castings shall be randomly selected from the production run and examined to the requirements of the pilot castings. The production run is accepted if all 20 castings meet the examination requirements and it is rejected if any one of the 20 castings does not meet the examination requirements. Acceptable castings may be retrieved from a rejected production run by examining all castings from that production run.

*(2)* The production run castings shall, in order of manufacture, be grouped into sublots with a maximum of 25 castings each. Five castings shall be randomly selected from each sublot and examined to the requirements of the pilot castings. The sublot is accepted if all five castings meet the examination requirements and it is rejected if any one of the five castings does not meet the examination requirements. In the event two sublots are rejected by the sampling examination, succeeding sublots shall have eight castings randomly selected for examination to the requirements of the pilot castings. In any event, acceptable castings may be retrieved from a rejected sublot by examining all castings from that sublot.

### NG-2572 Ultrasonic Examination of Castings

The requirements for ultrasonic examination of statically and centrifugally cast products are given in the following subparagraphs.

**NG-2572.1 Straight Beam Method.** When castings are to be examined ultrasonically, all sections, regardless of thickness, shall be examined in accordance with SA-609, Standard Method and Specification for Longitudinal Beam Ultrasonic Inspection of Carbon and Low Alloy Castings, as

shown in Section V; however, supplementary angle beam examination in accordance with NG-2572.2 or radiographic examination in accordance with NG-2573 shall be performed in areas where a back reflection cannot be maintained during the straight beam examination, or where the angle between the two surfaces of the casting is more than 15 deg.

**NG-2572.2 Angle Beam Method.** Examination shall be conducted in accordance with Section V, Article 5, T-571.4, except that the acceptance standards in Section V do not apply.

**NG-2572.3 Acceptance Standards.**

*(a)* The Quality Levels of SA-609 as shown in Section V shall apply for the casting thicknesses indicated.

*(1)* Quality Level 1 for thicknesses up to 2 in. (50 mm)

*(2)* Quality Level 3 for thicknesses 2 in. to 4 in. (50 mm to 100 mm)

*(3)* Quality Level 4 for thicknesses greater than 4 in. (100 mm)

*(b)* In addition to the Quality Level requirements stated in (a), the requirements in (1) through (5) shall apply for both straight beam and angle beam examination.

*(1)* Area imperfections producing indications exceeding the Amplitude Reference Line with any dimension longer than those specified in the following tabulation are unacceptable:

| UT Quality Level | Longest Dimension of Area [Notes (1)–(3)] |
|---|---|
| 1 | 1.5 in. (38 mm) |
| 2 | 2.0 in. (50 mm) |
| 3 | 2.5 in. (64 mm) |
| 4 | 3.0 in. (75 mm) |

NOTES:

(1) The areas for the Ultrasonic Quality Levels in SA-609 as shown in Section V refer to the surface area on the casting over which a continuous indication exceeding the transfer-corrected distance-amplitude curve is maintained.

(2) Areas are to be measured from dimensions of the movement of the search unit, using the center of the search unit as the reference point.

(3) In certain castings, because of very long metal path distances or curvature of the examination surfaces, the surface area over which a given discontinuity is detected may be considerably larger or smaller than the actual area of the discontinuity in the casting; in such cases, other criteria which incorporate a consideration of beam angles or beam spread must be used for realistic evaluation of the discontinuity.

*(2)* Quality Level 1 shall apply for the volume of castings within 1 in. (25 mm) of the surface regardless of the overall thickness.

*(3)* Imperfections indicated to have a change in depth equal to or greater than one-half the wall thickness or 1 in., whichever is less, are unacceptable.

*(4)* Two or more imperfections in the same plane with indication amplitudes exceeding the Amplitude Reference Line and separated by a distance less than the longest dimension of the larger of the adjacent imperfections are unacceptable if they cannot be encompassed within an area less than that of the Quality Level specified in (1) above.

*(5)* Two or more imperfections greater than permitted for Quality Level 1 for castings less than 2 in. (50 mm) in thickness, greater than permitted for Quality Level 2 for thickness 2 in. through 4 in. (50 mm to 100 mm), and greater than permitted for Quality Level 3 for thickness greater than 4 in. (100 mm), separated by a distance less than the longest dimension of the larger of the adjacent imperfections, are unacceptable if they cannot be encompassed in an area less than that of the Quality Level requirements stated in (a) above.

## NG-2573 Radiographic Examination

**NG-2573.1 Extent, Methods, and Acceptance Standards.** Radiographic examination, where required, shall be performed on castings used for core support structures. The radiographic methods shall be in accordance with ASTM E94, Recommended Practice for Radiographic Testing, and ASTM E142, Controlling Quality of Radiographic Testing, and shall meet the acceptance requirements of Severity Level 3 for Category A and B defects and Severity Level 2 for Category C defects of ASTM E446,[12] Reference Radiographs for Steel Castings Up To 2 in. (50 mm) In Thickness, ASTM E186,[12] Reference Radiographs for Heavy-Walled [2 to 4½ in. (50 mm to 114 mm)] Steel Castings, or ASTM E280,[12] Reference Radiographs for Heavy-Walled [4½ to 12 in. (114 mm to 300 mm)] Steel Castings, as applicable for the thickness being radiographed, except that Category D, E, F, or G defects are not acceptable. ASTM E280[12] shall also apply for castings over 12 in. (300 mm) in thickness.

**NG-2573.2 Examination Requirements.** Radiographic examination shall be performed in accordance with Section V, Article 2, Mandatory Appendix VII Radiographic Examination of Metallic Castings, with the following modifications:

*(a)* The geometric unsharpness limitations of Section V, Article 2, T-274.2 need not be met.

*(b)* The examination procedure or report shall also address the following:

*(1)* type and thickness of filters, if used

*(2)* for multiple film technique, whether viewing is to be single or superimposed, if used

*(3)* blocking or masking technique, if used

*(4)* orientation of location markers

*(5)* description of how internal markers, when used, locate the area of interest

*(c)* The location of location markers (e.g., lead numbers or letters) shall be permanently stamped on the surface of the casting in a manner permitting the area of interest on a radiograph to be accurately located on the casting and providing evidence on the radiograph that the extent of coverage required by NG-2573.1 has been obtained. For castings or sections of castings where stamping is not feasible, the radiographic procedure shall so state and a radiographic exposure map shall be provided.

## NG-2575 Magnetic Particle Examination

The magnetic particle examination, when required, shall be performed in accordance with the requirements of NG-2545.

## NG-2576 Liquid Penetrant Examination

The liquid penetrant examination, when required, shall be performed in accordance with the requirements of NG-2546.

## NG-2577 Time of Examination

Acceptance examinations, including those for weld repairs, shall be performed as stipulated in the following subparagraphs.

**NG-2577.1 Ultrasonic Examination.** Ultrasonic examination, if required, shall be performed at the stage of manufacture as required for radiography.

**NG-2577.2 Radiographic Examination.**

*(a)* Radiography shall be performed after final heat treatment as required by the material specification, except radiography may be performed prior to postweld heat treatment. The examination shall be performed at the stage of manufacture defined in this subparagraph.

*(b)* Castings prior to finish machining shall be radiographed at the limiting thicknesses stipulated in the following:

*(1)* For thicknesses less than 2 in. (50 mm), castings shall be radiographed within 50% of the finished thickness. The image quality indicator (IQI) shall be based on the final thickness.

*(2)* For thicknesses less than 6 in. (150 mm) but greater than 2 in. (50 mm), castings shall be radiographed within 20% of the finished thickness. The IQI shall be based on the final thickness.

*(3)* For thicknesses 6 in. (150 mm) and greater, castings shall be radiographed within 10% of the finished thickness. The IQI shall be based on the final thickness.

*(4)* Where casting practices for core support structure sections require thickness to exceed the finished machined thickness limits of (2) and (3) above, radiography of the as-cast thickness is acceptable provided the acceptance reference radiographs of the next lesser thickness are met in those areas; e.g., if the section being radiographed exceeds $4\frac{1}{2}$ in. (114 mm), use ASTM E186[12] reference radiographs. The IQI shall be based on the thickness of the section being radiographed.

**NG-2577.3 Magnetic Particle or Liquid Penetrant Examination.** Magnetic particle or liquid penetrant examination shall be performed after the final heat treatment required by the material specification. Repair weld areas shall be examined after postweld heat treatment when a postweld heat treatment is performed, except that repair welds in P-No. 1 material, 2 in. (50 mm) nominal thickness and less, may be examined prior to postweld heat treatment. For cast products with machined surfaces, all accessible finished machined surfaces, except threaded surfaces, shall also be examined by magnetic particle or liquid penetrant methods.

## NG-2578 Elimination of Surface Defects

Elimination of surface defects shall be in accordance with NG-2538.

## NG-2579 Repair by Welding

The Material Organization may repair castings by welding after removing the material containing defects. The depth of the repair is not limited. A cored hole or access hole may be closed by the Material Organization by welding in accordance with the requirements of this paragraph, provided the hole is closed by filler metal only. If the hole is closed by welding in a metal insert, the welding shall be in accordance with the requirements of Article NG-4000 by a Certificate of Authorization Holder.

**NG-2579.1 Defect Removal.** The defect shall be removed or reduced to an imperfection of an acceptable size by suitable mechanical or thermal cutting or gouging methods, and the cavity prepared for repair. When thermal cutting is performed, consideration shall be given to preheating the material.

**NG-2579.2 Qualification of Welding Procedures and Welders.** The welding procedure and welders or welding operators shall be qualified in accordance with Article NG-4000 and Section IX.

**NG-2579.3 Blending of Repaired Areas.** After welding, the surface shall be blended uniformly into the surrounding surface.

**NG-2579.4 Examination of Repair Welds.** Each repair weld shall be examined by the magnetic particle method (see NG-2545) or by the liquid penetrant method (see NG-2546). In addition, repair welds in cavities the depth of which exceeds the lesser of $\frac{3}{8}$ in. (10 mm) or 10% of the section thickness shall be radiographed in accordance with NG-2573. The radiographic method and acceptance standards of NG-2573 shall apply except that weld slag, including elongated slag, shall be

considered as inclusions under Category B of the applicable reference radiographs. The total area of all inclusions, including slag inclusions, shall not exceed the limits of the applicable severity level of Category B of the reference radiographs.

**NG-2579.5 Heat Treatment After Weld Repair.** After repair, the casting shall be heat-treated in accordance with NG-4620, except that the heating and cooling limitations of NG-4623 do not apply.

**NG-2579.6 Material Report Describing Defects and Repairs.** Each repair weld exceeding in depth either $^{3}/_{8}$ in. (10 mm) or 10% of the section thickness shall be described in the Certified Material Test Report. The Certified Material Test Report shall include a chart for each repaired casting which shows the location and size of the repaired cavity, the welding material identification, the welding procedure, the heat treatment, and the examination results, including radiographs.

## NG-2580 EXAMINATION OF THREADED STRUCTURAL FASTENERS

### NG-2581 Required Examinations

Threaded structural fasteners shall be visually examined in accordance with NG-2582. In addition, externally threaded structural fasteners $^{3}/_{8}$ in. (10 mm) and greater and nuts greater than 1 in. (25 mm) shall be examined by either the magnetic particle or liquid penetrant method in accordance with NG-2583. In addition, nominal sizes greater than $^{1}/_{2}$ in. (13 mm) but not over 4 in. (100 mm) shall be examined by ultrasonic methods in accordance with NG-2584, and nominal sizes greater than 4 in. (100 mm) shall be examined by ultrasonic methods in accordance with both NG-2584 and NG-2585.

### NG-2582 Visual Examination

The final surfaces of threads, shanks, and heads of externally threaded structural fasteners less than $^{3}/_{8}$ in. (10 mm) and nuts 1 in. (25 mm) and smaller shall be visually examined for workmanship, finish, and appearance in accordance with the requirements of ASTM F788 for threaded structural fasteners and ASTM F812 for nuts prior to plating or other surface protection-type treatments. The visual examination personnel shall be trained and qualified in accordance with the Material Organization's Quality System Program or the Certificate Holder's Quality Assurance Program. These examinations are not required to be performed either in accordance with procedures qualified to NG-5100 or by personnel qualified in accordance with NG-5500.

### NG-2583 Magnetic Particle or Liquid Penetrant Examination

Externally threaded structural fasteners $^{3}/_{8}$ in. (10 mm) and greater and nuts greater than 1 in. (25 mm) shall be examined by a magnetic particle method (see NG-2545) or a liquid penetrant method (see NG-2546). Such examination shall be performed on the finished threaded structural fastener after threading and prior to plating or other surface protection type treatments. On threaded surfaces no relevant indications are permitted. Relevant indications include any linear indications or rounded indications greater than $^{1}/_{16}$ in. (1.5 mm). Indications, caused by a particular manufacturing method, that may appear to be relevant, such as the crest of rolled threads or root of cut threads, may be shown to be nonrelevant and acceptable by prior process qualification or destructive metallographic examination. On all other accessible surfaces, no linear indications or rounded indications greater than $^{1}/_{16}$ in. (1.5 mm) are permitted, except that linear axial indications less than one diameter or 1 in. (25 mm) in length are permitted.

### NG-2584 Ultrasonic Examination for Sizes Greater Than $^{1}/_{2}$ in. (13 mm)

All threaded structural fasteners greater than $^{1}/_{2}$ in. (13 mm) nominal bolt size shall be ultrasonically examined over the entire cylindrical surface prior to threading, in accordance with the requirements of the following subparagraphs.

**NG-2584.1 Ultrasonic Method.** Examination shall be carried out by the straight beam, radial scan method.

**NG-2584.2 Examination Procedure.** Examination shall be performed at a nominal frequency of 2.25 MHz unless variables such as production material grain structure require the use of other frequencies to ensure adequate penetration or better resolution. The search unit area shall not exceed 1 in.$^2$ (650 mm$^2$).

**NG-2584.3 Calibration of Equipment.** Calibration sensitivity shall be established by adjustment of the instrument so that the first back reflection is 75% to 90% of full screen height.

**NG-2584.4 Acceptance Standards.** Any imperfection which causes an indication in excess of 20% of the height of the first back reflection or any imperfection which prevents the production of a first back reflection of 50% of the calibration amplitude is not acceptable.

### NG-2585 Ultrasonic Examination for Sizes Over 4 in. (100 mm)

In addition to the requirements of NG-2584, all threaded structural fasteners over 4 in. (100 mm) shall be ultrasonically examined over the entire surface of

each end before or after threading in accordance with the requirements of the following subparagraphs.

**NG-2585.1 Ultrasonic Method.** Examination shall be carried out by the straight beam, longitudinal mode scan method.

**NG-2585.2 Examination Procedure.** Examination shall be performed at a nominal frequency of 2.25 MHz unless variables such as production material grain structure require the use of other frequencies to ensure adequate penetration or better resolution. The search unit shall have a circular cross section with a diameter not less than ½ in. (13 mm) nor greater than 1⅛ in. (29 mm).

**NG-2585.3 Calibration of Equipment.** 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 ⅜ in. (10 mm) diameter × 3 in. (75 mm) 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.

**NG-2585.4 Acceptance Standards.** Any imperfection which causes an indication in excess of 50% of that produced by the calibration hole in the reference specimen, as corrected by the distance–amplitude correction curve, is not acceptable.

### NG-2586 Elimination of Surface Defects

Surface defects may be eliminated by grinding or machining, provided the final dimension of the affected portion meets the requirements of the design and the area is reexamined by the magnetic particle or liquid penetrant method in accordance with NG-2583.

## NG-2600 MATERIAL ORGANIZATIONS' QUALITY SYSTEM PROGRAMS

### (23) NG-2610 DOCUMENTATION AND MAINTENANCE OF QUALITY SYSTEM PROGRAMS

*(a)* Except as provided in (b) below, Material Organizations shall have a Quality System Program that meets the requirements of NCA-3300.

*(b)* The requirements of NCA-1224 and NCA-1225 shall be met as required by NG-2130. The other requirements of NCA-3300 and NCA-4200 need not be used by Material Organizations for small products, as defined in (c) below; for material used in items commensurate with their contribution to safety or risk, as defined in (d) below; and for material that is allowed by this Subsection to be furnished with a Certificate of Compliance. For these products, the Certificate Holder's Quality Assurance Program (see NCA-4100) shall include measures to provide assurance that the material is furnished in accordance with the material specification and with the applicable special requirements of this Subsection.

*(c)* For the purpose of this paragraph, small products are defined as given in the following:

*(1)* pipe, tube (except heat exchanger tube), pipe fittings, and flanges 2 in. nominal pipe size (DN 50) and less

*(2)* threaded structural fastener material, including studs and nuts of 1 in. (25 mm) nominal diameter and less

*(3)* bars with a nominal cross-sectional area of 1 in.$^2$ (650 mm$^2$) and less

*(d)* For the purpose of this paragraph, items commensurate with their contribution to safety or risk are defined as given in (1) and (2) below.

*(1)* the Owner or the Owner's designee has established that the exemption is consistent with the safety or risk significance of the item. The determination of the safety or risk significance of the item to design and operations is beyond the scope of this Section. Appropriate guidance for the safety or risk significance of the item shall be derived from system criteria documents for specific types of nuclear power systems and may be found in the requirements of regulatory and enforcement authorities having jurisdiction at the site.

*(2)* The Owner or the Owner's designee has permitted the exemption in the Design Specification and shall specify to which items this exemption applies.

# ARTICLE NG-3000
# DESIGN

## NG-3100 GENERAL DESIGN

### NG-3110 LOADING CRITERIA

### NG-3111 Loading Conditions

The loadings that shall be taken into account in designing core support structures include, but are not limited to, those in the following:

*(a)* pressure differences due to coolant flow

*(b)* weight of the core support structure

*(c)* superimposed loads such as those due to other structures, the reactor core, steam separating equipment, flow distributors and baffles, thermal shields, and safety equipment

*(d)* earthquake loads or other loads which result from motion of the reactor vessel

*(e)* reactions from supports, restraints, or both

*(f)* loads due to temperature effects, thermal gradients and differential expansion, or both

*(g)* loads resulting from the impingement or flow of reactor coolant, or other contained or surrounding fluids

*(h)* transient pressure difference loads, such as those which result from rupture of the main coolant pipe

*(i)* vibratory loads

*(j)* loads resulting from the operation of machinery, such as snubbing of control rods

*(k)* handling loads experienced in preparation for or during refueling or in-service inspection

### NG-3112 Design Loadings

The Design Loadings are the pressure differences, temperatures, and various forces applicable to the design of core support structures as defined in the following subparagraphs.

(23) **NG-3112.1 Design Pressure Difference.**

*(a)* The specified internal and external Design Pressure Difference shall be established in accordance with NCA-2142.1(a). When the occurrence of different pressure differences during service can be predicted for different zones of a structure, the Design Pressure Difference of the different zones may be based on their predicted pressure difference.

*(b)* The Design Pressure Difference shall include allowances for pressure difference surges.

**NG-3112.2 Design Temperature.** The Design Temperature shall be established in accordance with NCA-2142.1(b). It shall be used in computations involving the Design Pressure Difference and coincidental Design Mechanical Loads. The actual metal temperature at the point under consideration shall be used in all computations where the use of the actual service pressure difference is required.

*(a)* All temperatures referred to in this Article are the metal temperatures expressed in degrees Fahrenheit (°F) [degrees Celsius (°C)].

*(b)* Where a core support structure is heated by tracing, induction coils, jacketing, or internal heat generation, the effect of such heating shall be incorporated in the establishment of the Design Temperature.

**NG-3112.3 Design Mechanical Loads.** The specified Design Mechanical Loads shall be established in accordance with NCA-2142.1(c). They shall be used in conjunction with the Design Pressure Difference. The following requirements shall also apply: (23)

*(a)* Impact forces caused by either external or internal conditions shall be considered.

*(b)* The effects of earthquake shall be considered in the design of core support structures. The loadings, movements, and number of cycles to be used in the analysis shall be part of the Design Specifications. The stresses resulting from these earthquake effects shall be included with pressure differences or other applied loads.

*(c)* Core support structures shall be arranged and supported so that vibration will be minimized.

**NG-3112.4 Design Stress Intensity Values.** Design stress intensity values for materials are listed in Section II, Part D, Subpart 1, Tables 2A and 2B. The material shall not be used at metal temperatures and Design Temperatures that exceed the temperature limit in the applicability column for which stress intensity values are listed. The values in the Table may be interpolated for intermediate temperatures.

### NG-3113 Service Loadings

Each loading to which the structure may be subjected shall be classified in accordance with NCA-2142 and Service Limits [NCA-2142.4(b)] designated in the Design Specifications in such detail as will provide a

complete basis for design, construction, and inspection in accordance with these rules.

## NG-3120 SPECIAL CONSIDERATIONS

### NG-3121 Corrosion

Material subject to thinning by corrosion, erosion, mechanical abrasion, or other environmental effects shall have provision made for these effects during the design or specified life of the structure by a suitable increase in or addition to the thickness of the base metal over that determined by the design equations. Material added or included for these purposes need not be of the same thickness for all areas of the structure if different rates of attack are expected for the various areas. It should be noted that the tests on which the design fatigue curves (Section III Appendices, Mandatory Appendix I) are based did not include tests in the presence of corrosive environments which might accelerate fatigue failure.

### (23) NG-3122 Cladding

The rules of this paragraph apply to the design analysis of clad structures constructed of material permitted in Section II, Part D, Subpart 1, Tables 2A and 2B.

**NG-3122.1 Primary Stresses.** No structural strength shall be attributed to the cladding in satisfying NG-3210(c)(1) and Section III Appendices, Mandatory Appendix XIII, XIII-3110.

**NG-3122.2 Design Dimensions.** The dimensions given in (a) and (b) shall be used in the design of the component.

*(a)* For structures subjected to internal pressure difference, the inside diameter shall be taken at the nominal inner face of the cladding.

*(b)* For structures subjected to external pressure difference, the outside diameter shall be taken at the outer face of the base metal.

**NG-3122.3 Secondary and Peak Stresses.** In satisfying Section III Appendices, Mandatory Appendix XIII, XIII-3420 and XIII-3500(b), the presence of the cladding shall be considered with respect to both the thermal analysis and the stress analysis. The stresses in both materials shall be limited to the values specified in Section III Appendices, Mandatory Appendix XIII, XIII-3420 and XIII-3500. However, when the cladding is of the integrally bonded type and the nominal thickness of the cladding is 10% or less of the total thickness of the structure, the presence of the cladding may be neglected.

**NG-3122.4 Bearing Stresses.** In satisfying NG-3210(a)(2), the presence of cladding shall be included.

### NG-3123 Welds Between Dissimilar Metals

In satisfying the requirements of this subarticle, caution should be exercised in design and construction involving dissimilar metals having different coefficients of thermal expansion in order to avoid difficulties in service.

### NG-3124 Environmental Effects

Changes in material properties may occur due to environmental effects. In particular, fast (>1 MeV) neutron irradiation above a certain level may result in significant increase in the brittle fracture transition temperature and deterioration in the resistance to fracture at temperatures above the transition range (upper shelf energy). Therefore, structural discontinuities in ferritic structures should preferably not be placed in regions of high neutron flux.

## NG-3130 GENERAL DESIGN RULES

### NG-3131 Scope

Design rules generally applicable to core support structures are provided in the following paragraphs.

### NG-3132 Reinforcement for Openings

The rules for reinforcing applicable to Class 1 vessels and piping may be used in the design of core support structures if stipulated in the Design Specifications.

### NG-3133 External Pressure Difference

**NG-3133.1 General.** Rules are given in this paragraph for determining the stresses under external pressure difference loading in spherical shells, cylindrical shells with or without stiffening rings, and tubular products consisting of pipes, tubes, and fittings. Charts for determining the stresses in shells, hemispherical heads, and tubular products are given in Section II, Part D, Subpart 3.

**NG-3133.2 Nomenclature.** The symbols used in this paragraph are defined as follows:

$A$ = factor determined from Section II, Part D, Subpart 3, Figure G and used to enter the applicable material chart in Section II, Part D, Subpart 3. For the case of cylinders having $D_o/T$ values less than 10, see NG-3133.3(b). Also, factor determined from the applicable chart in Section II, Part D, Subpart 3 for the material used in a stiffening ring, corresponding to the factor $B$ and the design metal temperature for the shell under consideration.

$A_s$ = cross-sectional area of a stiffening ring

$B$ = factor determined from the applicable chart in Section II, Part D, Subpart 3 for the material used in a shell or stiffening ring at the design metal temperature

$D_o$ = outside diameter of the cylindrical shell course or tube under consideration

$E$ = modulus of elasticity of material at Design Temperature (for this value, see Section II, Part D, Subpart 2, Table TM). Use the curve with this value on the material/temperature line of the applicable chart in Section II, Part D, Subpart 3.

$I$ = available moment of inertia of the combined ring–shell section about its neutral axis, parallel to the axis of the shell, in.$^4$ (mm$^4$). The width of the shell which is taken as contributing to the combined moment of inertia shall not be greater than $1.10\sqrt{D_o / T_n}$ and shall be taken as lying one-half on each side of the centroid of the ring. Portions of shell plates shall not be considered as contributing area to more than one stiffening ring.

$I_s$ = required moment of inertia of the combined ring–shell section about its neutral axis parallel to the axis of the shell

$L$ = total length of a tube between tubesheets, or the design length of a cylindrical section, taken as the largest of the following:

*(a)* the distance between head tangent lines plus one-third of the depth of each head if there are no stiffening rings

*(b)* the greatest center-to-center distance between any two adjacent stiffening rings or

*(c)* the distance from the center of the first stiffening ring to the head tangent line plus one-third of the depth of the head, all measured parallel to the axis of the cylinder, in. (mm)

$L_s$ = one-half of the distance from the center line of the stiffening ring to the next line of support on one side, plus one-half of the center line distance to the next line of support on the other side of the stiffening ring, both measured parallel to the axis of the component. A line of support is

*(a)* a stiffening ring that meets the requirements of this paragraph

*(b)* a circumferential line on a head at one-third the depth of the head from the head tangent line or

*(c)* a circumferential connection to a jacket for a jacketed section of a cylindrical shell

$P$ = external design pressure (gage or absolute, as required)

$P_a$ = allowable external pressure (gage or absolute, as required)

$R$ = inside radius of spherical shell

$S$ = the lesser of 1.5 times the stress intensity at design metal temperature from Section II, Part D, Subpart 1, Tables 2A and 2B or 0.9 times the tabulated yield strength at design metal temperature from Section II, Part D, Subpart 1, Table Y-1

$T$ = minimum required thickness of cylindrical shell or tube, or spherical shell

$T_n$ = nominal thickness used, less corrosion allowance, of a cylindrical shell or tube

### NG-3133.3 Cylindrical Shells and Tubular Products.

*(a)* The minimum thickness of cylindrical shells or tubular products under external pressure difference having $D_o/T$ values equal to or greater than 10 shall be determined by the procedure given in Steps 1 through 8.

*Step 1.* Assume a value for $T$. Determine the ratios $L/D_o$ and $D_o/T$.

*Step 2.* Enter Section II, Part D, Subpart 3, Figure G at the value of $L/D_o$ determined in Step 1. For values of $L/D_o$ greater than 50, enter the chart at a value of $L/D_o$ of 50. For values of $L/D_o$ less than 0.05, enter the chart at a value of $L/D_o$ of 0.05.

*Step 3.* Move horizontally to the line for the value of $D_o/T$ determined in Step 1. Interpolation may be made for intermediate values of $D_o/T$. From this intersection move vertically downwards and read the value of factor $A$.

*Step 4.* Using the value of $A$ calculated in Step 3, enter the applicable material chart in Section II, Part D, Subpart 3 for the material/temperature under consideration. Move vertically to an intersection with the material/temperature line for the Design Temperature. Interpolation may be made between lines for intermediate temperatures. In cases where the value of $A$ falls to the right of the end of the material/temperature line, assume an intersection with the horizontal projection of the upper end of the material/temperature line. For values of $A$ falling to the left of the material line, see Step 7.

*Step 5.* From the intersection obtained in Step 4 move horizontally to the right and read the value of $B$.

*Step 6.* Using this value of $B$, calculate the maximum allowable pressure difference $P_a$ by the following equation:

$$P_a = \frac{4B}{3(D_o/T)}$$

*Step 7.* For values of $A$ falling to the left of the applicable material/temperature line, the value of $P_a$ can be calculated using the following equation:

$$P_a = \frac{2AE}{3(D_o/T)}$$

*Step 8.* Compare $P_a$ with $P$. If $P_a$ is smaller than $P$, select a larger value for $T$ and repeat the design procedure until a value for $P_a$ is obtained that is equal to or greater than $P$.

*(b)* The minimum thickness of cylindrical shells or tubular products under external pressure difference having $D_o/T$ values less than 10 shall be determined by the procedure given in Steps 1 through 4.

*Step 1.* Using the same procedure as given in (a) above, obtain the value of $B$. For values of $D_o/T$ less than 4, the value of factor $A$ can be calculated using the following equation:

$$A = \frac{1.1}{(D_o/T)^2}$$

For values of $A$ greater than 0.10 use a value of 0.10.

*Step 2.* Using the value of $B$ obtained in Step 1, calculate a value $P_{a1}$ using the following equation:

$$P_{a1} = \left[\frac{2.167}{(D_o/T)} - 0.0833\right]B$$

*Step 3.* Calculate a value $P_{a2}$ using the following equation:

$$P_{a2} = \frac{2S}{(D_o/T)}\left[1 - \frac{1}{(D_o/T)}\right]$$

*Step 4.* The smaller of the values of $P_{a1}$ calculated in Step 2 or $P_{a2}$ calculated in Step 3 shall be used for the maximum allowable external pressure $P_a$. Compare $P_a$ with $P$. If $P_a$ is smaller than $P$, select a larger value for $T$ and repeat the design procedure until a value for $P_a$ is obtained that is equal to or greater than $P$.

**NG-3133.4 Spherical Shells.** The minimum required thickness of a spherical shell under external pressure, either seamless or of built-up construction with butt joints, shall be determined by the procedure given in Steps 1 through 6.

*Step 1.* Assume a value for $T$ and calculate the value of factor $A$ using the following equation:

$$A = \frac{0.125}{(R/T)}$$

*Step 2.* Using the value of $A$ calculated in Step 1, enter the applicable material chart in Section II, Part D, Subpart 3 for the material under consideration. Move vertically to an intersection with the material/temperature line for the design temperature. Interpolation may be made between lines for intermediate temperatures. In cases where the value at $A$ falls to the right of the end of the material/temperature line, assume an intersection with the horizontal projection of the upper end of the material/temperature line. For values at $A$ falling to the left of the material/temperature line, see Step 5.

*Step 3.* From the intersection obtained in Step 2, move horizontally to the right and read the value of factor $B$.

*Step 4.* Using the value of $B$ obtained in Step 3, calculate the value of the maximum allowable external pressure $P_a$ using the following equation:

$$P_a = \frac{B}{(R/T)}$$

*Step 5.* For values of $A$ falling to the left of the applicable material/temperature line for the Design Temperature, the value of $P_a$ can be calculated using the following equation:

$$P_a = \frac{0.0625E}{(R/T)^2}$$

*Step 6.* Compare $P_a$ obtained in Steps 4 or 5 with $P$. If $P_a$ is smaller than $P$, select a larger value for $T$ and repeat the design procedure until a value for $P_a$ is obtained that is equal to or greater than $P$.

**NG-3133.5 Stiffening Rings for Cylindrical Shells.**

*(a)* The required moment of inertia of the combined ring–shell section is given by the following equation:

$$I_s = \frac{D_o^2 L_s(T + A_s/L_s)A}{10.9}$$

The available moment of inertia $I$ for a stiffening ring shall be determined by the procedure given in Steps 1 through 6.

*Step 1.* Assuming that the shell has been designed and $D_o$, $L_s$, and $T_n$ are known, select a member to be used for the stiffening ring and determine its area $A_s$ and the value of $I$ defined in NG-3133.2. Then calculate $B$ by the following equation:

$$B = \frac{3}{4}\left[\frac{PD_o}{T_n + A_s/L_s}\right]$$

*Step 2.* Enter the right-hand side of the applicable material chart in Section II, Part D, Subpart 3 for the material under consideration at the value of $B$ determined in Step 1. If different materials are used for the shell and stiffening ring, then use the material chart resulting in the larger value for factor $A$ in Step 4 or 5.

*Step 3.* Move horizontally to the left to the material/temperature line for the design metal temperature. For values of $B$ falling below the left end of the material/temperature line, see Step 5.

*Step 4.* Move vertically to the bottom of the chart and read the value of $A$.

*Step 5.* For values of $B$ falling below the left end of the material/temperature line for the Design Temperature, the value of $A$ can be calculated using the following equation:

$$A = 2B/E$$

*Step 6.* If the required $I_s$ is greater than the computed moment of inertia $I$ for the combined ring– shell section selected in Step 1, a new section with a larger moment of inertia must be selected and a new $I_s$ determined. If the required $I_s$ is smaller than the computed $I$ for the section selected in Step 1, that section should be satisfactory.

*(b)* Stiffening rings may be attached to either the outside or the inside of the component by continuous welding.

**NG-3133.6 Cylinders Under Axial Compression.** The maximum allowable compressive stress to be used in the design of cylindrical shells and tubular products subjected to loadings that produce longitudinal compressive stresses in the shell or wall shall be the lesser of the values given in (a) or (b).

*(a)* the $S_m$ value for the applicable material at Design Temperature given in Section II, Part D, Subpart 1, Tables 2A and 2B

*(b)* the value of the factor $B$ determined from the applicable chart contained in Section II, Part D, Subpart 3, using the following definitions for the symbols on the charts:

$R$ = inside radius of the cylindrical shell or tubular product, in. (mm)
$T$ = minimum required thickness of the shell or tubular product, exclusive of the corrosion allowance, in. (mm)

The value of $B$ shall be determined from the applicable chart contained in Section II, Part D, Subpart 3 in the manner given in Steps 1 through 5.

*Step 1.* Using the selected values of $T$ and $R$, calculate the value of factor $A$ using the following equation:

$$A = 0.125 / (R/T)$$

*Step 2.* Using the value of $A$ calculated in Step 1, enter the applicable material chart in Section II, Part D, Subpart 3 for the material under consideration. Move vertically to an intersection with the material/temperature line for the Design Temperature. Interpolation may be made between lines for intermediate temperatures. In cases where the value at $A$ falls to the right of the end of the material/temperature line, assume an intersection with the horizontal projection of the upper end of the material/temperature line. For values of $A$ falling to the left of the material/temperature line, see Step 4.

*Step 3.* From the intersection obtained in Step 2, move horizontally to the right and read the value of factor $B$. This is the maximum allowable compressive stress for the values of $T$ and $R$ used in Step 1.

*Step 4.* For values of $A$ falling to the left of the applicable material/temperature line, the value of $B$ shall be calculated using the following equation:

$$B = AE/2$$

*Step 5.* Compare the value of $B$ determined in Step 3 or 4 with the computed longitudinal compressive stress in the cylindrical shell or tube, using the selected values of $T$ and $R$. If the value of $B$ is smaller than the computed compressive stress, a greater value of $T$ must be selected and the design procedure repeated until a value of $B$ is obtained which is greater than the compressive stress computed for the loading on the cylindrical shell or tube.

## NG-3200 DESIGN BY ANALYSIS (23)

### NG-3210 REQUIREMENTS FOR ACCEPTABILITY

The requirements for the acceptability of a design by analysis are those set forth in (a) through (d).

*(a)* The design shall be such that stress intensities will not exceed the limits of Section III Appendices, Mandatory Appendix XIII, with the following stipulations:

*(1)* The term pressure shall be interpreted as pressure difference.

*(2)* For the special stress limits of Mandatory Appendix XIII, XIII-3700

*(-a)* the limits for Design, Level A, and Level B Service Loadings shall be those stated in XIII-3700, except the Level B primary stress limits shall be taken as 110% of the Level A primary stress limits in XIII-3700

*(-b)* the limits for Level C Service Loadings shall be taken as 150% of the Level A primary stress limits in XIII-3700

*(-c)* for the limits of XIII-3750, stresses in core support structure nozzles and piping shall be classified with respect to the limits of reinforcement in XIII-2600(c)

*(-d)* the limits of XIII-3760, XIII-3770, and XIII-3780 do not apply

*(b)* The design details shall conform to the rules given in NG-3100 and NG-3350.

*(c)* For configurations where compressive stresses occur, in addition to the requirements in (a) and (b), the critical buckling stress shall be taken into account.

*(1)* For external pressure difference, see NG-3133 for Design, Level A, and Level B Service Loadings. Where dynamic pressure differences are involved, the permissible external pressure difference shall satisfy the requirements of NG-3133 or be limited to 25% of the dynamic instability pressure difference due to Level A Service Loadings. For Level C Service Loadings, the permissible equivalent static external pressure shall be taken as 150% of that permitted by NG-3133. Where dynamic pressures are involved, the permissible external pressure shall satisfy the preceding requirements or be limited to 50% of the dynamic instability pressure.

*(2)* For all other loadings, buckling shall be considered by performing an evaluation of service and test conditions. Subsection NF provides acceptable methods for

plate- and shell-type supports in NF-3220 and linear-type supports in NF-3320.

*(d)* Protection against nonductile fracture shall be provided. An acceptable procedure for nonductile failure prevention is given in Section III Appendices, Nonmandatory Appendix G.

# NG-3300 CORE SUPPORT STRUCTURE DESIGN

## NG-3310 GENERAL REQUIREMENTS

### NG-3311 Acceptability

The requirements for acceptability of a core support structure design are given in (a) through (c).

*(a)* The design shall be such that the requirements of NG-3100 and NG-3200 are satisfied.

*(b)* The requirements of NG-3300 are satisfied. In case of conflict between NG-3200 and NG-3300, the requirements of NG-3300 shall govern.

*(c)* The requirements of this subarticle apply to internal structures, NG-1122, only as specifically stipulated by the Certificate Holder; however, the Certificate Holder shall certify that the design used for the internal structures shall not adversely affect the integrity of the core support structure.

## NG-3320 DESIGN CONSIDERATIONS

### NG-3321 Design and Service Loadings

The provisions of NG-3110 apply.

### NG-3322 Special Considerations

The provisions of NG-3120 apply.

### NG-3323 General Design Rules

The provisions of NG-3130 apply, except when they conflict with rules of this subarticle. In case of conflict, this subarticle governs in the design of core support structures.

## NG-3350 DESIGN FOR WELDED CONSTRUCTION

### NG-3351 Welded Joint Categories

*(a)* The term *category* as used herein defines the location of a joint. The categories established by this paragraph are for use elsewhere in this Subsection to identify special restrictions regarding type of joint permitted for the location. Figures NG-3351(a)-1 and NG-3351(a)-2 illustrate locations of some typical welded joints in each category. Joints whose design functions are neither to restrain nor support the core do not fall into any category.

*(b)* The *types* of joints that may be used at the various locations are defined in NG-3352.

**NG-3351.1 Joints of Category A.** Joints of Category A are longitudinal joints in cylindrical members. Category A joints may be of Type I, II, or, with the following restriction, Type IV. When a Type IV joint is used in Category A, the quality factor shall be one-half that permitted for Type I or II by Table NG-3352-1 for the examination used.

**NG-3351.2 Joints of Category B.** Joints of Category B are girth welds in cylindrical members. Category B joints may be of Type I, II, or, with the following restriction, Type IV or V. When Type IV or V joints are used in Category B, the quality factor shall be one-half that permitted for Type I or II by Table NG-3352-1 for the examination used.

**NG-3351.3 Joints of Category C.** Joints of Category C are primarily for joining flanges to cylinders. Category C joints may be of Type I, II, III, or, with the following restriction, Type IV or V. When Type IV or V joints are used in Category C, the quality factor shall be one-half that permitted for Type I or II by Table NG-3352-1 for the examination used.

**NG-3351.4 Joints of Category D.** Joints of Category D are primarily for attaching nozzles to other members. Category D joints may be of Type I, II, III, IV, V, VI, or VII.

**NG-3351.5 Joints of Category E.** Joints of Category E are for joints at the ends of webs of beams. Category E joints may be of Type I, II, III, IV, V, VI, VII, or VIII.

### NG-3352 Permissible Types of Welded Joints (23)

Subject to the limitations given in NG-3351, core support structures may use any of the types of joints described in the following subparagraphs, providing the quality factor, *n*, and fatigue factor, *f*, used in the analysis meet the requirements of Table NG-3352-1 for the method of examination employed. The quality factor, *n*, is used by multiplying the allowable stress limit for primary stress categories only. The quality factor is not used in fatigue applications, including evaluation of primary plus secondary stress range. In performing a fatigue analysis, use the fatigue factor, *f*, designated in Table NG-3352-1, and the applicable fatigue curve in Section III Appendices, MandatoryAppendix I.

**NG-3352.1 Type I Joints.** Full penetration welds between plates or other elements that lie approximately in the same plane or have an offset angle not greater than 30 deg meet the intent of this subparagraph when made either as double welded butt joints, or with consumable inserts or gas backup, or with metal backing strips that are later removed, provided the backface of such joints meets the requirements of NG-4424.

**NG-3352.2 Type II Joints.** Full penetration welds (23) between plates or other elements meet the intent of this subparagraph when made either according to NG-3352.1 or with edges of the joint prepared with opposing lips to form an integral backing strip, or with

**Figure NG-3351(a)-1**
**Typical Locations of Joints of Several Categories**

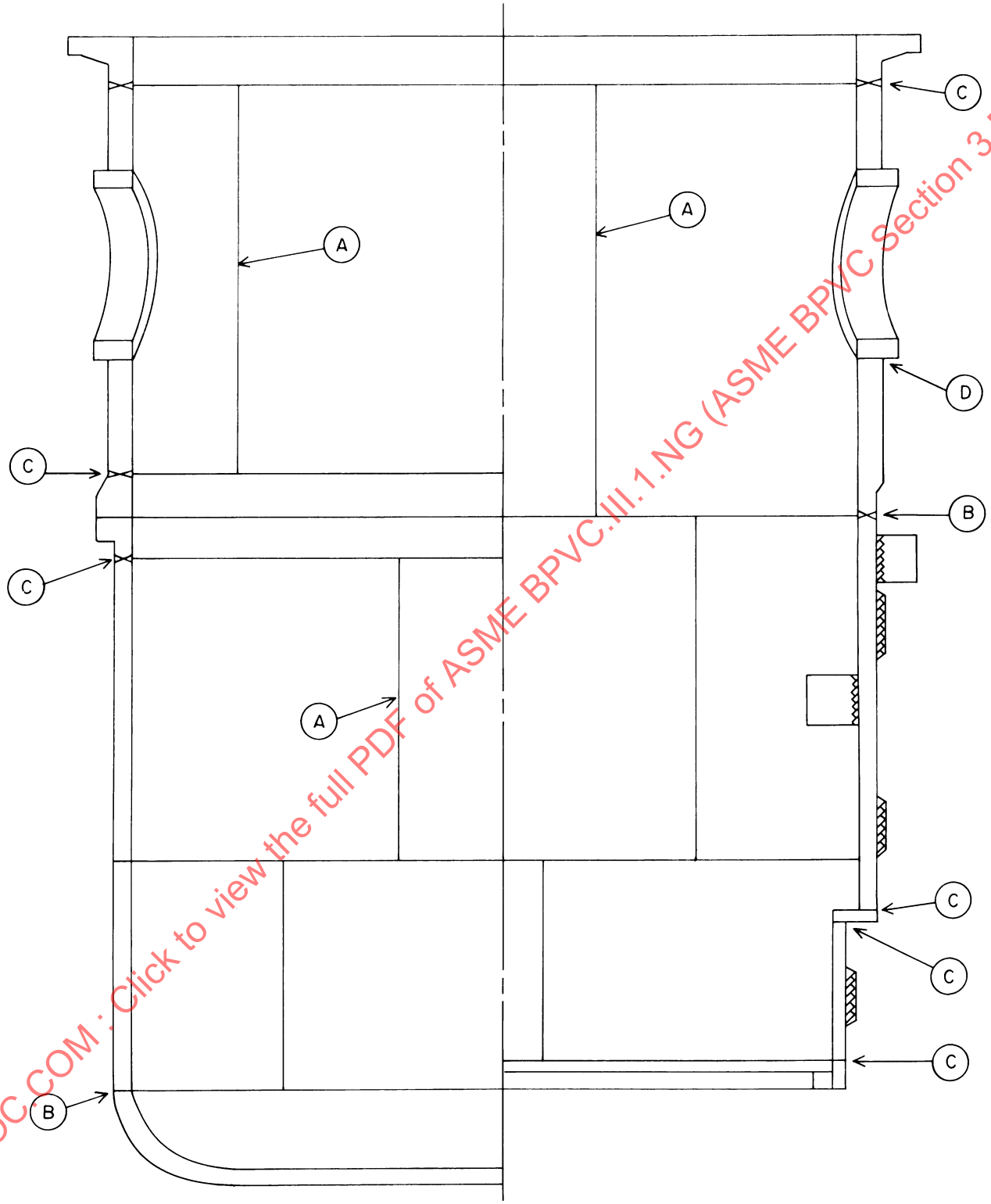


**Figure NG-3351(a)-2**
**Typical Welded Joint Category Locations**

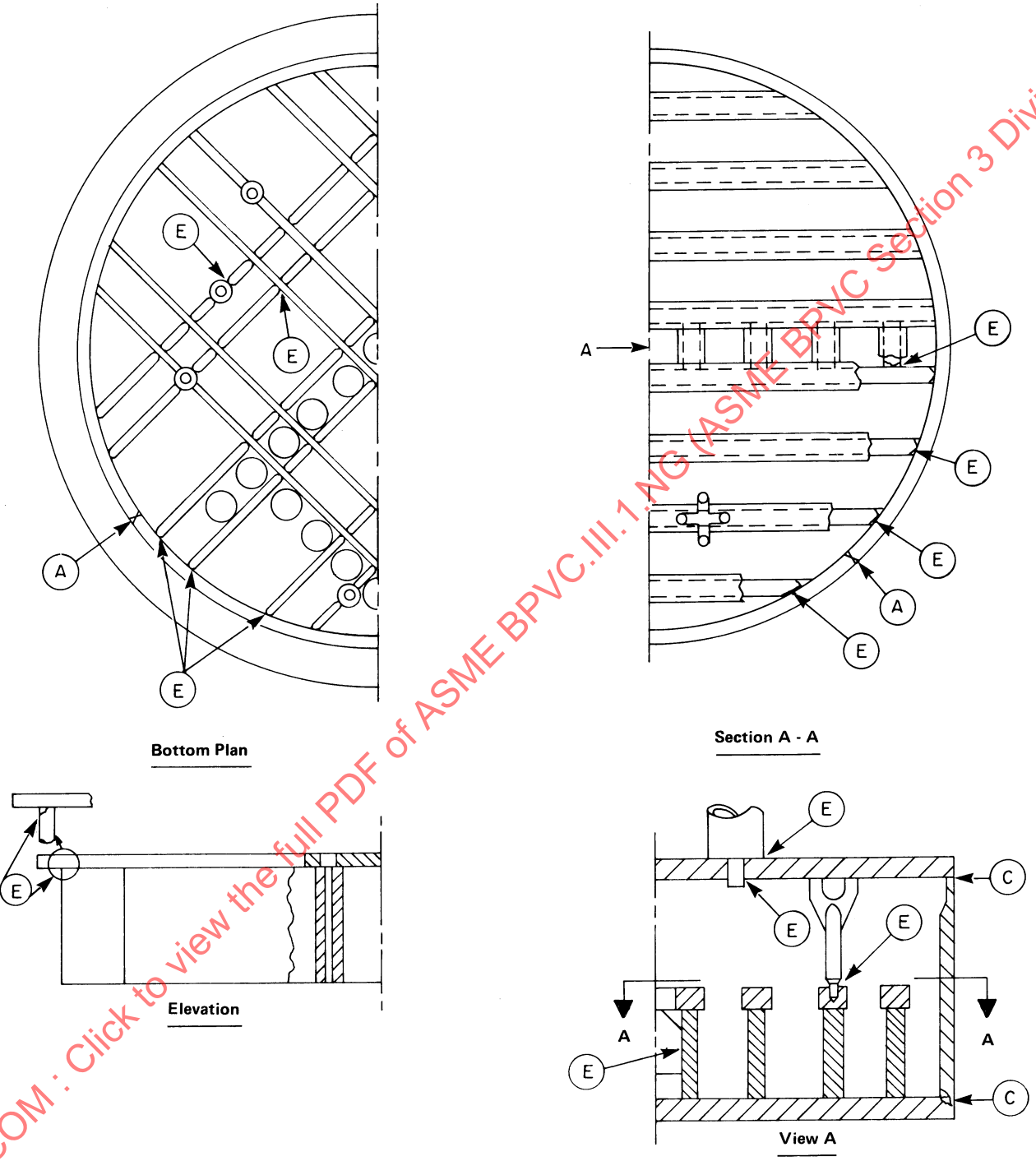


**Table NG-3352-1**
**Permissible Welded Joints and Design Factors**

| Type of Welded Joint | | Permissible for Category Shown Below | Quality Factor and Fatigue Factor [Note (1)] RT or UT [Note (2)] and PT or MT Examination NG-5220 | Progressive PT or MT Examination NG-5231 | Root and Final PT or MT Examination NG-5232 | Surface PT or MT Examination NG-5233 | Surface Visual Examination NG-5260 |
|---|---|---|---|---|---|---|---|
| I. | Full penetration | A, B, C, D, E | $n = 1.0\,f = 1$ | $n = 0.9\,f = 1$ | $n = 0.75\,f = 1$ | $n = 0.65\,f = 1$ | $n = 0.5\,f = 1$ |
| II. | Full penetration | A, B, C, D, E | $n = 1.0\,f = 2$ | $n = 0.9\,f = 2$ | $n = 0.75\,f = 2$ | $n = 0.65\,f = 2$ | $n = 0.5\,f = 2$ |
| III. | Full penetration | C, D, E | $n = 1.0\,f = 1$ | $n = 0.9\,f = 1$ [Note (3)] | $n = 0.75\,f = 1$ [Note (3)] | $n = 0.65\,f = 1$ [Note (3)] | $n = 0.5\,f = 1$ [Note (3)] |
| IV. | Double groove (RT not applicable) | A, B, C | $n = 0.5\,f = 4$ | $n = 0.45\,f = 4$ | $n = 0.4\,f = 4$ | $n = 0.35\,f = 4$ | $n = 0.25\,f = 4$ |
| | | D, E | $n = 0.9\,f = 4$ | $n = 0.8\,f = 4$ | $n = 0.7\,f = 4$ | $n = 0.6\,f = 4$ | $n = 0.4\,f = 4$ |
| V. | Double fillet (RT not applicable) | B, C | $n = 0.5\,f = 4$ | $n = 0.45\,f = 4$ | $n = 0.4\,f = 4$ | $n = 0.35\,f = 4$ | $n = 0.25\,f = 4$ |
| | | D, E | $n = 0.9\,f = 4$ | $n = 0.8\,f = 4$ | $n = 0.7\,f = 4$ | $n = 0.6\,f = 4$ | $n = 0.4\,f = 4$ |
| VI. | Single groove (RT not applicable) | D, E | $n = 0.6\,f = 4$ | $n = 0.55\,f = 4$ | $n = 0.45\,f = 4$ | $n = 0.4\,f = 4$ | $n = 0.35\,f = 4$ |
| VII. | Single fillet (RT not applicable) | D, E | $n = 0.6\,f = 4$ | $n = 0.55\,f = 4$ | $n = 0.45\,f = 4$ | $n = 0.4\,f = 4$ | $n = 0.35\,f = 4$ |
| VIII. | Intermittent fillet or plug | E | Not applicable | $n = 0.45\,f = 4$ | $n = 0.4\,f = 4$ | $n = 0.35\,f = 4$ | $n = 0.3\,f = 4$ |

NOTES:
(1) See NG-3352 for definitions.
(2) Electroslag butt welds shall be examined by radiography. Electroslag welds in ferritic material shall also be examined for their full length by the ultrasonic method after a grain refining heat treatment, when performed, or after a postweld heat treatment.
(3) A minimum fatigue strength reduction factor of 1.0 is permitted when both sides of weld are examined; otherwise a factor of 2.0 must be used in analysis for cyclic operation.

metal backing strips which are not later removed, except that the suitability for cyclic operation shall be analyzed by the method of Section III Appendices, Mandatory Appendix XIII, XIII-3500 (when used, backing strips shall be continuous and any splices shall be full penetration welded).

**NG-3352.3 Type III Joints.** Full penetration welds between plates or other elements that may have an offset angle up to 90 deg meet the intent of this subparagraph when either made according to NG-3352.2 or are corner welds. Attachment of connections using deposited weld metal as reinforcement and oblique connections meet the intent of this subparagraph.

**NG-3352.4 Type IV Joints.** Partial penetration welds of double groove design (minimum depth of each groove equals one-eighth times the thickness of the thinnest element) meet the intent of this subparagraph when the area of the connection is determined by the product of the throat thickness times the length of welds.

**NG-3352.5 Type V Joints.** Double fillet welds meet the intent of this subparagraph when the area of the connection is determined by the product of the theoretical throat thickness times the length of the welds (see Figure NG-4427-1). Joints made having one side a single fillet and the other side a single groove meet the intent of this subparagraph.

**NG-3352.6 Type VI Joints.** Partial penetration welds of single groove design meet the intent of this subparagraph when the area of the connection is determined as the product of the weld throat thickness times the length of weld.

**NG-3352.7 Type VII Joints.** Single fillet welds meet the intent of this subparagraph when the area of the connection is determined as the product of the theoretical throat thickness of the fillet welds times the length of weld (see Figure NG-4427-1).

**NG-3352.8 Type VIII Joints.** Intermittent fillet or plug welds meet the intent of this subparagraph when the area of the intermittent fillet weld connection is determined as the product of the theoretical throat thickness times the sum of weld lengths and the area of plug weld connection is determined as the product of the number of plug welds times the area of the minimum cross section.

**NG-3352.9 Limitations on Types of Joints.** The type of joint used for service shall be one of those permitted for the Category of the joint (see NG-3351). Reduced quality factors must be used for certain types of joints when used in Categories A, B, and C (see Table NG-3352-1).

# ARTICLE NG-4000
# FABRICATION AND INSTALLATION

## NG-4100 GENERAL REQUIREMENTS

### NG-4110 INTRODUCTION

*(a)* Core support structures (see NG-1121) shall be manufactured and installed in accordance with the requirements of this Article and shall be manufactured from materials which meet the requirements of Article NG-2000.

*(b)* The rules of this Article apply to the internal structures (see NG-1122) only as specifically implemented by the Certificate Holder; however, the Certificate Holder shall certify that each internal structure has been fabricated so as to avoid creating an adverse effect on the integrity of the core support structure.

### NG-4120 CERTIFICATION OF MATERIAL AND FABRICATION BY CERTIFICATE HOLDER

### NG-4121 Means of Certification

The Certificate Holder for an item shall certify, by application of the appropriate Certification Mark and completion of the appropriate data report in accordance with NCA-8000, that the materials used comply with the requirements of Article NG-2000 and that the fabrication and installation comply with the requirements of this Article.

**NG-4121.1 Certification of Treatments, Tests, and Examinations.** If the Certificate Holder performs treatments, tests, repairs, or examinations required by other Articles, it shall certify that it has fulfilled such requirements. Reports of all required treatments and of the results of all required tests, repairs, and examinations performed shall be available to the Inspector.

**NG-4121.2 Repetition of Tensile or Impact Tests.** If during the fabrication or installation of the item the material is subjected to heat treatment that has not been covered by treatment of the test coupons (see NG-2200), and that may reduce either tensile or impact properties below the required values, the tensile and impact tests shall be repeated by the Certificate Holder on test specimens taken from test coupons which have been taken and treated in accordance with the requirements of Article NG-2000.

### NG-4122 Material Identification

Material for core support structures shall carry identification markings which will remain distinguishable until the core support structure is fabricated or installed. If the original identification markings are cut off or the material is divided, the marks shall be accurately transferred to the parts or a coded marking shall be used to assure identification of each piece of material during subsequent fabrication or installation, unless otherwise provided by NG-2150. Material supplied with a Certificate of Compliance and welding and brazing material shall be identified and controlled so that they can be traced to the core support structure, or else a control procedure shall be employed which ensures that the specified material is used.

### NG-4123 Examinations

Visual examination activities that are not referenced for examination by other specific Code paragraphs, and are performed solely to verify compliance with requirements of Article NG-4000, may be performed by the persons who perform or supervise the work. These visual examinations are not required to be performed by personnel and procedures qualified to NG-5500 and NG-5100, respectively, unless so specified.

### NG-4125 Testing of Welding Material

All welding material shall meet the requirements of NG-2400.

### NG-4130 REPAIR OF MATERIAL

### NG-4131 Elimination and Repair of Defects

Material originally accepted on delivery in which defects exceeding the limits of NG-2500 are known or discovered during the process of fabrication or installation is unacceptable. The material may be used provided the condition is corrected in accordance with the requirements of NG-2500 for the applicable product form, except

*(a)* the limitation on the depth of the weld repair does not apply

*(b)* the time of examination of the weld repairs to weld edge preparations shall be in accordance with NG-5130

### NG-4132 Documentation of Repair Welds of Base Material

The Certificate Holder who makes a repair weld, exceeding in depth the lesser of $^{3}/_{8}$ in. (10 mm) or 10% of the section thickness, shall prepare a report which shall include a chart which shows the location and size of the prepared cavity, the welding material identification, the welding procedure, the heat treatment, and the examination results of repair welds. In addition, all repair welds exceeding an accumulated area of 20% of the area of the part or 15 in.$^2$ (9 700 mm$^2$), whichever is less, shall require the same documentation as welds exceeding the minimum depth.

## NG-4200 FORMING, FITTING, AND ALIGNING

### NG-4210 CUTTING, FORMING, AND BENDING

### NG-4211 Cutting

Materials may be cut to shape and size by mechanical means, such as machining, shearing, chipping, or grinding, or by thermal cutting.

**NG-4211.1 Preheating Before Thermal Cutting.** When thermal cutting is performed to prepare weld joints or edges, to remove attachments or defective material, or for any other purpose, consideration shall be given to preheating the material, using preheat schedules, such as suggested in Section III Appendices, Nonmandatory Appendix D.

**NG-4211.2 Material Preparation After Thermal Cutting for P-No. 8 Material.** When metal is to be removed by thermal cutting methods, additional material shall be removed by mechanical means to the extent required in the Design Specifications.

### NG-4212 Forming and Bending Processes

Any process may be used to hot or cold form or bend core support structure material, including weld metal, provided the required dimensions are attained (see NG-4214), and provided the specified impact properties of the material, when required, are not reduced below the minimum specified values or they are effectively restored by heat treatment following the forming operation. *Hot forming* is defined as forming with the material temperature higher than 100°F (56°C) below the lower transformation temperature of the material. When required, the process shall be qualified for impact properties as outlined in NG-4213.

### NG-4213 Qualification of Forming Processes for Impact Property Requirements

A procedure qualification test shall be conducted using specimens taken from material of the same specification, grade or class, heat treatment, and with similar impact properties as required for the material in the structure. These specimens shall be subjected to the equivalent forming or bending process and heat treatment as the material in the structure. Applicable tests shall be conducted to determine that the required impact properties of NG-2300 are met after straining.

**NG-4213.1 Exemptions.** Procedure qualification tests are not required for materials listed in (a) through (f)

*(a)* hot formed material, such as forgings, in which the hot forming is completed by the Material Organization prior to removal of the impact test specimens

*(b)* hot formed material represented by test coupons required in either NG-2211 or NG-4121.2 which has been subjected to heat treatment representing the hot forming procedure and the heat treatments to be applied to the parts

*(c)* material which does not require impact tests in accordance with NG-2300

*(d)* material which has a final strain less than 0.5%

*(e)* material where the final strain is less than that of a previously qualified procedure for that material

*(f)* material from which the impact testing required by NG-2300 is performed on each heat and lot, as applicable, after forming

**NG-4213.2 Procedure Qualification Test.** The procedure qualification test shall be performed in the manner stipulated in (a) through (f).

*(a)* The tests shall be performed on three different heats of material both before and after straining to establish the effects of the forming and subsequent heat treatment operations.

*(b)* Specimens shall be taken in accordance with the requirements of Article NG-2000 and from the tension side of the strained material.

*(c)* The percent strain shall be established by the following equations:

For cylinders

$$\% \text{ strain} = 50t/R_f \left[1 - \left(R_f/R_o\right)\right]$$

For spherical or dished surfaces

$$\% \text{ strain} = 75t/R_f \left[1 - \left(R_f/R_o\right)\right]$$

For pipe

$$\% \text{ strain} = 100r/R$$

where

$R$ = nominal bending radius to the center line of the pipe
$r$ = nominal radius of the pipe
$R_f$ = final radius to center line of shell
$R_o$ = original radius (equal to infinity for a flat part)
$t$ = nominal thickness

*(d)* The procedure qualification shall simulate the maximum percent surface strain, employing a bending process similar to that used in the fabrication of the material or by direct tension on the specimen.

*(e)* Sufficient $C_v$ specimens shall be taken from each of the three heats of material to establish a transition curve showing both the upper and lower shelves. On each of the three heats, tests consisting of three impact specimens shall be conducted at a minimum of five different temperatures distributed throughout the transition region. The upper and lower shelves may be established by the use of one test specimen each. Depending on the product form, it may be necessary to plot the transition curves using both lateral expansion and energy level data (see NG-2300). In addition, drop weight tests shall be made when required by NG-2300.

*(f)* Using the results of the impact test data from each of three heats, taken both before and after straining, determine either

*(1)* the maximum change in NDT temperature along with

*(-a)* the maximum change of lateral expansion and energy at the temperature under consideration or

*(-b)* the maximum change in temperature at the lateral expansion or energy levels under consideration or

*(2)* where lateral expansion is the acceptance criterion (see NG-2300), either the maximum change in temperature or the maximum change in lateral expansion

**NG-4213.3 Acceptance Criteria for Formed Material.** To be acceptable, the formed material used in the component shall have impact properties before forming sufficient to compensate for the maximum loss of impact properties due to the qualified forming procedure used.

**NG-4213.4 Requalification.** A new procedure qualification test is required when any of the following changes are made:

*(a)* the actual postweld heat treatment time at temperature is greater than previously qualified considering NG-2211. If the material is not postweld heat-treated, the procedure must be qualified without postweld heat treatment.

*(b)* the maximum calculated strain of the material exceeds the previously qualified strain by more than 0.5%.

*(c)* preheat over 250°F (120°C) is used in the forming or bending operation but not followed by a subsequent postweld heat treatment.

### NG-4214 Minimum Thickness of Fabricated Material

If any fabrication operation reduces the thickness below the minimum required to satisfy the rules of Article NG-3000, the material may be repaired in accordance with NG-4130.

## NG-4230 FITTING AND ALIGNING

### NG-4231 Fitting and Aligning Methods

Parts that are to be joined by welding may be fitted, aligned, and retained in position during the welding operation by the use of bars, jacks, clamps, tack welds, or temporary attachments.

**NG-4231.1 Tack Welds.** Tack welds used to secure alignment shall either be removed completely, when they have served their purpose, or their stopping and starting ends shall be properly prepared by grinding or other suitable means so that they may be satisfactorily incorporated into the final weld. Tack welds shall be made by qualified welders using qualified welding procedures. When tack welds are to become part of the finished weld, they shall be visually examined in accordance with NG-5261 and defective tack welds removed.

### NG-4232 Maximum Offset of Aligned Sections

Alignment of sections shall be such that the maximum offset of the finished welded joint will not be greater than $\frac{1}{2}t$, where $t$ is the nominal thickness of the thinner section at the joint. Alternatively, smaller alignment tolerances may be specified by the Design Specifications.

**NG-4232.1 Fairing of Offsets.** Any offset within the allowable limit provided shall be faired to at least a 3:1 taper, length to offset, over the width of the finished weld or, if necessary, by adding additional weld metal beyond what would otherwise be the edge of the weld. In addition, offsets greater than those stated in NG-4232 are acceptable provided the requirements of NG-3200 are met.

## NG-4240 REQUIREMENTS FOR WELD JOINTS IN COMPONENTS

### NG-4245 Complete Joint Penetration Welds

Complete joint penetration is considered to be achieved when the acceptance criteria for the examinations specified by this Subsection have been met. No other examination is required to assess that complete penetration has been achieved.

## NG-4300 WELDING QUALIFICATIONS

### NG-4310 GENERAL REQUIREMENTS

### NG-4311 Types of Processes Permitted

Only those welding processes which are capable of producing welds in accordance with the welding procedure qualification requirements of Section IX and this Subsection may be used for welding core support structure material or attachments thereto. Any process used shall be such that the records required by NG-4320 can be prepared. Stud welds are not permitted.

**NG-4311.2 Capacitor Discharge Welding.** Capacitor discharge welding may be used for welding temporary attachments and permanent nonstructural attachments, provided that

*(a)* temporary attachments are removed in accordance with the provisions of NG-4430(b),

*(b)* the energy output for permanent nonstructural attachments such as strain gages and thermocouples is limited to 125 W-sec and the minimum thickness of the material to which the attachment is made is greater than 0.09 in. (2.3 mm), and

*(c)* a Welding Procedure Specification is prepared describing the capacitor discharge equipment, the combination of materials to be joined, and the technique of application; qualification of the welding procedure is not required.

**NG-4311.3 Inertia and Continuous Drive Friction Welding.** Inertia and continuous drive friction welding shall not be used for the fabrication of core support structures.

## NG-4320 WELDING QUALIFICATIONS, RECORDS, AND IDENTIFYING STAMPS

### NG-4321 Required Qualifications

*(a)* Each Certificate Holder is responsible for the welding done by its organization, and it shall establish the procedure and conduct the tests required by this Article and by Section IX in order to qualify both the welding procedures and the performance of welders and welding operators who apply these procedures.

*(b)* Procedures, welders, and welding operators used to join permanent or temporary attachments to core support structure parts and to make permanent or temporary tack welds used in such welding shall also meet the qualification requirements of this Article.

*(c)* When making procedure test plates for butt welds, consideration shall be given to the effect of angular, lateral, and end restraint on the weldment. This applies particularly to material and weld metal of 80.0 ksi (550 MPa) tensile strength or higher and heavy sections of both low and high tensile strength material. The addition of restraint during welding may result in cracking difficulties that otherwise might not occur.

### NG-4322 Maintenance and Certification of Records

The Certificate Holder shall maintain a record of their qualified welding procedures and of the welders and welding operators qualified by them, showing the date and results of tests and the identification mark assigned to each welder. These records shall be reviewed, verified, and certified by the Certificate Holder by signature or some other method of control in accordance with the Certificate Holder's Quality Assurance Program and shall be available to the Authorized Nuclear Inspector.

**NG-4322.1 Identification of Joints by Welder or Welding Operator.**

*(a)* Each welder or welding operator shall apply the identification mark assigned to them by the Certificate Holder on or adjacent to all permanent welded joints or series of joints on which that person welds. The marking shall be at intervals of 3 ft (1 m) or less and shall be done with either blunt nose continuous or blunt nose interrupted dot die stamps. As an alternative, the Certificate Holder shall keep a record of permanent welded joints in each item and of the welders and welding operators used in making each of the joints.

*(b)* When a multiple number of permanent structural attachment welds, nonstructural welds, fillet welds, socket welds, welds of specially designed seals, weld metal cladding, hard surfacing, and tube-to-tubesheet welds are made on an item, the Certificate Holder need not identify the welder or welding operator who welded each individual joint, provided

*(1)* the Certificate Holder maintains a system that will identify the welders or welding operators that made such welds on each item so that the Inspector can verify that the welders or welding operators were all properly qualified

*(2)* the welds in each category are all of the same type and configuration and are welded with the same Welding Procedure Specification

*(c)* The identification of welder or welding operator is not required for tack welds.

### NG-4323 Welding Prior to Qualification

No welding shall be undertaken until after the welding procedures which are to be used have been qualified. Only welders and welding operators who are qualified in accordance with NG-4320 and Section IX shall be used.

### NG-4324 Transferring Qualifications

The welding procedure qualifications and the performance qualification tests for welders and welding operators conducted by one Certificate Holder shall not qualify welding procedures and shall not qualify welders or welding operators to weld for any other Certificate Holder except as provided in Section IX.

## NG-4330 GENERAL REQUIREMENTS FOR WELDING PROCEDURE QUALIFICATION TESTS

### NG-4331 Conformance to Section IX Requirements

All welding procedure qualification tests shall be in accordance with the requirements of Section IX as supplemented by the requirements of this Article.

## NG-4333 Heat Treatment of Qualification Welds for Ferritic Material

Postweld heat treatment of procedure qualification welds shall conform to the applicable requirements of NG-4600 and Section IX. The postweld heat treatment time at temperature shall be at least 80% of the maximum time to be applied to the weld material. The postweld heat treatment total time may be applied in one heating cycle.

## NG-4334 Preparation of Test Coupons and Specimens

*(a)* Removal of test coupons from the test weld and the dimensions of specimens made from them shall conform to the requirements of Section IX, except that the removal of impact test coupons and the dimensions of impact test specimens shall be in accordance with (b).

*(b)* Weld deposit of each process in a multiple process weld shall, where possible, be included in the impact test specimens. When each process cannot be included in the full-size impact test specimen at the $\frac{1}{4}t$ location required by this Section, additional full-size specimens shall be obtained from locations in the test weld that will ensure that at least a portion of each process has been included in full-size test specimens. As an alternative, additional test welds can be made with each process so that full-size specimens can be tested for each process.

**NG-4334.1 Coupons Representing the Weld Deposits.** Impact test specimens and testing methods shall conform to NG-2321. The impact specimen shall be located so that the longitudinal axis of the specimen is at least $\frac{1}{4}t$ and, where the thickness of the test assembly permits, not less than $\frac{3}{8}$ in. (10 mm) from the weld surface of the test assembly. In addition, when the postweld heat treatment temperature exceeds the maximum temperature specified in NG-4620 and the test assembly is cooled at an accelerated rate, the longitudinal axis of the specimen shall be a minimum of $t$ from the edge of the test assembly. The specimen shall be transverse to the longitudinal axis of the weld with the area of the notch located in the weld. The length of the notch of the Charpy V-notch specimen shall be normal to the surface of the weld. Where drop weight specimens are required, the tension surface of the specimen shall be oriented parallel to the surface of the test assembly.

**NG-4334.2 Coupons Representing the Heat-Affected Zone.** Where impact tests of the heat-affected zone are required by NG-4335.2, specimens shall be taken from the welding procedure qualification test assemblies in accordance with (a) through (c).

*(a)* If the qualification test material is in the form of a plate or a forging, the axis of the weld shall be oriented in the direction parallel to the principal direction of rolling or forging.

*(b)* The heat-affected zone impact test specimens and testing methods shall conform to the requirements of NG-2321.2. The specimens shall be removed from a location as near as practical to a depth midway between the surface and center thickness. The coupons for heat-affected zone impact specimens shall be taken transverse to the axis of the weld and etched to define the heat-affected zone. The notch of the Charpy V-notch specimen shall be cut approximately normal to the material surface in such a manner as to include as much heat-affected zone as possible in the resulting fracture. Where the material thickness permits, the axis of a specimen may be inclined to allow the root of the notch to align parallel to the fusion line. When a grain-refining heat treatment is not performed on welds made by the electroslag or electrogas welding process, the notch for the impact specimens shall be located in the grain-coarsened region.

*(c)* For the comparison of heat-affected zone values with base material values [see NG-4335.2(b)], Charpy V-notch specimens shall be removed from the unaffected base material at approximately the same distance from the base material surface as the heat-affected zone specimens. The axis of the unaffected base material specimens shall be parallel to the axis of the heat-affected zone specimens, and the axis of the notch shall be normal to the surface of the base material. When required by NG-4335.2(b), drop weight specimens shall be removed from a depth as near as practical to midway between the surface and center thickness of the unaffected base material and shall be tested in accordance with the requirements of NG-2321.1.

## NG-4335 Impact Test Requirements

When materials are required to be impact tested per NG-2300, impact tests of the weld metal and heat-affected zone shall be performed in accordance with the following subparagraphs. The weld procedure qualification impact test specimens shall be prepared and tested in accordance with the applicable requirements of NG-2330 and NG-4334. Retests in accordance with the provisions of NG-2350 are permitted.

**NG-4335.1 Impact Tests of Weld Metal.**

*(a)* Impact tests of the weld metal shall be required for welding procedure qualification tests for production weld joints exceeding $\frac{5}{8}$ in. (16 mm) in thickness when the weld will be made on the surface or will penetrate the base material that requires impact testing in accordance with NG-2310. In addition, such testing of the weld metal is required for the welding procedure qualification tests for any weld repair to base material that requires impact testing in accordance with NG-2310, regardless of the depth of the repair.

*(b)* The impact test requirements and acceptance standards for welding procedure qualification weld metal shall be the same as specified in NG-2330 for the base material to be welded or repaired. Where two materials are to be