December 18, 2012

Mr. William Lindsay
City Manager
City of Richmond
450 Civic Center Plaza
Richmond, CA 94804

Re: Material Selection For Repair Of Damaged Process Piping In High-Temperature Sulfidation Service In The No. 4 Crude Unit – December 12, 2012, Application for City of Richmond Permits

Dear Mr. Lindsay:

At the request of the City of Richmond, California, I have prepared this letter to provide an opinion as to whether the use of 9Cr material as a replacement for fire damaged piping in high-temperature sulfidation service in the No. 4 Crude Unit will meet the requirements of the California Fire Code (CFC).

Background Information

Chevron U.S.A. Inc. has submitted applications to the City of Richmond for permits pursuant to the California Fire Code to replace fire damaged piping in high temperature sulfidation service in the Crude Unit with 9 Chrome ("9Cr") alloy pipe. Chevron has prepared a technical report (the report) responding to the City of Richmond's request for additional information concerning Chevron's selection of materials for this repair. The decision on which materials to use is to be made by Chevron. However, prior to issuing the fire construction permits, the City of Richmond would like to conduct an independent review of the material selection for conformance with the CFC.

Scope of Assignment

It is my understanding that the assignment involves reviewing the referenced Chevron report, plus supporting documents (see references) and confirming that their material selection meets the CFC. The review should also assess whether the report is sufficiently complete to evaluate concurrence with the CFC. Although not directly related to compliance with the CFC, in order to provide a more complete review of the Chevron technical report, I have also reviewed Chevron's discussion on the American Petroleum Institute's (API's) Recommended Practice (RP) 939-C Guidelines for Avoiding Sulfidation Corrosion Failures in Oil Refineries.

City of Richmond Permitting Process & Requirements

The following summary describes my understanding of the City of Richmond permitting process and requirements for replacement of fire-damaged piping in high-temperature sulfidation service in the No. 4 Crude Unit, based on the information included in Appendix A:

Chevron selects materials for the repair work and submits building and fire permit applications to the City of Richmond. The City of Richmond first conducts a plan check to verify that no new or different equipment will be installed that would allow an increase in emissions or unit throughput. The City of Richmond also confirms that no discretionary permit approval is required (i.e., for changes to increase the quantities of throughput through the crude unit or change the category of chemicals to a more hazardous category).

Following these initial reviews, the building permit is reviewed for compliance with the California Building Code (CBC)(24 Cal. Code Regs Part 2), including codes, standards, and publications adopted as standard reference documents and enforced as part of the CBC. (CBC §§ 1.1.3; 1.1.5; 1.8.6.1). If the Building Official finds that the work described in an application and the plans, specifications, and other data filed with the application conforms to the requirements of RMC Chapter 6.02, including the CBC and associated standard reference documents, and that required building permit fees have been paid, the Building official must issue the requested building permit to the applicant. (RMC § 6.02.170(a)).

The fire permit applications are then reviewed for conformance with the CFC (and reference standards cited in the CFC), including Chapter 27 (Hazardous Materials) and Chapter 34 (Flammable and Combustible Liquids). For example, CFC Sections 3403.6.1 through 3403.6.11 apply to piping systems and their component parts for flammable and combustible liquids. These provisions require that piping systems and component parts for flammable and combustible liquids shall be designed and fabricated in accordance with the applicable standards listed in CFC Chapter 47. Fire construction permit applications submitted in connection with the Repair Project are reviewed to determine whether piping and component parts for flammable and combustible liquids meet the requirements set forth in CFC Sections 3403.6.1 through 3403.6.11, as well as any reference standards cited in those sections. Based on communication with the Richmond Fire Marshal, the referenced standards include the American Society of Mechanical Engineers (ASME) Code for Process Piping (ASMEB.31.3) and the fire safety standards of the National Fire Protection Association (NFPA) Flammable and Combustible Liquids Code (NFPA30). If the Fire Code Official is satisfied that the proposed work or operation conforms to the requirements of the CFC (including codes and standards listed in CFC Chapter 47 that are considered part of the CFC requirements), and laws and ordinances applicable thereto, the Fire Code Official is required to issue a permit as soon as practicable. (CFC §§ 1.1.5, 102.7; 105.2.4).

Discussion

The Technical Analysis section of the Chevron report states that: "Pursuant to ASME B31.3 and NFPA30, carbon steel, 5 Chrome alloy ("5Cr"), 9Cr, and 300 series Stainless Steel ("300SS") are suitable for service in the Crude Unit." Appendix I of the report describes Chevron's understanding of the permitting process, the pertinent sections of the 2010 California Fire Code, Title 24, Part 9 and their technical basis for justification that 9Cr material meets the CFC requirements, specifically, Chapter 27 – Hazardous Materials, and Chapter 34 – Flammable and Combustible Materials. With respect to piping handling hazardous chemicals, those two chapters refer to the requirements of ASME B31.3, Process Piping and NFPA 30, Flammable and Combustible Liquids Code. Chevron discusses their opinion that the use of 9Cr meets the CFC requirements in Appendix I; Technical Standards of the CFC section.

Chevron also states in the Technical Analysis section of the report that API 939-C identifies carbon steel with adequate silicon, 5Cr, 9Cr, and 300 SS as examples of materials suitable for high temperature sulfidation (HTS) service, depending on various factors. This is demonstrated by the Modified McConomy Curves, presented in API 939-C, which show the sulfidation corrosion rates of carbon steel

with silicon, 5Cr, 9Cr, and 300 SS. According to Chevron, each of these materials may be suitable for HTS service in the Crude Unit, in particular when one takes into account the Crude Unit's operational history.

Opinions

Based on communication with the City of Richmond Fire Marshal and my review of: (1) the City of Richmond memorandum outlining the permitting process (Appendix A), (2) the Chevron report, including Appendix I, (3) the 2010 California Fire Code, Title 24, Part 9, Chapters 27, 34 and 47, (4) ASME B31.3, (5) NFPA 30, 2012 Ed and (6) API RP 939-C, I offer the following opinions:

- The use of 9Cr material meets the requirements of CFC, based on compliance with B31.3 and NFPA 30. My opinion that 9Cr material meets the requirements of B31.3 is supported by the extracts from B31.3 (Appendix B). In summary, B31.3 is intended to be a code detailing requirements for the design, fabrication, testing and inspection of piping, piping components and piping supports. B31.3 scope states that the piping designer is responsible for the selection of piping materials to resist corrosion and erosion (K 302.1). It further states that "Any material used in pressure containing piping components shall conform to a listed specification except as provided in paragraph 323.1.2." 9Cr material is a listed material in B31.3 with allowable stresses to be used in pressure containment design, if ordered to the requirements of one of the listed ASTM specifications for that material, such as ASTM A335 (Appendix C).

- Similarly, in NFPA 30 the primary section relating to compliance with this code is Chapter 27 – Piping Systems. Paragraph 27.4.1 Materials Specifications, states that "Pipe, valves, faucets, couplings, flexible connectors, fittings, and other pressure-containing parts shall meet the material specifications and pressure and temperature limitations of ASME B31, Code for Pressure Piping, except as provided for in 27.4.2, 27.4.3, and 27.4.4." (Appendix D). The appropriate B31 Code for Pressure Piping for the Chevron No. 4 Crude Unit rebuild is B31.3, Process Piping and the support for 9Cr material meeting the requirements of B31.3 has been provided.

- There are two distinct and separate sets of curves that the industry uses to predict high-temperature sulfidation corrosion. These curves, plus other information and data useful for material selection in high-temperature sulfur containing environments, are included in API RP 939-C. The RP is intended to provide practical guidance to inspectors, maintenance, reliability, project, operations and corrosion personnel on how to address sulfidation corrosion in petroleum refining operations.

  The modified McConomy curves are intended to be used in H_2 free streams. These curves show that at a given temperature and total sulfur level, steels with increasing chromium content (from carbon steel, to 5Cr to 9Cr to stainless steel) will experience lower corrosion rates. Where no prior experience or information is available, the modified McConomy curves would indicate the following materials selections for resistance to sulfidation corrosion (not considering the effect of naphthenic acid corrosion or mercaptan corrosion) in H_2-free, 2 wt.% S environments is as follows:

  - Carbon steel for temperatures up to 525 °F (275 °C). Use fully killed steels to assure silicon content > 0.10 wt %.

- 5Cr-0.5Mo for temperatures between 525 °F and 620 °F (275 °C and 325 °C).
- 9Cr-1Mo above 620 °F (325 °C).

These selections could vary depending on sulfur species, hydrocarbon phase, flow regime and the other operating variables; *therefore, materials and corrosion specialists should be consulted for additional unit-specific interpretation and application of the RP*.

In summary, API RP 939-C is a recommended practice that provides guidelines on the mechanism of high-temperature sulfidation, parameters that affect corrosion rates and operating regimes where various materials are known to resist high-temperature sulfidation, based on experience and empirical data. 9Cr is one such alloy included in RP 939-C. It is the responsibility of an experienced materials and corrosion specialist to select the most appropriate alloy for the specific application at hand.

- In Chevron's selection of 9Cr material as replacement piping for the No. 4 Crude Unit rebuild project, it is my opinion that, based on my review of their technical report, Chevron followed a logical, technically sound and defendable basis for their selection. Chevron stated that they relied on experienced materials engineers to conduct the material selection review and recognized that any selection of material must include a comprehensive monitoring and inspection program to ensure that the selection would meet performance expectations. They also appeared to recognize the complexity of the material selection process and the many input parameters that needed to be reviewed in order to make an appropriate selection. Their use of API RP 939-C as an industry recognized resource document in their selection process was appropriate.

- I am not in a position as of this writing to fully evaluate Chevron's selection of 9Cr for replacement piping material, as I have not reviewed the process, operational and maintenance data required to do so. However, assuming that both 9Cr and 300SS are resistant to the type of high-temperature sulfidation environment encountered in the Crude Unit at the Chevron Richmond Refinery, Chevron's rationale for selecting 9Cr material versus 300SS is appropriate. The 300SS alloys are widely known for their susceptibility to chloride stress corrosion cracking (CSCC) in aqueous streams containing chlorides at temperatures greater than approximately 140 degrees Fahrenheit. The unstabilized grades of the SS alloys are also susceptible to polythionic acid stress corrosion cracking (PASCC) in sulfur containing environments when exposed to oxygen. Internal CSCC and PASCC are damage mechanisms that are difficult to detect from the exterior of pressure containment components. Because high-temperature sulfidation causes general corrosion, detection of this damage mechanism is much easier using conventional non-destructive inspection techniques.

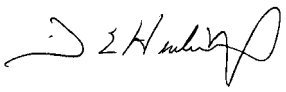
Conclusions

1. Based on my review of the documents cited in the References section of this letter, I agree with the interpretation in the Chevron report that 9Cr material meets the requirements of CFC and its referenced standards and codes.
2. I found that the Chevron report was sufficiently complete to evaluate concurrence with the CFC.

3. API 939-C is an appropriate resource document for selecting materials for the rebuild of the Chevron Crude Unit.
4. Based on the information contained in Chevron's technical report, it is my opinion that Chevron's logic and procedures used in their materials selection process is consistent with industry practice.
5. These opinions are limited to the review and conclusions set forth above, and do not constitute a professional opinion that Chevron should install 9Cr materials in its repair project.

I trust that this letter complies with your request for information on the selection of 9Cr in support of the permitting process.

Sincerely,



David E. Hendrix, P.E.
President
The Hendrix Group, Inc.

References

1. Memorandum from Lina Velasco (City of Richmond Senior Planner) to Richard Mitchell (City of Richmond Director of Planning and Building Services). Overview of City Building and Fire Permit Review Process, November 7, 2012.
2. Chevron Report - Material Selection For Repair Of Damaged Process Piping In High-Temperature Sulfidation Service in the No. 4 Crude Units, December 12, 2012.
3. The 2010 California Fire Code, Title 24, Part 9, Chapters 27, 34 and 47.
4. ASME B31.3, Process Piping, 2008.
5. NFPA 30, Flammable and Combustible Liquids Code, 2012.
6. API RP 939-C, Guidelines for Avoiding Sulfidation Corrosion Failures in Oil Refineries.

Appendix A

City of Richmond Fire Permit Review Process Letter

DATE: November 7, 2012

TO: Richard Mitchell, Director of Planning and Building Services

FROM: Lina Velasco, Senior Planner

CC: Terry Harris, Fire Marshal

SUBJECT: Overview of City Building and Fire Permit Review Process for Chevron No. 4 Crude Unit and No. 3 Cat Cooling Tower Repair

I. INTRODUCTION

Pursuant to your request and to our discussions, this memorandum briefly describes: 1) the City of Richmond's (City) process for issuing building and fire permits relating to the repair of the Chevron Crude No. 4 Unit and No. 3 Cat Cooling Tower that were damaged by the August 6, 2012 fire (Repair Project); and 2) how the City determined that issuance of these permits are ministerial actions by the City.

The Repair Project includes the removal and replacement or repair of structural steel, electrical systems and connections, instrumentation and the cooling tower structure, as well as process equipment such as pressure vessels, tanks, pumps, and piping. As documented by Chevron in its October 6, 2012 notification to the City (Repair Project Description), all repair and replacement equipment/materials are to be repaired or replaced with "in-kind" or equivalent equipment/materials that meet or exceed applicable industry standards and/or codes. No new or different equipment will be installed that would allow an increase in emissions or unit throughput or changes to the operation of the crude unit, cooling tower, and associated equipment. The plan check process has been and will be used to verify that no new or different equipment will be installed that would allow an increase in emissions or unit throughput or changes to the operation of the crude unit, cooling tower, and associated equipment.

As described further below, the proposed Repair Project has not required any discretionary actions by the City and involves only the issuance of building permits and fire permits by the City.

II. DISCUSSION

A. Review for Applicability of City Discretionary Permits

The City reviewed the Repair Project components to confirm that no discretionary City approval by the City is required. For example, if the Repair Project were to propose a modification that would increase the quantities of throughput through the crude unit or change the category of chemicals to a more hazardous category, a conditional use permit would be

required per Section 15.04.820.020 of the Richmond Municipal Code (RMC). The Repair Project Description, however, does not propose these modifications. Per Section 15.4.930.020(C)(6) of the RMC, "replacement or reconstruction of existing equipment and appurtenant facilities where new equipment and facilities are similar in size, design, and appearance to the equipment or facility replaced" are exempt from Design Review. Because Chevron is only seeking such replacement/reconstruction of existing equipment, their proposed work is exempt from Design Review. Of course, the City reviews each building and fire permit as it is submitted to confirm that none of the Repair Project components deviate from the overall Repair Project Description so as to trigger the need for a discretionary approval.

B. Building Permits

Under the City's Building Regulations Administrative Code, a building permit is required to construct, enlarge, alter, repair, move, improve, remove, convert, or demolish a building, structure, or service equipment. (RMC § 6.02.150(a)). In order to obtain a building permit, the permit application must identify the work to be covered by the permit. (RMC § 6.02.160(A)). The application must include plans and specifications that indicate the location, nature, and extent of the work proposed and show in detail that the work will conform to the provisions of the technical codes and all relevant laws, ordinances, rules and regulations. (RMC §§ 6.02.160(B)-(C)).

The application is reviewed by the Building Official, and may be reviewed by other departments to verify compliance with any applicable laws under their jurisdiction. (RMC § 6.02.170(a)). Review of a building permit application includes review for compliance with the California Building Code (CBC)(24 Cal. Code Regs Part 2), including codes, standards, and publications adopted as standard reference documents and enforced as part of the CBC. (CBC §§ 1.1.3; 1.1.5; 1.8.6.1).

If the Building Official finds that the work described in an application and the plans, specifications, and other data filed with the application conforms to the requirements of RMC Chapter 6.02, including the CBC and associated standard reference documents, and that required building permit fees have been paid, the Building official must issue the requested building permit to the applicant. (RMC § 6.02.170(a)). This action is ministerial, as further described in Section D below.

C. Fire Permits

The City Fire Department (which also contracts with the Contra Costa County Fire District for fire permit plan review and inspection services), administers the California Fire Code (CFC) permit requirements (24 Cal. Code Regs. Part 9). A fire permit is required under specified conditions to: (1) maintain, store or handle hazardous materials; (2) conduct processes which produce conditions hazardous to life or property; (3) install equipment utilized in connection with such activities; (4) install or modify any fire protection system or equipment; or (5) engage in other construction, equipment installation or modification activities where a fire permit is required. (CFC § 105.3, 105.6, and 105.7).

While the Building Code requires permits for construction activities, the Fire Code requires both construction permits as well as annual operating permits for designated activities.

- Construction permits allow an applicant to install or modify systems and equipment that require a permit under CFC Section 105.7.

- Operational permits allow an applicant to conduct an operation or business that requires a permit under CFC Section 105.6. (CFC § 105.1.2).

Section 105 of the CFC outlines the permit application process. A permit application must include construction documents and supporting data to indicate the location, nature, and extent of the work proposed, and must show in detail that the work will conform to the provisions of the CFC and relevant laws, ordinances, rules and regulations. (CFC §§ 105.4.1 - 105.4.2).

Fire permit applications for the Repair Project are reviewed for conformance with the CFC (and reference standards cited in the CFC), including Chapter 27 (Hazardous Materials) and Chapter 34 (Flammable and Combustible Liquids). For example, CFC Sections 3403.6.1 through 3403.6.11 apply to piping systems and their component parts for flammable and combustible liquids. These provisions require that piping systems and component parts for flammable and combustible liquids shall be designed and fabricated in accordance with the applicable standards listed in CFC Chapter 47. Fire construction permit applications submitted in connection with the Repair Project are reviewed to determine whether piping and component parts for flammable and combustible liquids meet the requirements set forth in CFC Sections 3403.6.1 through 3403.6.11, as well as any reference standards cited in those sections.

If the Fire Code Official is satisfied that the proposed work or operation conforms to the requirements of the CFC (including codes and standards listed in CFC Chapter 47 that are considered part of the CFC requirements), and laws and ordinances applicable thereto, the Fire Code Official is required to issue a permit as soon as practicable. (CFC §§ 102.7; 105.2.4). This action is ministerial, as further described below.

D. CEQA Considerations

The California Environmental Quality Act (CEQA) applies only to discretionary City approvals, and does not apply to ministerial approvals. (Cal. Pub. Res. Code § 21080(a), (b)). A "ministerial" decision is defined as:

> [A] governmental decision involving little or no personal judgment by the public official as to the wisdom or manner of carrying out the project. The public official merely applies the law to the facts as presented but uses no special discretion or judgment in reaching a decision. A ministerial decision involves only the use of fixed standards or objective measurements, and the public official cannot use personal, subjective judgment in deciding whether or how the project should be carried out....

(CEQA Guidelines § 15369).

The City's *Guidelines and Procedures for the Implementation of the California Environmental Quality Act* (Adopted September 23, 2003, Resolution No. 125-03) identify issuance of a building permit as an example of a ministerial decision.

Approval of a building permit or fire construction or operation permit in accordance with the City's procedures as outlined in this report are ministerial and statutorily exempt from CEQA where (1) the application is reviewed for conformance with specific standards or objective measurements, and (2) the permit **must** be issued if applicable objective standards and objectives measurements are met. Here, for the Repair Project, each component of the repair activity is reviewed to identify applicable standards and, if the activity complies with applicable standards, the permit is issued as a ministerial decision. If the permit application does not demonstrate compliance with applicable standards, the permit application is denied until and unless the application is modified to demonstrate compliance.

III. CONCLUSION

Consistent with the above analysis, the City has determined that the Repair Project permits issued to date by the City are exempt under CEQA as ministerial actions. The City has issued building permits for the Repair Project consistent with these laws. In addition, the City continues to coordinate with the other agencies who are investigating the August 6, 2012 fire. Notably, as you know, CSB and CalOSHA provided the City with written notification that they have no objection to the City's issuance of permits related to the repair. In addition, the Bay Area Air Quality Management District (BAAQMD) has, like the City, determined that no discretionary BAAQMD approvals are required for the Repair Project based on information provided by Chevron to date. BAAQMD is reviewing components of the Repair Project to ensure the repair work does not result in an increase of throughput through the crude unit and that Chevron's proposal to incorporate best available control technology (BACT) is demonstrated in the plans for the Repair Project. City staff is continuing to coordinate with those agencies reviewing the Repair Project and investigating the root cause of the August 6, 2012 fire.

Appendix B

B31.3 Excerpts

The Code prohibits designs and practices known to be unsafe and contains warnings where caution, but not prohibition, is warranted.

This Code Section includes the following:

(a) references to acceptable material specifications and component standards, including dimensional requirements and pressure–temperature ratings

(b) requirements for design of components and assemblies, including piping supports

(c) requirements and data for evaluation and limitation of stresses, reactions, and movements associated with pressure, temperature changes, and other forces

(d) guidance and limitations on the selection and application of materials, components, and joining methods

(e) requirements for the fabrication, assembly, and erection of piping

(f) requirements for examination, inspection, and testing of piping

ASME Committee B31 is organized and operates under procedures of The American Society of Mechanical Engineers that have been accredited by the American National Standards Institute. The Committee is a continuing one, and keeps all Code Sections current with new developments in materials, construction, and industrial practice. New editions are published at intervals of two years.

Code users will note that clauses in the Code are not necessarily numbered consecutively. Such discontinuities result from following a common outline, insofar as practical, for all Code Sections. In this way, corresponding material is correspondingly numbered in most Code Sections, thus facilitating reference by those who have occasion to use more than one Section.

It is intended that this edition of Code Section B31.3 not be retroactive. Unless agreement is specifically made between contracting parties to use another issue, or the regulatory body having jurisdiction imposes the use of another issue, the latest edition issued at least 6 months prior to the original contract date for the first phase of activity covering a piping installation shall be the governing document for all design, materials, fabrication, erection, examination, and testing for the piping until the completion of the work and initial operation.

Users of this Code are cautioned against making use of Code revisions without assurance that they are acceptable to the proper authorities in the jurisdiction where the piping is to be installed.

The B31 Committee has established an orderly procedure to consider requests for interpretation and revision of Code requirements. To receive consideration, such request must be in writing and must give full particulars in accordance with Appendix Z.

The approved reply to an inquiry will be sent directly to the inquirer. In addition, the question and reply will be published as part of an Interpretation supplement.

A Case is the prescribed form of reply when study indicates that the Code wording needs clarification, or when the reply modifies existing requirements of the Code or grants permission to use new materials or alternative constructions. The Case will be published as part of a Case supplement.

The ASME B31 Standards Committee took action to eliminate Code Case expiration dates effective September 21, 2007. This means that all Code Cases in effect as of this date will remain available for use until annulled by the ASME B31 Standards Committee.

A request for revision of the Code will be placed on the Committee's agenda. Further information or active participation on the part of the proponent may be requested during consideration of a proposed revision.

Materials ordinarily are listed in the stress tables only when sufficient usage in piping within the scope of the Code has been shown. Requests for listing shall include evidence of satisfactory usage and specific data to permit establishment of allowable stresses, maximum and minimum temperature limits, and other restrictions. Additional criteria can be found in the guidelines for addition of new materials in the ASME Boiler and Pressure Vessel Code, Section II and Section VIII, Division 1, Appendix B. (To develop usage and gain experience, unlisted materials may be used in accordance with para. 323.1.2.) Metric versions of Tables A-1 and A-2 are in the course of preparation. Please refer to the B31.3 Process Piping Web pages at *http://cstools.asme.org/csconnect/CommitteePages.cfm.*

Chapter III
Materials

323 GENERAL REQUIREMENTS

Chapter III states limitations and required qualifications for materials based on their inherent properties. Their use in piping is also subject to requirements and limitations in other parts of this Code [see para. 300(d)]. See also para. 321.1.4 for support materials, and Appendix F, para. F323, for precautionary considerations.

323.1 Materials and Specifications

323.1.1 Listed Materials. Any material used in pressure containing piping components shall conform to a listed specification except as provided in para. 323.1.2.

323.1.2 Unlisted Materials. Unlisted materials may be used provided they conform to a published specification covering chemistry, physical and mechanical properties, method and process of manufacture, heat treatment, and quality control, and otherwise meet the requirements of this Code. Allowable stresses shall be determined in accordance with the applicable allowable stress basis of this Code or a more conservative basis.

323.1.3 Unknown Materials. Materials of unknown specification shall not be used for pressure-containing piping components.

323.1.4 Reclaimed Materials. Reclaimed pipe and other piping components may be used, provided they are properly identified as conforming to a listed or published specification (para. 323.1.1 or 323.1.2) and otherwise meet the requirements of this Code. Sufficient cleaning and inspection shall be made to determine minimum wall thickness and freedom from imperfections which would be unacceptable in the intended service.

323.2 Temperature Limitations

The designer shall verify that materials which meet other requirements of the Code are suitable for service throughout the operating temperature range. Attention is directed to Note (7) in Appendix A, which explains the means used to set both cautionary and restrictive temperature limits in Tables A-1 and A-2.

323.2.1 Upper Temperature Limits, Listed Materials. A listed material may be used at a temperature above the maximum for which a stress value or rating is shown, only if

(a) there is no prohibition in Appendix A or elsewhere in the Code

(b) the designer verifies the serviceability of the material in accordance with para. 323.2.4

323.2.2 Lower Temperature Limits, Listed Materials

(a) A listed material may be used at any temperature not lower than the minimum shown in Table A-1, provided that the base metal, weld deposits, and heat-affected zone (HAZ) are qualified as required by the applicable entry in Column A of Table 323.2.2.

(b) For carbon steels with a letter designation in the Min. Temp. column of Table A-1, the minimum temperature is defined by the applicable curve and Notes in Fig. 323.2.2A. If a design minimum metal temperature-thickness combination is on or above the curve, impact testing is not required.

(c) A listed material may be used at a temperature lower than the minimum shown in Table A-1 or Fig. 323.2.2A (including Notes), unless prohibited in Table 323.2.2, Table A-1, or elsewhere in the Code, and provided that the base metal, weld deposits, and HAZ are qualified as required by the applicable entry in Column B of Table 323.2.2.

(d) Where the stress ratio defined in Fig. 323.2.2B is less than one, Fig. 323.2.2B provides a further basis for the use of carbon steels covered by paras. 323.2.2(a) and (b), without impact testing.

(1) For design minimum temperatures of −48°C (−55°F) and above, the minimum design metal temperature without impact testing determined in para. 323.2.2(b), for the given material and thickness, may be reduced by the amount of the temperature reduction provided in Fig. 323.2.2B for the applicable stress ratio. If the resulting temperature is lower than the minimum design metal temperature, impact testing of the material is not required. Where this is applied, the piping system shall also comply with the following requirements:

(a) The piping shall be subjected to a hydrostatic test at no less than 1½ times the design pressure.

(b) Except for piping with a nominal wall thickness of 13 mm (½ in.) or less, the piping system shall be safeguarded (see Appendix G) from external loads such as maintenance loads, impact loads, and thermal shock.

(2) For design minimum temperatures lower than −48°C (−55°F), impact testing is required for all materials, except as provided by Note (3) of Table 323.2.2.

(e) The allowable stress or component rating at any temperature below the minimum shown in Table A-1 or Fig. 323.2.2A shall not exceed the stress value or rating at the minimum temperature in Table A-1 or the component standard.

K301.5 Dynamic Effects

Paragraph 301.5 applies with the exception of para. 301.5.4.

K301.5.4 Vibration. Suitable dynamic analysis shall be made where necessary, to avoid or minimize conditions which lead to detrimental vibration, pulsation, or resonance effects in the piping.

K302 DESIGN CRITERIA

K302.1 General

In para. K302, pressure–temperature ratings, stress criteria, design allowances, and minimum design values are stated, and permissible variations of these factors as applied to design of high pressure piping systems are formulated.

The designer shall be satisfied as to the adequacy of the design, and of materials and their manufacture, considering at least the following:

(a) tensile, compressive, flexural, and shear strength at design temperature
(b) fatigue strength
(c) design stress and its basis
(d) ductility and toughness
(e) possible deterioration of mechanical properties in service
(f) thermal properties
(g) temperature limits
(h) resistance to corrosion and erosion
(i) fabrication methods
(j) examination and testing methods
(k) hydrostatic test conditions
(l) bore imperfections

K302.2 Pressure–Temperature Design Criteria

K302.2.1 Listed Components Having Established Ratings. Pressure-temperature ratings for certain piping components have been established and are contained in some of the standards in Table K326.1. Unless limited elsewhere in this Chapter, those ratings are acceptable for design pressures and temperatures under this Chapter. With the owner's approval, the rules and limits of this Chapter may be used to extend the pressure–temperature ratings of a component beyond the ratings of the listed standard, but not beyond the limits stated in para. K323.2.

K302.2.2 Listed Components Not Having Specific Ratings

(a) Piping components for which design stresses have been developed in accordance with para. K302.3, but which do not have specific pressure–temperature ratings, shall be rated by rules for pressure design in para. K304, within the range of temperatures for which stresses are shown in Table K-1, modified as applicable by other rules of this Chapter.

(b) Piping components which do not have allowable stresses or pressure–temperature ratings shall be qualified for pressure design as required by para. K304.7.2.

K302.2.3 Unlisted Components

(a) Piping components not listed in Table K326.1 or Table K-1, but which conform to a published specification or standard, may be used subject to the following requirements:

(1) The designer shall determine that composition, mechanical properties, method of manufacture, and quality control are comparable to the corresponding characteristics of listed components.

(2) Pressure design shall be verified in accordance with para. K304, including the fatigue analysis required by para. K304.8.

(b) Other unlisted components shall be qualified for pressure design as required by para. K304.7.2.

K302.2.4 Allowance for Pressure and Temperature Variations. Variations in pressure above the design pressure at the coincident temperature, except for accumulation during pressure relieving (see para. K322.6.3), are not permitted for any piping system.

K302.2.5 Ratings at Junction of Different Services. Paragraph 302.2.5 applies.

K302.3 Allowable Stresses and Other Design Limits

K302.3.1 General. The allowable stresses defined below shall be used in design calculations unless modified by other provisions of this Chapter.

(a) Tension. Allowable stresses in tension for use in design in accordance with this Chapter are listed in Table K-1, except that maximum allowable stress values and design stress intensity values for bolting, respectively, are listed in the BPV Code, Section II, Part D, Tables 3 and 4.

The tabulated stress values in Table K-1 are grouped by materials and product form and are for stated temperatures up to the limit provided for the materials in para. K323.2.1. Straight line interpolation between temperatures to determine the allowable stress for a specific design temperature is permissible. Extrapolation is not permitted.

(b) Shear and Bearing. Allowable stress in shear shall be 0.80 times the allowable stress in tension tabulated in Table K-1. Allowable stress in bearing shall be 1.60 times the allowable stress in tension.

(c) Compression. Allowable stress in compression shall be no greater than the allowable stress in tension tabulated in Table K-1. Consideration shall be given to structural stability.

(d) Fatigue. Allowable values of stress amplitude, which are provided as a function of design life in the BPV Code, Section VIII, Division 2, Part 3, para. 3.15 and Annex 3.F, or Division 3, Article KD-3, as applicable, (08)

Table A-1 Basic Allowable Stresses in Tension for Metals[1] (Cont'd)

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Material	Spec. No.	P-No. or S-No. (5)	Grade	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi		Min. Temp.	
						Tensile	Yield	to 100	200
Low and Intermediate Alloy Steel Pipes (2)									
½Cr–½Mo	A 335	3	P2	...	−20	55	30	18.3	18.3
½Cr–½Mo A 387 Gr. 2 Cl. 1	A 691	3	½CR	(11)(67)	−20	55	33	18.3	18.3
C–½Mo	A 335	3	P1						
C–½Mo	A 369	3	FP1	(58)	−20	55	30	18.3	18.3
½Cr–½Mo	A 369	3	FP2	...	−20	55	30	18.3	18.3
1Cr–½Mo A 387 Gr. 12 Cl. 1	A 691	4	1CR	(11)(67)	−20	55	33	18.3	18.3
½Cr–½Mo	A 426	3	CP2	(10)	−20	60	30	18.4	17.7
1½Si–½Mo	A 335	3	P15	...					
1½Si–½Mo	A 426	3	CP15	(10)	−20	60	30	18.8	18.2
1Cr–½Mo	A 426	4	CP12	(10)	−20	60	30	18.8	18.3
5Cr–½Mo–1½Si	A 426	5B	CP5b	(10)	−20	60	30	18.8	17.9
3Cr–Mo	A 426	5A	CP21	(10)	−20	60	30	18.8	18.1
¾Cr–¾Ni–Cu–Al	A 333	4	4	...	−150	60	35	20.0	19.1
2Cr–½Mo	A 369	4	FP3b	...	−20	60	30	20.0	18.5
1Cr–½Mo	A 335	4	P12						
1Cr–½Mo	A 369	4	FP12	...	−20	60	32	20.0	18.7
1¼Cr–½Mo	A 335	4	P11						
1¼Cr–½Mo	A 369	4	FP11	...	−20	60	30	20.0	18.7
1¼Cr–½Mo A 387 Gr. 11 Cl. 1	A 691	4	1¼CR	(11)(67)	−20	60	35	20.0	20.0
5Cr–½Mo A 387 Gr. 5 Cl. 1	A 691	5B	5CR	(11)(67)	−20	60	30	20.0	18.1
5Cr–½Mo	A 335	5B	P5						
5Cr–½Mo–Si	A 335	5B	P5b	...	−20	60	30	20.0	18.1
5Cr–½Mo–Ti	A 335	5B	P5c						
5Cr–½Mo	A 369	5B	FP5						
9Cr–1Mo	A 335	5B	P9						
9Cr–1Mo	A 369	5B	FP9	...	−20	60	30	20.0	18.1
9Cr–1Mo A 387 Gr. 9 Cl. 1	A 691	5B	9CR						
3Cr–1Mo	A 335	5A	P21						
3Cr–1Mo	A 369	5A	FP21	...	−20	60	30	20.0	18.7
3Cr–1Mo A 387 Gr. 21 Cl. 1	A 691	5A	3CR	(11)(67)	−20	60	30	20.0	18.5

Appendix C

ASTM A335

Designation: A335/A335M – 11

Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service[1]

This standard is issued under the fixed designation A335/A335M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification[2] covers nominal wall and minimum wall seamless ferritic alloy-steel pipe intended for high-temperature service. Pipe ordered to this specification shall be suitable for bending, flanging (vanstoning), and similar forming operations, and for fusion welding. Selection will depend upon design, service conditions, mechanical properties, and high-temperature characteristics.

1.2 Several grades of ferritic steels (see Note 1) are covered. Their compositions are given in Table 1.

NOTE 1—Ferritic steels in this specification are defined as low- and intermediate-alloy steels containing up to and including 10 % chromium.

1.3 Supplementary requirements (S1 to S7) of an optional nature are provided. These supplementary requirements call for additional tests to be made, and when desired, shall be so stated in the order together with the number of such tests required.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 2—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E92 Test Method for Vickers Hardness of Metallic Materials[4]

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

E570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ASME Standard:*

B36.10M Welded and Seamless Wrought Steel Pipe

2.3 *AWS Specifications*[5]

A5.5/A5.5M Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

A5.23/A5.23M Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

A5.28/A5.28M Specification for Low-Alloy Steel Electrodes for Gas Shielded Arc Welding

A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding

2.4 *Other Documents:*

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification[6]

SAE J 1086 Practice for Numbering Metals and Alloys (UNS)[7]

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.10 on Stainless and Alloy Steel Tubular Products.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-335 in Section II of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

[5] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.

[6] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[7] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

***A Summary of Changes section appears at the end of this standard.**

TABLE 1 Chemical Requirements

Grade	UNS Designation[A]	Composition, %							
		Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Others
P1	K11522	0.10–0.20	0.30–0.80	0.025	0.025	0.10–0.50	. . .	0.44–0.65	. . .
P2	K11547	0.10–0.20	0.30–0.61	0.025	0.025	0.10–0.30	0.50–0.81	0.44–0.65	. . .
P5	K41545	0.15 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	. . .
P5b	K51545	0.15 max	0.30–0.60	0.025	0.025	1.00–2.00	4.00–6.00	0.45–0.65	. . .
P5c	K41245	0.12 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	. . .[B]
P9	S50400	0.15 max	0.30–0.60	0.025	0.025	0.25–1.00	8.00–10.00	0.90–1.10	. . .
P11	K11597	0.05–0.15	0.30–0.60	0.025	0.025	0.50–1.00	1.00–1.50	0.44–0.65	. . .
P12	K11562	0.05–0.15	0.30–0.61	0.025	0.025	0.50 max	0.80–1.25	0.44–0.65	. . .
P15	K11578	0.05–0.15	0.30–0.60	0.025	0.025	1.15–1.65	. . .	0.44–0.65	. . .
P21	K31545	0.05–0.15	0.30–0.60	0.025	0.025	0.50 max	2.65–3.35	0.80–1.06	. . .
P22	K21590	0.05–0.15	0.30–0.60	0.025	0.025	0.50 max	1.90–2.60	0.87–1.13	. . .
P23	K41650	0.04–0.10	0.10–0.60	0.030 max	0.010 max	0.50 max	1.90–2.60	0.05–0.30	V 0.20–0.30 Cb 0.02–0.08 B 0.0010–0.006 N 0.015 max Al 0.030 max W 1.45–1.75 Ni 0.40 max Ti 0.005–0.060 Ti/N ≥ 3.5[C]
P24	K30736	0.05–0.10	0.30–0.70	0.020	0.010	0.15–0.45	2.20–2.60	0.90–1.10	V 0.20–0.30 Ti 0.06–0.10 N 0.012 max Al 0.02 max B 0.0015–0.007
P36	K21001	0.10–0.17	0.80–1.20	0.030 max	0.025 max	0.25–0.50	0.30 max	0.25–0.50	Ni 1.00-1.30 Cu 0.50-0.80 Cb 0.015-0.045 V 0.02 max N 0.02 max Al 0.050 max
P91	K91560	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.00–9.50	0.85–1.05	V 0.18–0.25 N 0.030–0.070 Ni 0.40 max Al 0.02 max Cb 0.06–0.10 Ti 0.01 max Zr 0.01 max
P92	K92460	0.07–0.13	0.30–0.60	0.020	0.010	0.50 max	8.50–9.50	0.30–0.60	V 0.15–0.25 N 0.03–0.07 Ni 0.40 max Al 0.02 max Cb 0.04–0.09 W 1.5–2.00 B 0.001–0.006 Ti 0.01 max Zr 0.01 max
P122	K92930	0.07–0.14	0.70 max	0.020	0.010	0.50 max	10.00–11.50	0.25–0.60	V 0.15–0.30 W 1.50–2.50 Cu 0.30–1.70 Cb 0.04–0.10 B 0.0005–0.005 N 0.040–0.100 Ni 0.50 max Al 0.020 max Ti 0.01 max Zr 0.01 max
P911	K91061	0.09–0.13	0.30–0.60	0.020 max	0.010 max	0.10–0.50	8.5–9.5	0.90–1.10	V 0.18–0.25 Ni 0.40 max Cb 0.060–0.10 B 0.0003–0.006 N 0.04–0.09 Al 0.02 max W 0.90–1.10 Ti 0.01 max Zr 0.01 max

[A] New designation established in accordance with Practice E527 and SAE J 1086, Practice for Numbering Metals and Alloys (UNS).

[B] Grade P 5c shall have a titanium content of not less than 4 times the carbon content and not more than 0.70 %; or a columbium content of 8 to 10 times the carbon content.

[C] Alternatively, in lieu of this ratio minimum, the material shall have a minimum hardness of 275 HV in the hardened condition, defined as after austenitizing and cooling to room temperature but prior to tempering. Hardness testing shall be performed at mid-thickness of the product. Hardness test frequency shall be two samples of product per heat treatment lot and the hardness testing results shall be reported on the material test report.

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (seamless alloy steel pipe),

3.1.3 Grade (Table 1),

3.1.4 Manufacture (hot-finished or cold-drawn),

3.1.5 Size using one of the following:

3.1.5.1 NPS and schedule number,

3.1.5.2 Outside diameter and nominal wall thickness,

3.1.5.3 Outside diameter and minimum wall thickness,

3.1.5.4 Inside diameter and nominal wall thickness, and

3.1.5.5 Inside diameter and minimum wall thickness.

3.1.6 Length (specific or random),

3.1.7 End finish (Ends Section of Specification A999/A999M),

3.1.8 Optional requirements (Section 8, 12 and 13 of this specification. See the Sections on Hydrostatic Test Requirements and Permissible Variation in Weight for Seamless Pipe in Specification A999/A999M),

3.1.9 Specification designation, and

3.1.10 Special requirements or any supplementary requirements selected, or both.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 Pipe may be either hot finished or cold drawn with the finishing treatment as required in 5.3.

5.2 *Grade P2 and P12*—The steel shall be made by coarse-grain melting practice. Specific limits, if any, on grain size or deoxidation practice shall be a matter of agreement between the manufacturer and purchaser.

5.3 *Heat Treatment*:

TABLE 2 Heat Treatment Requirements[A]

Grade	Heat Treat Type	Normalizing Temperature, min or range °F [°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]
P1	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1200 [650]
	subcritical anneal	. . .	. . .	1200-1300 [650-705]
P2	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1250 [675]
	subcritical anneal	. . .	. . .	1200-1300 [650-705]
P5	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1250 [675]
P5b	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1250 [675]
P5c	subcritical anneal	. . .	. . .	1325-1375 [715-745]
P9	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1250 [675]
P11	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1200 [650]
P12	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1200 [650]
	subcritical anneal	. . .	. . .	1200-1300 [650-705]
P15	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1200 [650]
P21	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1250 [675]
P22	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1250 [675]
P23	normalize and temper	1900-1975 [1040-1080]	air or accelerated cooling	1350-1470 [730-800]
P24	normalize and temper	1800–1870 [980–1020]	air or accelerated cooling	1350–1420 [730–770]
P36	normalize and temper[B]	1650 [900]	. . .	1100 [595]
P91	normalize and temper	1900-1975 [1040-1080]	. . .	1350-1470 [730-800][C]
	quench and temper[D]	1900-1975 [1040-1080]	. . .	1350-1470 [730-800]
P92	normalize and temper	1900-1975 [1040-1080]	[E]	1350-1470 [730-800]
P122	normalize and temper	1900-1975 [1040-1080]	. . .	1350-1470 [730-800]
P911	normalize and temper	1900-1975 [1040-1080]	[E]	1365-1435 [740-780]

[A] Where ellipses (…) appear in this table there is no requirement.

[B] Alternatively, Grade P36, Class 2 shall be cooled from the austenitizing temperature by accelerated cooling in air or by liquid quenching.

[C] Except when Supplementary Requirement S7 is specified by the purchaser.

[D] When mutually agreed upon between the manufacturer and the purchaser, quenching and tempering shall be permitted for thicknesses greater than 3 in. [75 mm].

[E] Accelerated cooling from the normalizing temperature shall be permitted for section thicknesses greater than 3 in. [75 mm].

5.3.1 All pipe shall be reheated for heat treatment and heat treated in accordance with the requirements of Table 2.

NOTE 3—It is recommended that the temperature for tempering should be at least 100 °F [50 °C] above the intended service temperature; consequently, the purchaser should advise the manufacturer if the service temperature is to be over 1100 °F [600 °C].

NOTE 4—Certain of the ferritic steels covered by this specification will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures. Therefore, operations involving heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Workmanship, Finish, and Appearance

7.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to ensure compliance with 7.2

7.2 Surface imperfections that penetrate more than 12½ % of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

7.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

7.2.2 Repaired in accordance with the repair welding provisions of 7.6.

7.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

7.2.4 Rejected.

7.3 To provide a workmanlike finish and basis for evaluating conformance with 7.2, the pipe manufacturer shall remove by grinding the following:

7.3.1 Mechanical marks, abrasions (see Note 5) and pits, any of which imperfections are deeper than 1⁄16 in. [1.6 mm].

NOTE 5—Marks and abrasions are defined as cable marks, dinges, guide marks, roll marks, ball scratches, scores, die marks, and the like.

7.3.2 Visual imperfections, commonly referred to as scabs, seams, laps, tears, or slivers, found by exploration in accordance with 7.1 to be deeper than 5 % of the nominal wall thickness.

7.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 7.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

7.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

7.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

7.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A999/A999M.

7.6.1 All repair welds in P91 shall be made with one of the following welding processes and consumables: SMAW, A5.5/A5.5M E90XX-B9; SAW, A5.23/A5.23M EB9 + neutral flux; GTAW, A5.28/A5.28M ER90S-B9; and FCAW A5.29/A5.29M E91T1-B9. In addition, the sum of the Ni+Mn content of all welding consumables used to weld repair P91 shall not exceed 1.0 %.

7.6.2 All repair welds in P92, P911, and P122, shall be made using welding consumables meeting the chemical requirements for the grade in Table 1.

7.6.3 After weld repair, Grades P23, P91, P92, and P122 shall be heat treated at 1350-1470 ºF [730-800 ºC].

7.6.4 After weld repair, Grade P911 shall be heat treated at 1365-1435 ºF [740-780 ºC].

7.6.5 After weld repair, Grade P24 shall be heat treated at 1350-1420 °F [730-770 °C].

7.7 The finished pipe shall be reasonably straight.

8. Product Analysis

8.1 At the request of the purchaser, an analysis of two pipes from each lot as defined hereafter shall be made by the manufacturer. A lot is all pipe of the same nominal size and wall thickness (schedule) which is produced from the same heat of steel and shall be limited as follows:

NPS Designator	Maximum Number of Lengths in a Lot
Under 2	400
2 to 5	200
6 and over	100

8.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Table 1.

8.3 For grade P 91 the carbon content may vary for the product analysis by –0.01 % and +0.02 % from the specified range as per Table 1.

8.4 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in 6.1, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

9. Tensile and Hardness Requirements

9.1 The tensile properties of the material shall conform to the requirements prescribed in Table 3.

9.2 Table 4 lists elongation requirements.

9.3 Pipe of Grade P91 shall have a hardness inclusively in the range 190 to 250 HBW/196 to 265 HV [91 HRB to 25 HRC]. Pipe of Grades P24, P92, P122, and P36 shall have a hardness not exceeding 250 HBW/265 HV30 [25 HRC].

9.4 Table 5 gives the computed minimum elongation values for each 1⁄32-in. [0.8-mm] decrease in wall thickness. Where the

TABLE 3 Tensile Requirements

	Grade								
	P1, P2	P12	P23	P24	P91	P92, P911 P36 Class 1	P122	P36 Class 2	All Others
Tensile strength, min:									
ksi	55	60	74	85	85	90	90	95.5	60
MPa	380	415	510	585	585	620	620	660	415
Yield strength, min:									
ksi	30	32	58	60	60	64	58	66.5	30
MPa	205	220	400	415	415	440	400	460	205

TABLE 4 Elongation Requirements

	Elongation Requirements				
	All grades except P23, P36 P91, P92, P122, and P911		P23, P24, P91, P92, P122, and P 911		P36
	Longi-tudi-nal	Trans-verse	Longi-tudi-nal	Trans-verse	Longi-tudi-nal
Elongation in 2 in. or 50 mm, (or 4*D*), min, %:					
Basic minimum elongation for wall 5⁄16 in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	30	20	20	. . .	15
When standard round 2-in. or 50-mm gage length or proportionally smaller size specimen with the gage length equal to 4*D* (4 times the diameter) is used	22	14	20	13	. . .
For strip tests a deduction for each 1⁄32-in. [0.8 mm] decrease in wall thickness below in. [8 mm] from the basic minimum elongation of the following percentage points shall be made	1.50[A]	1.00[A]	1.00[A]	. . .	1.00[A]

[A] Table 5 gives the calculated minimum values.

wall thickness lies between two values above, the minimum elongation value is determined by the following formula:

Direction of Test	Equation[B]
Longitudinal, all grades except P23, P91, P92, P122, and P911	E = 48t + 15.00 [E = 1.87*t* + 15.00]
Transverse, all grades except P23, P91, P92, P122, and P911	E = 32t + 10.00 [E = 1.25*t* + 10.00]
Longitudinal, P23, P24, P91, P92, P122, and P911	E = 32t + 10.00 [E = 1.25*t* + 10.00]
Longitudinal, P36	E = 32t + 5.0 [E = 1.25*t* + 5.0]

where:
E = elongation in 2 in. or 50 mm, %, and
t = actual thickness of specimens, in. [mm].

9.5 For Grade P91, when quenching and tempering has been agreed upon in accordance with Note D in Table 2, the tensile and hardness properties shall be met and verified on material taken from the half-thickness location.

10. Permissible Variations in Diameter

10.1 For pipe ordered to NPS [DN] or outside diameter, variations in outside diameter shall not exceed those specified in Table 6.

10.2 For pipe ordered to inside diameter, the inside diameter shall not vary more than ± 1 % from the specified inside diameter.

11. Permissible Variations in Wall Thickness

11.1 In addition to the implicit limitation of wall thickness for pipe imposed by the limitation on weight in Specification A999/A999M, the wall thickness for pipe at any point shall be within the tolerances specified in Table 7. The minimum wall thickness and outside diameter for inspection for compliance with this requirement for pipe ordered by NPS [DN] and schedule number is shown in ASME B36.10M.

12. Hydrostatic Test

12.1 The requirements for grades other than P91, P92, P911, and P122 are shown in 12.1.1-12.1.4.

12.1.1 Each length of pipe with outside diameter greater than 10 in. [250 mm] and wall thickness less than or equal to 0.75 in. [19 mm], shall be submitted to the hydrostatic test, except as provided for in 12.1.4.

12.1.2 Pipe of all other sizes shall be subjected to the nondestructive electric test as shown in Section 13, except as provided for in 12.1.3 and 12.1.4.

12.1.3 When specified by the purchaser, pipe of all other sizes shall be furnished without the hydrostatic test and without nondestructive examination.

12.1.4 When specified by the purchaser, pipe shall be furnished with both the hydrostatic test and a nondestructive examination having been performed.

12.2 The requirements for grades P91, P92, P911, and P122 are shown in 12.2.1-12.2.3.

12.2.1 Each length of pipe with outside diameter greater than 10 in. [250 mm] and wall thickness less than or equal to 0.75 in. [19 mm], shall be submitted to both the hydrostatic test and the ultrasonic test as shown in Section 13.

TABLE 5 Calculated Minimum Elongation Values

Wall Thickness		Elongation in 2 in. or 50 mm, min, %			
		All grades except P23, P36, P91, P92, P122, and P911		P23, P24, P91, P92, P122, and P911	P36
in.	mm	Longi-tudinal	Transverse	Longi-tudinal	Longi-tudinal
5/16 (0.312)	8	30	20	20	15
9/32 (0.281)	7.2	28	19	19	14
1/4 (0.250)	6.4	27	18	18	13
7/32 (0.219)	5.6	26	. . .	17	12
3/16 (0.188)	4.8	24	. . .	16	11
5/32 (0.156)	4	22	. . .	15	10
1/8 (0.125)	3.2	21	. . .	14	9
3/32 (0.094)	2.4	20	. . .	13	8
1/16 (0.062)	1.6	18	. . .	12	7

TABLE 6 Permissible Variations in Outside Diameter

NPS [DN] Designator	Over		Under	
	in.	mm	in.	mm
1/8 to 1½ [6 to 40], incl.	1/64 (0.015)	0.40	1/64 (0.015)	0.40
Over 1½ to 4 [40 to 100], incl.	1/32 (0.031)	0.79	1/32 (0.031)	0.79
Over 4 to 8 [100 to 200], incl.	1/16 (0.062)	1.59	1/32 (0.031)	0.79
Over 8 to 12 [200 to 300], incl.	3/32 (0.093)	2.38	1/32 (0.031)	0.79
Over 12 [300]	± 1 % of the specified outside diameter			

TABLE 7 Permitted Variations in Wall Thickness

NPS [DN] Designator	Tolerance, % from Specified	
	Over	Under
1/8 to 2½ [6 to 65] incl., all t/D ratios[A]	20.0	12.5
Above 2½ [65], t/D ≤ 5 %[A]	22.5	12.5
Above 2½ [65], t/D > 5 %[A]	15.0	12.5

[A] t = Specified Wall Thickness; D = Specified Outside Diameter.

12.2.2 Pipe of all other sizes shall be subjected to the nondestructive electric test as shown in Section 13, except as provided for in 12.2.3.

12.2.3 When specified by the purchaser, pipe of all other sizes shall be furnished with both the hydrostatic test and a nondestructive examination having been performed.

13. Nondestructive Examination

13.1 When required by 12.1.2 or 12.2 above, or when specified in the purchase order in addition to the hydrostatic test (12.2.3), each pipe shall be examined by a nondestructive examination method in accordance with Practice E213, Practice E309, or Practice E570. Except for Grades P91, P92, P911, and P122, the type of nondestructive examination shall be at the option of the manufacturer, unless otherwise specified in the order. Grades P91, P92, P911, and P122 shall be examined by an examination method in accordance with Practice E213. When specified in the order, pipe of Grades P91, P92, P911, and P122 shall be examined by an examination method in accordance with Practices E309 or E570, in addition to the examination method in accordance with Practice E213. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

13.2 Following conditions apply in lieu or in addition to those in Specification A999/A999M:

13.2.1 The width of the notch shall not exceed the depth.

13.2.2 If upon any standardization, the reference signal amplitude has decreased by more than 25 % (2 db), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization shall be re-tested.

13.2.3 Pipes producing a signal equal to or greater than the signal produced by the reference standard shall be subject to one of the following four dispositions:

13.2.3.1 The pipes may be rejected without further examination, at the discretion of the manufacturer.

13.2.3.2 The pipes shall be rejected if the test signal was produced by imperfections which cannot be identified, or was produced by cracks or crack-like imperfections.

13.2.3.3 The pipes may be repaired by grinding (in accordance with 7.2.1), welding (in accordance with 7.6) or sectioning (in accordance with 7.2.3). To be accepted, a repaired pipe must pass the same nondestructive examination by which it was rejected, and it must meet the remaining wall thickness requirements of this specification.

13.2.3.4 If the test signals were produced by visual imperfections such as those listed below, the pipes may be evaluated in accordance with the provisions of Section 7:

(a) Scratches,
(b) Surface roughness,
(c) Dings,
(d) Straightener marks,
(e) Cutting chips,
(f) Steel die stamps,
(g) Stop marks, or
(h) Pipe reducer ripple.

14. Mechanical Tests Required

14.1 *Lot*—For mechanical testing, a lot is all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same

finishing treatment in a continuous furnace; when final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge.

14.2 *Transverse or Longitudinal Tension Test and Flattening Test, Hardness Test, or Bend Test*—For material heat treated in a batch-type furnace, tests shall be made on 5 % of the pipe from each treated lot. For small lots, at least 1 pipe shall be tested. For material heat treated by the continuous process, tests shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than 2 pipe.

14.3 *Hardness Test*:

14.3.1 The Vickers hardness testing shall be made in accordance with Test Method E92.

14.3.2 For pipes with wall thickness 0.200 in [5.1 mm] or over, either the Brinell or Rockwell hardness test shall be used. When Brinell hardness testing is used, a 10-mm ball with 3000, 1500, or 500-kg load shall be used at the option of the manufacturer.

14.3.3 For pipes with wall thickness 0.065 in. [1.7 mm] or over, but less than 0.200 in [5.1 mm], the Rockwell hardness test shall be used.

14.3.4 For pipes with wall thickness less than 0.065 in [1.7 mm], the hardness test shall not be required.

14.3.5 The Brinell test shall be made, at the option of the manufacturer, on the outside of the pipe near the end, on the outside of a specimen cut from the pipe, or on the wall cross section of a specimen cut from the pipe. This test shall be made so that the center of the impression to the edge of the specimen is at least 2.5 times the diameter of the impression.

14.3.6 The Rockwell hardness test shall, at the option of the manufacturer, be made on the inside surface, on the wall cross section, or on a flat of the outside surface.

14.3.7 For pipe of Grades P24, P91, P92, P122, P911, and P36, Brinell, Vickers, or Rockwell hardness tests shall be made on a specimen from each lot.

14.4 *Bend Test*:

14.4.1 For pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less shall be subjected to the bend test instead of the flattening test. Other pipe whose diameter equals or exceeds NPS 10 may be given the bend test in place of the flattening test subject to the approval of the purchaser.

14.4.2 The bend test specimens shall be bent at room temperature through 180° without cracking on the outside of the bent portion. The inside diameter of the bend shall be 1 in. [25 mm].

14.4.3 Test specimens for the bend test specified in 14.4 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either ½ by ½ in. [12.5 by 12.5 mm] in section or 1 by ½ in. [25 by 12.5 mm] in section with the corners rounded to a radius not over 1/16 in. [1.6 mm] and need not exceed 6 in. [150 mm] in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe, respectively.

15. Certification

15.1 Certification and test reports, as described in Section 25 of Specification A999/A999M, are required.

15.2 In addition to the information required by Specification A999/A999M, the certification shall state whether or not the pipe was hydrostatically tested. If the pipe was nondestructively examined, the certification shall so state and shall show which practice was followed and what reference discontinuities were used. In addition, the test method information as given in Table 8 shall be appended to the specification number and grade shown on the certification.

16. Product Marking

16.1 In addition to the marking prescribed in Specification A999/A999M, the marking shall include the length, an additional symbol "S", if the pipe conforms to any of the Supplementary Requirements S1 to S6, the schedule number, if the pipe is ordered to a schedule number, and the heat number or manufacturer's number by which the heat can be identified. Furthermore, the marking designated in Table 8 to indicate the test method(s) shall be included. Marking may be by stenciling, stamping, or rolling. Pipe that has been weld repaired in accordance with 7.6 shall be marked "WR."

17. Government Procurement

17.1 *Scale Free Pipe*:

17.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale free pipe is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

17.1.2 The requirements of Specification A999/A999M for pipe shall be applicable when pipe is ordered to this specification.

17.1.3 Pipe shall be one of the following grades as specified herein:

Grade	UNS Designation
P11	K11597
P22	K21590
P5	K41545

17.1.4 *Part Number*:

TABLE 8 Test Method Information for Certification and Marking

Ultrasonic	Flux Leakage	Eddy Current	Hydrostatic	Marking
YES	NO	NO	NO	UT
NO	YES	NO	NO	FL
NO	NO	YES	NO	EC
YES	NO	NO	YES	UT/TEST PRESSURE
NO	YES	NO	YES	FL/TEST PRESSURE
NO	NO	YES	YES	EC/TEST PRESSURE

17.1.4.1 Pipe shall be ordered to nominal pipe size and schedule specified in ASME B36.10M
Example: A335/A335M Pipe P-11 NPS 12 Sch 40

Specification Number	ASTM A335/A335M
Pipe	P
Grade	P-11
NPS	12
Wall	0.375

17.1.4.2

Specification Number	ASTM A335/A 335 M
Tube	T
Grade	P-11
Outside Diameter	0.250
Wall	0.035

17.1.5 *Ordering Information*—Orders for material under this specification shall include the following in addition to the requirements of Section 3:
17.1.5.1 Pipe or tube,
17.1.5.2 Part number,
17.1.5.3 Ultrasonic inspection, if required,
17.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions, and
17.1.5.5 Level of preservation and packing required.

18. Keywords

18.1 alloy steel pipe; high temperature service; seamless steel pipe; steel pipe; temperature service applications

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A999/A999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound. The bend test of 13.2 shall be substituted for the flattening test for pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less.

S4. Metal Structure and Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

NOTE S4.1—Pending development of etching methods applicable to the product covered by this specification, it is recommended that the Recommended Practice for a Standard Macro Etch Test for Routine Inspection of Iron and Steel, described in the *Metals Handbook*, Am. Soc. for Metals, 1948 edition, p. 389, be followed.

S5. Photomicrographs

S5.1 When requested by the purchaser and so stated in the order, the manufacturer shall furnish one photomicrograph at 100 diameters from a specimen of pipe in the as-finished condition for each individual size and wall thickness from each heat, for pipe NPS 3 and over. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S6. Such photomicrographs are for information only, to show the actual metal structure of the pipe as finished.

S6. Photomicrographs for Individual Pieces

S6.1 In addition to the photomicrographs required in accordance with Supplementary Requirement S5, the purchaser may specify that photomicrographs shall be furnished from each end of one or more pipes from each lot of pipe NPS 3 and larger in the as-finished condition. The purchaser shall state in the order the number of pipes to be tested from each lot. When photomicrographs are required on each length, the photomicrographs from each lot of pipe in the as-finished condition which may be required under Supplementary Requirement S5

may be omitted. All photo-micrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S7. Alternative Heat Treatment—Grade P91

S7.1 Grade P91 shall be normalized in accordance with Table 2 and tempered at a temperature, to be specified by the purchaser, less than 1350 °F [730 °C]. It shall be purchaser's responsibility to subsequently temper at 1350-1470 °F [730-800 °C] minimum. All mechanical tests shall be made on material heat treated in accordance with Table 2. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S7" shall be included with the required marking of the pipe.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A335/A335M–10b, that may impact the use of this specification. (Approved October 1, 2011)

(*1*) Added new 2.3 to Referenced Documents to add AWS specifications and renumbered subsequent paragraphs.

(*2*) Inserted new 7.6.1 and 7.6.2 to add process and consumable chemistry restrictions for P91 weld repairs and weld consumable chemistry restrictions for P92, P122, and P911, and renumbered subsequent paragraphs.

Committee A01 has identified the location of selected changes to this specification since the last issue, A335/A335M–10a, that may impact the use of this specification. (Approved November 1, 2010)

(*1*) Rewrote Section 12 Hydrostatic Test and Section 13 Nondestructive Examination, thus making the nondestructive test mandatory and the hydrotest optional. Revised Table 8 to ensure coherence with these changes.

(*2*) Modified the chemical composition of grade P23 in Table 1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A335/A335M–10, that may impact the use of this specification. (Approved May 1, 2010)

(*1*) Added new 9.5 dealing with compliance of the tensile and hardness properties at mid-thickness for Grade P91 quenched and tempered.

(*2*) Added a citation for Footnote E to Grade P92 in Table 2.

(*3*) Added new Grade P24 to 7.6.5, 9.3, 14.3.7, and Tables 1-5.

Committee A01 has identified the location of selected changes to this specification since the last issue, A335/A335M–09a, that may impact the use of this specification. (Approved April 1, 2010)

(*1*) Added new 15.1 to make the certification and test reports mandatory in all cases and renumbered subsequent paragraphs.

(*2*) Revised 14.3 to permit performance of the hardness testing.

(*3*) Moved the text of Notes 6 and 7 into the main body of the standard.

Appendix D

NFPA 30 Excerpts

25.10.3 Failure of the exhaust airflow shall automatically shut down the dispensing system.

25.10.4 The exhaust system shall be designed to provide air movement across all parts of the vault floor.

25.10.5 Supply and exhaust ducts shall extend to within 3 in. (75 mm), but not more than 12 in. (300 mm) of the floor.

25.10.6 The exhaust system shall be installed in accordance with the provisions of NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.*

25.11 Reserved.

25.12 Explosion Control. (Reserved)

25.13 Vents for Tanks Inside Storage Tank Vaults.

25.13.1 Vent pipes that are provided for normal tank venting shall terminate outside the vault and at least 12 ft (3.6 m) above ground level and shall meet the requirements of 27.8.1.

25.13.2 Emergency vents shall be vaportight and shall be permitted to discharge inside the vault. Long-bolt manhole covers shall not be permitted for this purpose.

25.14 Tank Openings Other than Vents for Tanks Inside Storage Tank Vaults. (Reserved)

25.15 Detection and Alarm Systems for Storage Tank Vaults.

25.15.1 Each vault shall be provided with an approved vapor and liquid detection system that is equipped with on-site audible and visual warning devices with battery backup.

25.15.2 The vapor detection system shall sound an alarm when the system detects vapors that reach or exceed 25 percent of the lower flammable limit of the liquid stored.

25.15.3 Vapor detectors shall be located no higher than 12 in. (300 mm) above the lowest point in the vault.

25.15.4 The liquid detection system shall sound an alarm upon detection of any liquid, including water.

25.15.5 Liquid detectors shall be located in accordance with the manufacturer's instructions.

25.15.6 Activation of either the vapor detection system or the liquid detection system shall cause a signal to be sounded at an approved, constantly attended location within the facility serving the tanks or at an approved location.

25.16 Inspection and Maintenance of Storage Tank Vaults and Equipment. Vaults and their required equipment shall be maintained in accordance with the requirements of this chapter.

Chapter 26 Reserved

Chapter 27 Piping Systems

27.1 Scope.

27.1.1 This chapter shall apply to the design, installation, testing, operation, and maintenance of piping systems for flammable and combustible liquids or vapors. Such piping systems shall include but not be limited to pipe, tubing, flanges, bolting, gaskets, valves, fittings, flexible connectors, the pressure-containing parts of other components including but not limited to expansion joints and strainers, and devices that serve such purposes as mixing, separating, snubbing, distributing, metering, control of flow, or secondary containment.

27.1.2 This chapter shall not apply to any of the following:

(1) Tubing or casing on any oil or gas wells and any piping connected directly thereto
(2) Motor vehicles, aircraft, boats, or piping that is integral to a stationary engine assembly
(3) Piping within the scope of any applicable boiler and pressure vessel code

27.2 Definitions Specific to Chapter 27. For the purpose of this chapter, terms in this section shall be have the definitions given.

27.2.1 Corrosion Protection. A means to lessen or prevent the deterioration of the piping system from exposure to its contents or its environment.

27.2.2 Flexible Connector. A connection joint in a piping system that allows differential movement of the piping system and limits system stress and mechanical damage.

27.2.3 Leak. An unintended release of liquid or vapor from the piping system due to failure of the piping system.

27.2.4 Secondary Containment. Containment that is external to and separate from the primary piping system.

27.3 General Requirements.

27.3.1 Performance Standards. The design, fabrication, assembly, test, and inspection of piping systems shall be suitable for the working pressures and structural stresses to be encountered by the piping system. Compliance with applicable sections of ASME B31, *Code for Pressure Piping,* and the provisions of this chapter shall be considered *prima facie* evidence of compliance with the foregoing provisions.

27.3.2 Tightness of Piping. Piping systems shall be maintained liquidtight. A piping system that has leaks that constitute a hazard shall be repaired in a manner acceptable to the authority having jurisdiction, or it shall be emptied of liquid, vapor freed, and no longer be used.

27.4 Materials of Construction for Piping Systems.

27.4.1 Materials Specifications. Pipe, valves, faucets, couplings, flexible connectors, fittings, and other pressure-containing parts shall meet the material specifications and pressure and temperature limitations of ASME B31, *Code for Pressure Piping,* except as provided for in 27.4.2, 27.4.3, and 27.4.4.

27.4.2 Ductile Iron. Ductile (nodular) iron shall meet the specifications of ASTM A 395, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures.*

27.4.3 Materials of Construction for Valves. Valves at storage tanks, as required by Sections 22.13 and 24.14, and their connections to the tank shall be of steel or ductile iron, except as provided for in 27.4.3.1, 27.4.3.2, or 27.4.4.

27.4.3.1 Valves at storage tanks shall be permitted to be other than steel or ductile iron where the chemical characteristics of the liquid stored are not compatible with steel or where the valves are installed internally to the tank.