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Materials, Fabrication, Inspection, and Testing

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ASME SECTION VIII, DIVISION 1
Materials, Fabrication, Inspection, and Testing

Table of Contents

Introduction to Codes and Standards

The Need

Standards and codes have been established for manufacturing, operation of equipment, and personal conduct that represent the minimum standard of quality or behavior that is to be expected by the manufacturer, supplier, operator or individual. Codes and standards that deal with manufacturing and operation of pressure systems establish the rules for minimum safety. For equipment components to be safe, they must be standardized so that personnel can become familiar with the various pieces of equipment for their safe operation. While the safety aspects are easy to understand, the standardization concept requires various manufacturers to make equipment that will interface with other equipment or components so that the equipment can be safely coupled together.

Therefore, while codes and standards have subtle different meanings and requirements, the ultimate goal is to produce products that function safer. In the "Foreword" section of ASME VIII, Division1, this role is clearly defined: "The Committee's function is to establish rules of safety...". Similar wording is presented in the "Introduction" of ASME B31.3; "The Code sets forth engineering requirements deemed necessary for safe design and construction of pressure piping."

The Canadian Standards Association has been providing a Code for the manufacture and operation of pressured components since 1939. The need for such a standard however was recognized in the previous century when investigations were undertaken by a US congressional committee to define the safety requirements for pressure containment systems.

What we have today is a set of safety standards that have been developed over many years through the experience and deliberation of engineers and scientists who have the goal of making equipment that functions properly and safely.

The Legal Position of the Pressure Equipment Codes

In Canada, the jurisdiction for public safety is split between the Federal and Province governments with the Federal government responsible for issues that transcribe provincial boundaries while the provincial governments are confined to issues within their boundaries. It is the responsibility of the applicable jurisdiction to decide upon the rules and regulations for the design, manufacture, operation and inspection of pressure containment systems.

In Canada, we have an organization of volunteers known as the Canadian Standards Association (CSA) that produces standards and guidelines for various facets of product manufacture and use. The CSA Standards Steering Committee on public safety has a technical subcommittee on boilers and pressure vessels. This committee has been active for a great many years and in 1939, published the first Canadian Standard dealing with pressure containment systems. The Standard CSA B51 "Boiler, Pressure Vessel, and Pressure Piping Code", and was produced to standardize the safety aspects of pressure containment systems among the Provincial Jurisdictions in Canada. This Standard makes a number of codes and standards by other organizations mandatory, a listing of which is given in the following excerpt from B51. Among those mandatory standards are the ASME Standards relating to pressure piping and boiler and pressure vessels, and the CSA Standard for oil and gas pipeline systems.

In Canada, the legislative assemblies of the various jurisdictions have passed Acts normally referred to as the Boiler and Pressure Vessel Act. These Acts set up an authority to administer matters related to pressure vessels, boilers, and pressure piping. The authority in turn makes regulations to facilitate the administration of their legislated responsibility and the key component of all these regulations is the adoption of CSA B51 in whole or in part. Most of the jurisdictions also have a Pipelines Act that establishes one or more authorities that are responsible for pipelines. These legislated Acts make the ASME pressure vessel, boiler and pressure piping Standards and Codes, and the CSA pipeline standard the law for minimum safety in the design, operation and inspection of pressure systems.

Codes and Standards for Pressure Vessels and Piping

As previously indicated, the overriding Standard in Canada is CSA B51 "Boiler, Pressure Vessel, and Pressure Piping Code". This Code requires that drawings and specifications of designs of boilers, pressure vessels, and piping systems must be submitted to the regulatory authority and the design must be accepted and registered in the jurisdiction before construction is commenced. In addition, fittings shall likewise be registered if they are to form a part of a boiler or pressure vessel or pressure piping system. When a design is acceptable, a Canadian Registration Number (CRN) is issued. This design will be a sequential number issued by the jurisdictional authority. That number will be followed by a decimal with another number indicating the jurisdictional authority which has approved the design, e.g. 1) British Columbia, 2) Alberta, 3) Saskatchewan, 4) Manitoba, 5) Ontario, 6) Quebec, 7) New Brunswick, 8) Nova Scotia, 9) Prince Edward Island, 0) Newfoundland, T) Northwest Territories, Y) Yukon Territory, N) Nunavit.

In a similar manner, welding and brazing procedures are to be registered with the regulatory authority. As with pressure vessel and piping design, the Provincial code number shall be used following the decimal point of the registration number.

To ensure that the fabricated system is traceable to manufacturer and original material of use, the documentation specified in the applicable ASME Code (known as the "Data Report") must be submitted to the jurisdictional authority. As well, a means of permanently identifying the part so that it is traceable back to that Data Report shall be undertaken. As a minimum, this identification will include the CRN.

For manufacture of pressure containment systems, a satisfactory quality control system is required. Those companies within Canada that possess a valid stamp of authorization by the ASME are presumed to have in place a satisfactory quality control system. Not all pressure containment work is applicable to the ASME Code, nor do all jurisdictions require that pressure work be done strictly by those firms conforming to the ASME Code and therefore, other forms of quality control programs may be accepted by the jurisdictional authority.

Pressure Equipment Standards List from CSA B51

CSA (Canadian Standards Association)

CSA B52 – *Mechanical Refrigeration Code*
CAN/CSA-B149.1 – *Natural Gas and Propane installation Code*
CAN/CSA-B149.2 – *Propane Storage and Handling Code*
CAN/CSA-B149.5 – *Installation Code for Propane Fuel Systems and Tanks on Highway Vehicles*
CAN/CSA-ISO 9001 – *Quality Management Systems — Requirements*
CAN/CSA-Z180.1 – *Compressed Breathing Air and Systems*
CAN3-Z299.1 – *Quality Assurance Program — Category 1*
CAN3-Z299.2 – *Quality Assurance Program — Category 2*
CAN3-Z299.3 – *Quality Assurance Program — Category 3*
CAN3-Z299.4 – *Quality Assurance Program — Category 4*
CAN/CSA-Z305.3 – *Pressure Regulators, Gauges, Flow-Metering Devices for Medical Gases*
CAN3-Z305.4 – *Qualification Requirements for Agencies Testing Nonflammable Medical Gas Piping Systems*
CSA Z662 – *Oil and Gas Pipeline Systems*
CAN/CSA-Z7396.1 – *Medical Gas Pipeline Systems — Part 1*

ANSI (American National Standards Institute)

ANSI K61.1 – *Safety Requirements for the Storage and Handling of Anhydrous Ammonia*

ANSI/ASQ (American National Standards Institute/American Society for Quality)

ANSI/ASQ Z1.4 – *Sampling Procedures and Tables for Inspection by Attributes*

API (American Petroleum Institute)

API STD 530 – *Calculation of Heater Tube Thickness in Petroleum Refineries*

ASME (The American Society of Mechanical Engineers)

ASME Boiler and Pressure Vessel Code:
- Section I – *Power Boilers*
- Section II – *Materials — Part A — Ferrous Material Specifications*
- Section II – *Materials — Part B — Nonferrous Material Specifications*
- Section II – *Materials — Part C — Specifications for Welding Rods, Electrodes, and Filler Metals*
- Section II – *Materials — Part D — Properties*
- Section IV – *Heating Boilers*
- Section V – *Nondestructive Examination*
- Section VIII – *Rules for Construction of Pressure Vessels — Division 1*
- Section VIII – *Rules for Construction of Pressure Vessels — Division 2 — Alternative Rules*
- Section VIII – *Rules for Construction of Pressure Vessels — Division 3 — Alternative Rules for High Pressure Vessels*
- Section IX – *Welding and Brazing Qualifications*
- Section X – *Fiber-Reinforced Plastic Pressure Vessels*

ASME B31 Pressure Piping Code:

B31.1 – *Power Piping*

B31.3 – *Process Piping*

B31.4 – *Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids*

B31.5 – *Refrigeration Piping and Heat Transfer Components*

B31.9 – *Building Services Piping*

ASME CSD-1 – *Controls and Safety Devices for Automatically Fired Boilers*

ASME PVHO-1 – *Safety Standard for Pressure Vessels for Human Occupancy*

CDA (Copper Development Association)

CDA A4015 – *Copper Tube Handbook* (no longer in print)

CGSB (Canadian General Standards Board)

CAN/CGSB 48.9712 – *Nondestructive Testing; Qualification and Certification of Personnel*

ISO (International Organization for Standardization)

ISO 9001 – *Quality Management Systems — Requirements*

MSS (Manufacturers Standardization Society of the Valves and Fittings Industry)

MSS SP-25 – *Standard Marking System for Valves, Fittings, Flanges and Unions*

National Board of Boiler and Pressure Vessel Inspectors

NB-18 – *National Board Pressure Relief Device Certifications*

NB-23 – *National Board Inspection Code*

NFPA (National Fire Protection Association)

NFPA 58 – *Liquefied Petroleum Gas Code*

PACE (Petroleum Association for the Conservation of the Canadian Environment)

Report No. 87-1 – *Guideline Specification for the Impressed Current Method of Cathodic Protection of Underground Petroleum Storage Tanks*

RMA (Rubber Manufacturers Association)

RMA/IP-2 – *The 2003 Hose Handbook*

ULC (Underwriters' Laboratories of Canada)

CAN/ULC-S603.1 – *External Corrosion Protection Systems for Steel Underground Tanks for Flammable and Combustible Liquids*

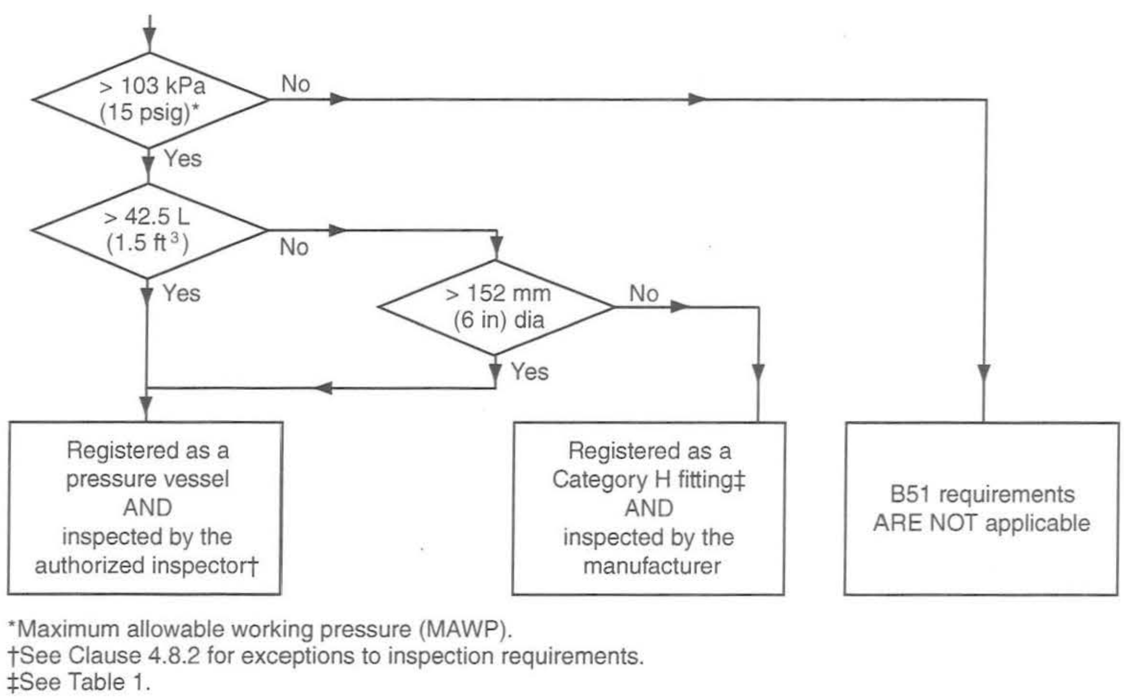
Requirements for Quality Control Systems

CSA Standard B51 requires that any manufacturer of a boiler, pressure vessel, piping or fitting must have a quality control system in place that meets the requirements of the applicable manufacturing standard. The jurisdictional authority may further require that any organization conducting repairs or modifications to such equipment also have in place a quality control system. The in-service reliability is not a required function of CSA B51 or of the ASME Code sections, except for boiler operation. CSA B51 however does have a non mandatory appendix to the Standard (Appendix C), which details the requirements for a quality assurance program for defect prevention and in-service reliability. Appendix C is usually adopted by jurisdictional authorities which requires users of pressure containment systems to have in place a quality control system to ensure in service reliability (safety) of their pressure retaining components.

When repairs and modifications are made to pressure equipment, the jurisdictional authority will require a quality control system. It should be noted; in many instances that there is very little differentiation between a modification and a new manufacture so the same requirements for material control, design, and workmanship are applicable.

Alterations to Registered Designs

B51 requires that any alteration to a vessel, registered piping system, weld procedure, or fitting will require registration of the alteration with the jurisdictional authority. Fittings are defined in CSA B51 in accordance with their pressure rating and volumetric size as defined by Figure 1(c) of B51.



*Maximum allowable working pressure (MAWP).
†See Clause 4.8.2 for exceptions to inspection requirements.
‡See Table 1.

CSA B51 Figure 1(c) – Registration and inspection for pressure vessels (modified)

As previously indicated, each fitting manufacture must register the design of their fitting in the jurisdiction in which the fitting is to be used. To avoid having to obtain a CRN for each size and type of fitting, manufactures need only obtain a CRN for a fitting category as defined below.

Category	**Type of fitting**
A	Pipe fittings; such as couplings, tees, elbows, reducers, plugs, unions, nipples, pipe caps, and wyes
B	All flanges
C	All line valves
D	All types of expansion joints, flexible connections, and hose assemblies
E	Strainers, filters, separators, and steam traps
F	Measuring devices; such as pressure gauges, level gauges, sight glasses, levels, and pressure transmitters
G	Pressure-relief devices and fusible plugs
H	Pressure-retaining components that do not fall into Categories A to G

In accordance with B51, Code users need to be aware that any modification to a fitting is an alteration and requires that the firm doing the modification register the design of the modified fitting; hence to become the manufacturer of the modified fitting. Modification includes such things as cutting an elbow to change its manufactured angle, cutting a hole in a fitting to accommodate a thermo-well, o-let, or other fitting, welding a support element to a fitting, placing a hole in a blind flange other than as permitted in ASME B16.5, etc.

ABSA Statement on Fitting Modification

"A recent inquiry involved the alteration of one Manufacturer's registered fittings by someone else. The original Canadian Registration Number (CRN) would no longer cover the altered fittings. It is understood that the original manufacturer's markings and warrantee would no longer be applicable to these fittings once they are altered.

Cutting up fittings and welding parts of them together to create a fitting of a different shape constitutes the creation of a new fitting. Hence, under the Safety Codes Act (SCA) and the regulations, this new fitting would require design registration, with the pertinent back-up documentation, and it would have to carry the name, trademark or logo of the Manufacturer who created the new fitting.

The SCA forbids the sale or use of fittings or pressure piping which does not comply with the requirements of the Act. It also holds the manufacturer of such an Item responsible for ensuring that it complies with the Act. For public safety and for liability considerations, manufacturers, users, contractors or others are cautioned to ensure that altered fittings have been properly designed and subsequently registered before putting them into pressure piping service.

Note however that such operations as cutting a 90 degree elbow to accommodate an 80 degree change in direction or taper-boring a schedule 80 fitting to match a schedule 40 mating pipe would not be considered alterations of fittings and would not require re-registration."

Standard for Marking on Components
MSS-SP25

TSSA Statement on Fitting Modification

"Only fittings, which are produced to a design registered under a valid fitting CRN (Canadian Registration Number) and manufactured under a valid quality control program, are acceptable for used with registered piping systems. An alteration to a fitting may cause its registration to become invalid, and its use may be contrary to the provision of the Technical Standards and Safety Act, 2000, and Regulations for Boiler and Pressure Vessels. The following paragraphs described the procedures applicable for a number of typical situations.

A) Alterations by the Original Fitting Manufacturer

Registered fittings altered by the original fitting manufacturer are acceptable without reregistration if the alterations do not impact on the pressure boundary. Altered fittings may be registered under the original fitting CRN as an alternate configuration.

B) Alterations by Others

Alterations of registered fittings other that the original manufacturer require reregistration and an new CRN. The Company making the alterations must work under a valid quality control program.

C) Modifications to Existing Fittings

Modifications to existing fittings require design review and registration by TSSA."

→ It is not required in Alberta to have an "ASME stamp" on Vessels.

New Regulation

Comparing CSA B51 vs. ASME B&PV Codes

Broadly speaking, the differences between CSA B51 and the ASME P&PV codes may be grouped as:

(I) scope and details
(II) administrative requirements
(III) product and process specific requirements and
(IV) other technically related requirements.

(I) Scope and Details

The Scope of the CSA B51 is far wider than that of the ASME in that CSA B51 applies to boilers, pressure vessels and pressure piping but unlike ASME, it does not apply to nuclear pressure equipment. In the case of ASME Boiler and Pressure Vessel Code, as indicated in the name, applies to "Boilers" and "Pressure Vessels" and not normally to "Piping". The scopes of the ASME Code are different depending on the different "Section" of the ASME Code being referred to. ASME Section I is specific to "Power Boilers", Section IV, "Heating Boilers" and so on. Another major distinction here is that the ASME Code is for "new construction" only but CSA B51 also has requirements for repairs, alterations, installation and others things in addition to new construction.

Accordingly, one may ask how CSA B51 can cover such a wide range of equipment and operation while the ASME Code, in many volumes and tens of thousands of pages, is only applicable to new construction. The difference here is in the amount of detail contained in the two Codes. CSA B51 normally references other codes and standards and only provides for exceptions, additional and/or alternative requirements. This way, CSA B51 does not provide detailed design, construction, testing and inspection requirements for the majority of the items under the code but simply refers to other codes and standards (the ASME Boiler and Pressure Vessel Code being a major one) for these requirements. In the case of the ASME Boiler and Pressure Vessel Code, similar to other national and international boiler and pressure vessel codes and standards, very detailed requirements are provided for the materials, design calculations, heat treatment, welding, inspection, destructive and non-destructive testing etc.

It should also be noted that because of the scope differences, different sections of the ASME Boiler and Pressure Vessel Code quite often invoke different requirements. Accordingly, even for a similar design configuration, if it were acceptable under one Section of the Code, one must not assume that it would be automatically acceptable under another Section of the Code without checking in the Section concerned. While the different ASME Code Sections are working to achieving uniformity in requirements, because of the scope and application of the different Sections, this can not always be done.

CSA B51 is essentially a code of exception with very wide applications, referencing other codes and standards for detail requirements while providing for additional or alternative requirements. ASME Boiler and Pressure Vessel Code is for new construction application only and although the Code provides for all the necessary construction details, its scope depends entirely on the different Section of the Code.

(II) Administrative Requirements

In both codes, similar administrative requirements are detailed relative to documentation of manufacturer's certification of code compliance and inspectors verification. In all cases, proper implementation of a documented quality control system and approval from the jurisdiction having authority is required. The one major significant difference here is the application of the ASME Code Symbol Stamp (such as the S, U, UM and other ASME Code Symbol Stamps which are hereunder referred to as the ASME Code Stamp) to ASME Code vessels. It is a requirement that a manufacturer who wishes to hold and apply the ASME Code Stamp must first submit its quality control program to the ASME for review and implementation audit. If successful, the ASME will authorize the manufacturer to hold and apply the appropriate ASME Code Stamp on the boiler or the pressure vessel.

For the CSA B51 equipment where there is a counterpart in the ASME Code, all stamping requirements are the same as the ASME Code on the nameplates of the equipment with the exception of the ASME Code Stamp.

Accordingly, product manufactured with the ASME Code Stamp will have to satisfy the ASME Code Stamp requirements with respect to the manufacturer's data report and, if imported from outside of Canada, the MDR must also be filed with the National Board of Boiler and Pressure Vessel Inspectors. Boilers and pressure vessels produced to CSA B51 without the ASME Code Stamp will need to be documented with the CSA *Manufacturer s Data Reports.* For cast-iron sectional boilers, since an ASME form is not available, the CSA B51 I*nstallation Form for Cast- Iron Sectional Boilers* must be completed upon installation.

As noted previously, the scope of the CSA B51 is considerably wider. In the case of safety relief valve repair organizations, separate guidelines are given and the National Board VR stamp is deemed meeting the requirements. Other CSA B51 administrative requirements include *Manufacturer s Data Report for Fired Process Heaters, Construction Data Report for Piping systems, Statutory Declaration for Registration of Fittings* and *Repair and Alteration Form.*

One difference in administrative requirements between the two codes is in the design and welding procedure verifications. This may also be interpreted at times as a difference in technical requirements. For the ASME Code, the inspector is required to *make such other inspections as in his judgment are necessary to permit him to certify that the vessel has been designed and constructed in accordance with the requirements.* Also, *The Inspector has the duty of verifying that the applicable calculations have been made and are on file in the Manufacturer s plant at the time the Data Report is signed* (see ASME Section VIII Div. 1 Para. U-2(e)). ASME Section I is clear in that *The Authorized Inspector has the duty to review a selected number of the manufacturer s design calculations to verify compliance with Section I.*

Unlike the ASME Code but similar to almost all oversea codes and jurisdictional requirements, a design registration is imposed in the CSA B51. The manufacturer is required to submit the design, with all applicable calculations, and upon verification that the applicable calculations have been carried out by the manufacturer and that the design meets all applicable code and regulatory requirements, a Canadian Registration Number (CRN) is issued. Provided there are no changes in code or regulatory requirements, an unlimited number of boilers or pressure vessels may be built to the registered design. In addition to providing the jurisdiction and, subsequently the users and repair organizations, a record of the design, the individual inspector in the field need not carry out verification of the calculations each and every time a registered design is used, thus providing more efficient inspection monitoring functions. Similarly, the welding procedure registration system is also detailed in the CSA B51.

The administrative requirements in the CSA B51 are similar to those in ASME but are very much national in nature allowing the users to obtain the necessary and fairly uniform administrative requirement information for all provincial and territorial jurisdictions. Thus, almost identical forms are used in these jurisdictions. Without the CSA B51 code, these jurisdictions will most likely be using very different forms or imposing different requirements. In the case of the ASME Code, the forms are widely accepted by the industry and jurisdictions but it will be up to the user to ascertain the different and possibly additional jurisdictional requirements each and everytime. Furthermore, some of the ASME Code administrative requirements, particularly those relative to the ASME Code Stamp authorization, are Trade Mark related matters and are governed solely by the ASME policy.

(III) Product and Process Specific Requirements

The scope of the CSA B51, in some respects, is considerably wider than that of the ASME. In particular, CSA B51 provides very specific product- and process-related requirements, while the ASME Code generally does not do so. The products that ASME Code touches on in some way are air and steam/water where some specific requirements may need to be provided for.

The one major product-specific area addressed by the CSA B51 is compressed natural gas (CNG). Part 2 of the CSA B51 deals specifically with *High-Pressure Cylinders for the Onboard Storage of Natural Gas as a Fuel for Automotive Vehicles* and Part 3 provides for *Requirements for CNG Refuelling Station Pressure Piping Systems and Ground Storage Vessels* . Together, Parts 2 and 3 of the CSA B51 provide the mandatory requirements for compressed natural gas usage in the automotive industry.

In accordance with CSA B51, vessels in anhydrous ammonia service, except those used in refrigeration systems, shall be subject to *post-weld heat treatment prior to hydrostatic test* and *the head and shell materials shall be made in accordance with fine-grain practice* (see Clause 7.6.3). Also, irrespective of ASME Section VIII requirements, storage and transport tanks for anhydrous ammonia service (like the ones for liquefied petroleum gas service) having a water capacity of 13,660 litres (3000 Imp. gal) or more shall be constructed with a manhole opening under CSA B51. Also for liquefied petroleum gas service, CSA B51 requirements are provided through referencing a list of codes and standards for highway vehicle engine fuel tanks, ground storage tanks, bulk transport tanks and cylinders.

Guidance to the underground installation of pressure vessels is provided in CSA B51. Specifically, there is a reference standard for the underground installation of propane tanks.

CSA B51 requires that where there is a check valve between an air receiver and the safety valve protecting it, the air receiver shall be equipped with a fusible plug.

Another service CSA B51 addresses is *Pressure Coils in Petroleum and Chemical-Plant Fired Heaters*. In addition to referencing the existing design and construction standards, CSA B51 provides some detailed guidelines including requirements for the inspection of welds exposed to direct radiant heat. Considering the number of pressure-coil-related incidents that are known to occur,

CSA B51 stands out as one of the very few standards giving overall guidelines on this type of equipment.

Another point worthy of note is on *Blowoff Vessels* for use in conjunction with boilers. CSA B51 has very specific design requirements as to the design pressure, diameter, volume, thickness, corrosion allowance and inspection openings for this type of equipment in Clause 7.5 of the code.

So, it should be noted that the ASME Code provides specific requirements for the methods of construction (e.g. welded, layered, coil-wound or forged) and materials of construction (e.g. carbon steel, high alloy steel, and non-ferrous metals). In the case of CSA B51, in addition to referencing ASME for these requirements, it introduces product- or process-specific provisions. However, one may say that the CSA B51 requirements are actually complementary to those of the ASME for the products or processes concerned.

(IV) Other Technically Related Requirements

Manways

For Inspection Openings of a size commonly termed manholes, ASME Section I allows for a minimum circular opening to be not less than 15 in. (381 mm) in diameter or, if the opening is elliptical, not less than 12 in. x 16 in. (305 mm x 406 mm). Manholes are seldom used in Section IV heating boilers. But if they were required, similar to ASME Section VIII (Divisions 1 and 2), manholes may be 15 in. in diameter or, if elliptical, 11 in. x 15 in. or 10 in. x 16 in. (254 mm x 406 mm). However, CSA B51, Clauses 6.3.5 for boilers and 7.3 for pressure vessels require that manholes be a minimum of 406 mm (16 in) in inside diameter or an oval with minimum inside dimensions of 305 mm x 406 mm (12 in x 16 in).

Impact Testing

In Section VIII Division 1 of the ASME Code, impact testing consideration has to be given to all materials through a series of evaluations. An example of this is the requirements of UG-84. However, there are a number of exemptions through which impact testing may be waived. The most common one is the exemption through meeting all the conditions of paragraph UG20(f) for P-1 Group Nos. 1 and 2 materials when the minimum design metal temperature is no colder than -20°F (-29°C). Under paragraph UCS-66, exemption from impact testing for carbon and low alloy steel is possible for minimum design metal temperatures as low as -155° F (-104° C). In that case, only a fraction (35% for the ASME Code Section VIII Division 1 with 1999 Addenda) of maximum allowable design stress may be used for the design.

CSA B51 generally references the ASME Code requirements for the construction of pressure vessels. However, in addition to the ASME Code requirements, impact testing is required for carbon steel used for the construction of pressure vessels at a minimum design metal temperature below -46°C (-50°F) (see Clause 7.1.2). This requirement parallels that of ASME B31.3 but is more stringent than ASME Section VIII, Division 1 and must be followed for Canadian pressure vessels.

Cast Iron Boilers

For Cast Iron Steam and Hot-Water Boilers, CSA B51 Clause 6.7 requires that the maximum allowable working pressure shall be not more than 1/6 of the lowest hydrostatic proof test pressure at which any particular cast section failed. ASME Section IV uses a factor of 1/5 to derive the maximum allowable working pressure that must be further de-rated by the ratio of the specified minimum tensile strength to the average tensile strength of the associated test bars produced for the test. It is interesting to note that ASME Section VIII Division 1 provides for an even higher factor. Paragraph UCI-101 requires that the maximum working pressure of cast iron vessels or vessel parts, based on testing one of them to destruction, be limited to 1/6.67 of the destruction test pressure. This allowable working pressure is also de-rated by a ratio of the specified minimum tensile strength of the material to the average tensile strength of test specimens produced for the test. It should also be noted that UCI-101 further assumes that failure will occur in bending.

Low-Water Cut-Offs

CSA B51 has very specific requirements (Clause 6.3.2.1) that every steam boiler not under continuous attendance by a certified operator shall be equipped with a low-water fuel cut-off device that serves no other purpose. In addition, this device shall be installed so that it cannot be rendered inoperative and the installation shall be such that it can be tested under operational conditions. These requirements are additional to the ASME Code.

Repairs and Alterations

The scope of the CSA B51 includes repairs, alterations, installations, re-qualification and other things in addition to new construction. It is worth noting that the National Board Inspection Code, NB-23, is the code referenced for guidance in repair or alteration procedures as well as the R certificate of authorization as generally being deemed a satisfactory quality control system.

Miscellaneous

An age limit is provided for lapseam riveted boilers in the CSA B51 Code. Beyond that date, the factor of safety is to be increased annually. It is indicative of the origin of the boiler and pressure vessel code as well as an example of the wide-ranging issues addressed by this Code.

An excerpt from the ABSA Pressure News, December 1998 to Sept. 1999.

Basic Principles and Responsibilities for the Review and Registration of a Design[1]

Basic Principle: Before a pressure vessel can be built right, it must be designed right.

Responsibilities for Design

Safety Codes Act: A person who creates, alters, has care and control of or owns a design or offers a design for use by others shall ensure that the design complies with this Act." (Section 6, Design Duties)

This is a master code for pressure vessels in Canada

CSA B51 Code: The manufacturer maintains "responsibility for the design or construction of a boiler, pressure vessel, fitting, fired heater pressure coil, or piping." (Clause 4.1.6)

ASME Code: "The user or his designated agent shall establish the design requirements." (Para. U-2(a))

The Manufacturer "...has the responsibility of complying with all of the applicable requirements..." (Para. U-2(b))

Example of Another Code (PD 5500): "The manufacturer shall be responsible for the completeness and accuracy of all design calculations and for compliance with all applicable requirements of this standard for the whole vessel". (Clause 1.4.2)

Design Review and Registration

Safety Codes Act: Section 40(1) states that "An Administrator may register the design of any thing, process or activity that is required by this Act to be registered if the submitted design meets the requirements of this Act and the Administrator is of the opinion that the design is safe", and

Section 40(2) states "If this Act requires that the design... be registered, no person shall construct or manufacture the thing... unless the design is registered".

Section 14 of the Pressure Equipment Safety Regulation (AR 49/2006) establishes the requirements that a person must not:

- construct or manufacture for use in Alberta, or
- import for use in Alberta

any pressure equipment unless the design of that pressure equipment is registered.

CSA B51 Code: "Drawings, specifications and calculations of designs for all boilers, pressure vessels, fittings... shall be submitted to the regulatory authority" for acceptance and registration. (Clause 4.1.1)

ASME Code: The Authorized Inspector "shall make such other inspections as in his judgment are necessary to permit him to certify that the vessel has been designed and constructed in accordance with the requirements" of the Code and "The Inspector has the duty of verifying that the applicable calculations have been made". (Para. U-2(e))

Example of Another Code (PD 5500): "The Inspecting Authority shall be responsible for verifying that all parts of the vessel have been designed in accordance with the requirements of this specification as are applicable for the conditions specified by the purchaser..." (Clause 1.4.3)

In Summary

The manufacturer or person constructing or bringing into Alberta a boiler, pressure vessel, pressure piping system or fitting must submit designs, including drawings, calculations and specifications, for review and registration. Design Surveyors conduct an independent survey of the design to verify that it meets the requirements of the Act for registration. A Canadian Registration Number or Pressure Piping number is issued if the design is satisfactory.

Canadian Registration Number

A Canadian Registration Number (CRN) for a boiler or pressure vessel is defined by CSA B51 Clause 4.3 as:

- consisting of a letter, four digits, and a decimal point followed by up to ten digits and/or two letters
- the first letter and four digits are part of a sequential numbering system used by the issuing province or territory
- the first digit or letter to the right of the decimal point indicates the province that issued the particular number
- the following identifications are used in accordance with the code:

1 – British Columbia	5 – Ontario	9 – Prince Edward Island
2 – Alberta	6 – Quebec	0 (zero) – Newfoundland
3 – Saskatchewan	7 – New Brunswick	N – Nunavut
4 – Manitoba	8 – Nova Scotia	T – Northwest Territories
		Y – Yukon Territory

The letter C may follow the designation of first registration if a design is registered in all jurisdictions. No jurisdiction issues the letter C; it is a convenience for stamping once the manufacturer has received all the registrations.

To be eligible for use in Alberta, the CRN must have the digit 2 somewhere after the decimal point. For example, the following could be valid CRNs: B1079.23 and M2138.5C

An Alberta Identification "A" Number

An Alberta identification number (or "A-number") is a unique number that identifies each boiler or pressure vessel manufactured for use in Alberta. The number is assigned by a Safety Codes Officer upon completion of the shop inspection (if manufactured in Alberta) or upon completion of initial inspection (if imported into Alberta).

An A-number begins with an "A" (in a circle) followed by up to seven numbers. It is usually stamped on the pressure equipment item, on or near the nameplate or code stamping.

Pressure vessels and boilers manufactured in Alberta for export are not usually assigned an A-number.

Recently issued.

ABSA Design Registration Program Last Revision on 2014/01/09

The primary quality objective of the Design Registration Program is to ascertain, within reasonable bounds, that designs or procedures submitted for registration under the Safety Codes Act are in compliance with the Act, regulations and relevant codes and standards. One must, however, keep in mind that the owner of the design has ultimate responsibility for its correctness. Acceptable designs and procedures will be registered in accordance with the regulations.

Where the word Act is used here, it means the Safety Codes Act, the applicable regulations under that Act and the relevant codes and standards.

The scope of the Design Registration Program involves:

- Assessment of new and revised designs of boilers, pressure vessels, pressure piping, fittings and other pressure equipment for compliance with the Act and registration of those found acceptable
- Assessment of alterations to boilers, pressure vessels and fittings and registration of those found acceptable
- Assessment of new joining procedures and registration of those found acceptable
- Assessment of various other procedures, e.g. repair or testing procedures, and registration of those found acceptable
- Maintenance of a database and records of registered designs and procedures

Design Submission Requirements

Detailed design submission requirements are available for the following areas:

→ pressure vessels, on truck & Railways in under Federal Government Control.

- Boilers and Pressure Vessels
- Pressure Piping
- Fitting Design
- Welding, Brazing and other Joining Procedures
- Other

Design registration form AB-31 and document package should be sent to ABSA Edmonton office at the following address:

Design Survey Department
ABSA, the pressure equipment safety authority
9410 20 Avenue
Edmonton, Alberta T6N 0A4
Canada

Submission Requirements for Boiler & Pressure Vessel Design Registration (New Designs)

In part, the following amplifies the requirements in the Pressure Equipment Safety Regulation (AR49/2006).

Registration submissions shall include:

- the design drawings in duplicate (folded);
- one set of calculations;
- proof of registration in another Canadian jurisdiction (if applicable);
- a completed Design Registration Application form for each design (AB-31).

The drawings, specifications and other information must be submitted to Design Survey in duplicate and shall show:

- the design pressure(s) and temperature(s) including the MDMT (if applicable);
- Heat exchanger mean metal temperatures, if applicable.
- details of the arrangement and dimensions of all component parts (including the specified minimum thickness after forming for formed heads);
- the ASME material specification numbers for all materials, including grades, types etc.;
- weld joint details including weld sizes;
- the extent of Code-required and other non-destructive examination;
- the welding procedure number(s);
- applicable Code edition and Addenda;
- heat treatment (holding temperature and holding time), if applicable;
- impact testing (if applicable);
- hydrostatic or pneumatic testing pressure;
- flange ratings;
- identification of any Code Cases or Interpretations intended to be applied to the design;
- a report of any physical tests conducted for the purpose of establishing the working pressure of the boiler or pressure vessel or any part thereof;
- and, such other information as the Design Surveyor may require to ascertain that the design is suitable for registration;

In short, the drawings must be complete enough that, without having to assume anything, one could use the submitted drawings and specifications to build the exact same item and have it meet the Code.

Notes

- The drawings, specifications etc., must bear the signature of the owner of the design, or the person who will be the manufacturer of the boiler or pressure vessel.
- It is not necessary that drawings be stamped by a Registered Professional Engineer unless the Code or the Design Surveyor requires such stamping.
- If any revisions of the drawings are provided after the first submission, they will be assessed for evidence of proper design control. Manual changes to CAD drawings will generally be cause for rejection of the submission.
- Any number of units may be made to one registered design, unless the Code or regulations change to invalidate the registered design or unless the registration limits the number of units that may be built to the design. Design registration is denoted by the Canadian Registration Number (CRN) or other registration number assigned to the design.
- The fees depend on the size of the boiler, pressure vessel or heat exchanger, the complexity of the design and the time the Design Surveyor must spend in ascertaining that the design is suitable for registration. The fees are specified in Schedule A of the Fee Schedule. Charges for design registration will be invoiced once the designs are accepted. Fees will be charged for designs that are rejected.

Submission Requirements for Registration of Boiler and Pressure Vessel Designs in Other Provinces Through ABSA

The Alberta Boilers Safety Association (ABSA) offers a one-window service to boiler and pressure vessel manufacturers wishing to register their designs in multiple Canadian provinces. The manufacturer makes one submission, deals with one agency for clarifying any outstanding details and receives two invoices, one for the ABSA registration and a second for all the other registrations.

The following documentation is required for ABSA to register your design and to apply for its registration in other provinces on your behalf:

> Two copies of the design data on the items, (i.e. the drawings & specifications) and one copy of the calculation for each jurisdiction in which registration is required. Note: treat Nova Scotia, New Brunswick, PEI, Newfoundland, Yukon, NWT and Nunavut as one jurisdiction as these are processed by ACI Central Inc. Therefore, if registration is required across Canada, a total of 14 copies are required (i.e. two each for BC, Alberta, Saskatchewan, Manitoba, Ontario, Quebec and ACIC.)

Note that for registration in Ontario, the drawings must be stamped and signed by an Ontario-registered Professional Engineer. Note that P.Eng. stamping is required for submissions to ACI Central and Quebec jurisdictions.

Following a successful review for registration in Alberta, ABSA will submit this information plus proof of registration in Alberta to the respective jurisdictions for their registration and will pay the applicable registration fees on your behalf. Note that these registration fees vary by province, and by the scope of the registration, so it is not feasible to state the fees in advance. ABSA will, in turn, bill you for their own registration fee and the other registration bodies' fees plus an administration fee (regardless of how many jurisdictions you are applying to) plus courier and handling of charges for each province for which you request registration. Where possible, ABSA will answer any questions that may arise from any other jurisdictions without your having to get involved.

Note that an additional fee may apply if the request to register in other jurisdictions is received after the Alberta registration has been completed.

Generic Designs

Introduction

It is desirable that Manufacturers be able to maximize the use of their registered designs. Hence the desire to register generic designs. However, an inspector performing his Authorized Inspector duties in the Manufacturer's shop or looking at a vessel in the field should be able to quickly see that the vessel is covered by the registered design.

ABSA is supportive of the registration of generic designs. It must be appreciated though, that when creating a generic design, the designer will be giving up some design flexibility. It would not be practicable, for example, to include nozzle positionings varying from "on the centreline of head" to "tangential to the shell and parallel to the vessel centreline" (maximum offset on the head) or to include every combination of width and thickness of reinforcing pad to provide a given area of reinforcing material. In our experience, Manufacturers who have a need for generic vessel designs are generally involved in the supply of vessels for very specific services, e.g. air receivers, refrigeration vessels, propane vessels etc. There is typically no real value in trying to include every conceivable nozzle size, position, angularity and proximity to any other opening. There would likely be a typical number of nozzles, in fairly predictable locations, for a given type of vessel. The Manufacturer knows his product line best, so he should keep the generic design aligned with that. Trying to include every variation imaginable, even though a configuration has never been made and probably will never need to be made, is a waste of time.

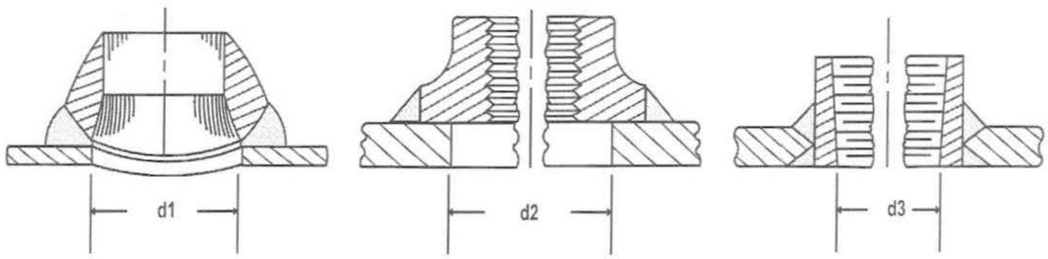
Remember, the originator of a generic design expects to get more value from the registered design, so it is only reasonable that more work must go into preparing and presenting the design. One can't get something for nothing.

Designs submitted for registration in Alberta may be generic within the following limits:

- The design conditions (MAWP, design temperature & MDMT) must be fixed.
- Vessel diameter and shell and head thicknesses must be fixed. Maximum and minimum lengths shall be shown on the drawing.
- Materials of construction must be fixed. Reasonable substitutions identified on the drawing may be permitted. An example of an acceptable substitution would be SA-106 Grade B for SA-53 Grade B.
- Corrosion allowance must be fixed.
- All optional nozzle sizes must be identified.

- For each nozzle size in the shell of the vessel, only one configuration of minimum nozzle neck thickness, minimum internal projection, minimum weld size(s) and added reinforcement shall be permitted. Some leeway would be permissible for fittings covered by UW-16(f). See sketches below.

- For each nozzle size in the heads of the vessel, only one configuration of minimum nozzle neck thickness, minimum internal projection, minimum weld size(s) and added reinforcement shall be permitted. Some leeway would be permissible for fittings covered by UW-16(f). See sketches below.



Note that different types of small fittings may have different spacing requirements for the same NPS connection because of the different size openings in the pressure vessel.

- Only one dished head form may be used on a design. For small vessel diameters (up to 24" O.D.), optional flat heads or flanged ends with blind flanges are permissible, if detailed on the drawing.

- Nozzle quantities and positions shall preferably be fixed. If this is not the case, tables specifying the minimum centre-to-centre distance in inches or millimetres between any two nozzles shall be provided. See Note below.

- Any provisions for openings in nozzle necks shall be detailed as for nozzles themselves.

- Any provisions for communicating chambers such as sumps, boots or domes must be fully detailed, including the form of the closure. These and any openings in them shall be treated the same as nozzles with respect to separation from any other nozzles or communicating chambers.

- Nozzle outboard ends may show options of being flanged, threaded, beveled for welding, grooved etc. Care must be taken that the minimum required nozzle neck thickness is maintained in grooved or threaded ends. (Ref. UG-45)

- The applicable welding procedure specifications must be identified.

- Where applicable, postweld heat treatment holding temperature and holding time must be specified.

- It is permissible to identify that, where postweld heat treatment is not a Code requirement, postweld heat treatment may be performed at an identified holding temperature for an identified time, provided that the drawing also stipulates the welding procedures to be used in the event that PWHT is performed as a customer request.

- Nozzles in heads must be sufficiently reinforced so as to meet Code whether they are in the dish region or the knuckle region; otherwise, the nozzles and the material required for reinforcement shall be confined to the dish area alone. This latter shall be done by limiting the nozzle centreline offset from the centre of the head.

- Nozzles must be defined as being normal to the shell or head surface or otherwise defined such that all nozzles can be shown to be adequately reinforced in any permitted orientation. Finished opening size must be established for each nozzle size, position and angle of intersection with the vessel shell or head or with a communicating chamber shell or head.

- The minimum extent of radiography or other Code-required nondestructive examination shall be specified.

- Inspection openings must be identified and may not be moved significantly from the locations shown or eliminated from the finished vessel. Such a note must appear on the drawing. This applies equally for Code-required vents and drains.

- Bills of materials must identify every piece of pressure-boundary material that might be used in any vessel built to the registered generic design.

- Vessels may be shown as supported optionally horizontally or vertically.

- All applicable Code requirements must be shown to have been met.

Note

Attention is drawn to the requirements of UG-36(c)(3) which can further limit spacings in clusters of three or more nozzles for which reinforcement calculations would not be necessary if the nozzles were isolated. Note that, where small nozzles have been calculated to show adequate reinforcement, the requirements of UG-36(c)(3) for clusters will not apply. It is suggested that for thin wall designs, demonstrating that as many small nozzles as possible are adequately reinforced will give the greatest flexibility to the design.

Fittings Design Registration

Any person who intends to manufacture a fitting for use in Alberta in connection with any boiler, pressure vessel or pressure piping system shall apply for registration of the fitting.

As defined in the Pressure Equipment Safety Regulation (AR 49/2006) section 1 (1)(n), fitting means a valve, gauge, regulating and controlling device, flange, pipe fitting or any other appurtenance that is attached to or forms part of a boiler, pressure vessel, fired-heater pressure coil, thermal liquid heating system or pressure piping system.

Submission Requirements for Registration of Fittings Designs in Alberta

Any person who intends to manufacture a fitting for use in Alberta in connection with any boiler, pressure vessel or pressure piping system shall apply for registration of the fitting.

As defined in the Pressure Equipment Safety Regulation (AR 49/2006) section 1 (1)(n), fitting means a valve, gauge, regulating and controlling device, flange, pipe fitting or any other appurtenance that is attached to or forms part of a boiler, pressure vessel, fired-heater pressure coil, thermal liquid heating system or pressure piping system.

Registration submissions shall include:

- a completed Design Registration Application AB-31 for each design;
- two original* completed Statutory Declaration Forms, Form AB-41, witnessed by a Commissioner for Oaths or a Notary Public. See Form AB-41a for guidance. [* with original signatures];
- a copy of a document from the agency that verified the Manufacturer's quality management system, attesting to the fact that a suitable quality management system exists and that it is being implemented. (Typically a certificate of registration.);
- the design details (drawings, brochures, catalogues etc., as appropriate) in duplicate;
- proof of registration in another Canadian jurisdiction (if applicable);

For guidance in completing the Statutory Declaration Form AB-41, please refer to AB-41a (Guide for Completing Form AB-41).

Note: Errors or omissions in completing the Statutory Declaration will likely extend the time necessary to complete the registration process.

Submission Requirements for Registration of Fittings Designs in Other Provinces Through ABSA

The Alberta Boilers Safety Association (ABSA) offers a one-window service to fitting manufacturers wishing to register their designs in multiple Canadian provinces. The manufacturer makes one submission, deals with one agency for clarifying any outstanding details and receives two invoices, one for the ABSA registration and a second for all the other registrations. Please note that categories A, B, C, & G fitting registration are exempt in BC & SK.

The following documentation is required for ABSA to register your fitting design and to apply for fitting registration in other provinces on your behalf:

- Two copies of the design data on the fittings, (i.e. the catalogs/drawings) for each jurisdiction in which registration is required. Note: treat Nova Scotia, New Brunswick, PEI, Newfoundland, Yukon, NWT and Nunavut as one jurisdiction as these are processed by ACI Central Inc. Therefore, if registration is required across Canada, a total of 14 copies are required (i.e. two each for BC, Alberta, Saskatchewan, Manitoba, Ontario, Quebec and ACIC.) To obtain a ACIC statutory declaration form you may download one from www.acicrn.com.
- Two signed (i.e. with original signatures) Statutory Declaration forms for each of the jurisdictions. Again, treat ACI Central Inc. member jurisdictions as one. ACIC requires their own "Universal Statutory Declaration Form" along with a "Fitting Information Form" both forms are available on their website www.acicrn.com. All others will accept the Alberta Statutory Declaration form AB-41.
- One copy of the manufacturer's QC Certificate for each provincial submission.

Following a successful review for registration in Alberta, ABSA will submit this information plus proof of registration in Alberta to the respective jurisdictions for their registration and will pay the applicable registration fees on your behalf. Note that these registration fees vary by province, and by the scope of the registration, so it is not feasible to state the fees in advance. ABSA will, in turn, bill you for their own registration fee and the other registration bodies fees plus an administration fee (regardless of how many jurisdictions you are applying to) plus courier and handling charges for each province for which you request registration. Where possible, ABSA will answer any questions that may arise from any other jurisdictions without your having to get involved.

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[1] Reference: Reprinted with permission from ABSA, the pressure equipment safety authority of the Province of Alberta. This information may be updated at any time and you are requested to check with ABSA for the latest information by visiting www.absa.ca or contacting ABSA directly.

New Boiler Construction Requirements

Category of Equipment	Code of Construction (PESR-6 - CSA B51)	ASME Code Stamp	ASME Code Stamp Requirement	Certificate of Authorization Permit Requirements (Required within Alberta only)	Design Registration Requirements	Certificate of Inspection Permit Required? [Blue Certificate. PESR 33]
Power Boilers Power Boiler 'S'. Miniature Boiler 'M' Electric Boiler 'E' Field Assembled Boiler 'A'	ASME I (ASME: American Society of Mechanical Engineers)	S M E A	No (PESR 28)	Yes, Certificate of Authorization Permit is required for the construction of Boilers and Fired Heaters in Alberta – PESR Section 11 (1) (a).	• Yes – PESR, Section 14(1): Design registration with ABSA required. • CSA B51, Clause 4.1: Design registration with the jurisdiction of installation required. • ASME: No design registration with anyone required but must meet the requirements of ASME I.	• Shop: Yes • Installation Insp.: Yes
Heating Boilers Steam Boilers Hot Water Boilers	ASME IV	H	No (PESR 28)		• BPVR & CSA same as above. • ASME: No design registration required but must meet requirements of ASME IV.	• Shop: Yes • Installation Insp.: Yes
Fired Heaters	ASME I	S	No (PESR 28)		• Same requirements as in row 1.	• Same as above.
Imported Boilers & Heaters (from within Canada)	ASME I or IV (Heaters ASME I only)	S M E H	No (CSA B51-5.3.1)	No. CSA B51: 4.9.1.1-QMS registration with the local jurisdiction required.	• Yes – PESR, Section 14: Design registration with ABSA required; CSA B51, Clause 4.1.	• Installation Insp.: Yes
Imported Boilers & Heaters (from outside Canada)	ASME I or IV (Heaters ASME I only)		Yes (PESR 28)	No. Registration with ASME required. No registration with ABSA required.	• Yes – PESR, Section 14: Design registration with ABSA required.	• Installation Insp.: Yes

Category of Equipment	Code of Construction (PESR-6 - CSA B51)	Manufacturing Requirements (Only parts of materials, welding, NDE and testing requirements are considered below. All other construction requirements of the QMS and applicable Codes/Standards must be complied with)	Inspection Requirements: By Owner	Inspection Requirements: By Manufacturer	Inspection Requirements: By an A.I.	Manufacturer's Certification Data Reports and ABSA Forms (PESR 29, 31)	A-Number Stamping by ABSA (ABSA Identification)
Power Boilers Power Boiler 'S'. Miniature Boiler 'M' Electric Boiler 'E' Field Assembled Boiler 'A'	ASME I (ASME: American Society of Mechanical Engineers)	• **Materials:** PG-5 to 13, Listed in ASME II • **WPS:** PESR 18 - WPS must be registered with ABSA. • **Welders:** PWR-2(1)-Only 'A', 'B' or 'C' pressure welders can weld on boilers. • **NDE:** Per PW-11 & ASME V. Personnel per PW-50; Min. ASNT/CGSB II. • **Testing:** PG-99-Hydro test 1.5 x MAWP	Recommended	Yes	Yes [by an ABSA A.I. (PG-90.1)]	**Boilers stamped with code symbol:** Applicable ASME I Data Reports P2, P2A, P2B, P3, P3A, P4, P5, P6. **Boilers not stamped with code symbol:** ABSA's AB-26 or 27.	The boiler should come stamped with an A-number when constructed in an Alberta shop.
Heating Boilers Steam Boilers Hot Water Boilers	ASME IV	• **Materials:** Per Article 2 of ASME IV. • **WPS and Welders** requirements are same as in Row 1. • **Testing:** Hydro test per the requirements of the code section applicable to the type of boiler (requirements vary).	Recommended	Yes [C.I. can sign off materials and hydro test for Cast Iron Sections]	Yes [by an ABSA A.I. (HG-515.4), except for Cast Iron sections]	**Boilers stamped with code symbol:** Applicable ASME IV Data Reports H2, H3, H5 **Boilers not stamped with code symbol:** ABSA's AB-26 or AB-27.	Same as above
Fired Heaters	ASME I	Same as in Row 1.	Recommended	Yes	Yes, by ABSA	P3 for code stamped AB-82 non code stamp	Stamped in shop or in field by ABSA.
Imported Boilers & Heaters (from within Canada)	ASME I or IV (Heaters ASME I only)	Same as in Row 1 except that the WPS and Welders may be registered with local jurisdiction.	Recommended	Yes	Yes, by an A.I.	P3 for code stamped AB-82 non code stamp	Stamped in field by ABSA.
Imported Boilers & Heaters (from outside Canada)	ASME I or IV (Heaters ASME I only)	Per ASME I or IV as applicable. WPS + Welders must comply with ASME IX; no registration reqd.	Recommended	Yes	Yes, by an A.I.	ASME I or IV Data Report as applicable.	Stamped in field by ABSA.

Legend: PESR: Pressure Equipment Safety Regulation; PWR: Pressure Welders Reg.; QMS: Quality Management System; A.I.: Authorized Inspector; C.I.: Certified Individual; WPS: Welding Procedure Specification; BP: Boiler Proper; BEP: Boiler External Piping;

New Pressure Vessel Requirements

Category of Equipment	Code of Construction (PESR-6 - CSA B51)	ASME Code Stamp	ASME Code Stamp Requirement	Certificate of Authorization Permit Requirements (Required within Alberta only)	Design Registration Requirements	Certificate of Inspection Permit Required? [Blue Certificate. PESR 33]
Pressure Vessels	ASME VIII-1	U	No [PESR 28]	Yes, Certificate of Authorization Permit is required for the construction of Pressure Vessels in Alberta - PESR Section 11 (1) (a).	• Yes – PESR, Section 14(1): Design registration with ABSA required. • CSA B51, Clause 4.1: Design registration with the jurisdiction of installation required. • ASME: No registration required but must meet the requirements of ASME VIII-1, 2 or 3 as applicable (ASME VIII requirements do not apply to Fired Heaters) Note: Design requirements for ASME Div. 2 and 3 are extensive.	• Shop: Yes • Installation: Yes (Except for certified O/U companies)
Miniature Vessels	ASME VIII-1	UM	No [PESR 28]			• No
Fired Heaters	Designed to API 530 & fabricated to B31.3	None	No [PESR 28]			• Shop: Yes • Installation Insp.: Yes (Except for certified O/U companies)
Pressure Vessels	ASME VIII-2	U2	Yes [PESR 28]			
Pressure Vessels	ASME VIII-3	U3	No (Except ASME)			
Imported Vessels (from within Canada)	ASME VIII-1, 2, 3 (including miniature vessels)	Applicable ASME VIII Code Stamp	VIII-2, 3)	No. CSA B51: 4.9.1.1-QMS registration with the local jurisdiction required.	• Yes – PESR, Section 14: Design registration with ABSA required.	• Installation Insp.: Yes
Imported Vessels (from outside Canada)			Yes [PESR 28]	No. Registration with ASME required. No registration with ABSA required.		• Installation Insp.: Yes

Category of Equipment	Code of Construction (PESR-6 - CSA B51)	Manufacturing Requirements (Only parts of materials, welding, NDE and testing requirements are considered below. All other construction requirements of the QMS and applicable Codes/Standards must be complied with)	Inspection Requirements: By Owner	Inspection Requirements: By Manufacturer	Inspection Requirements: By an A.I.	Manufacturer's Certification Data Reports and ABSA Forms (PESR 29, 31)	A-Number Stamping by ABSA (ABSA Identification)
Pressure Vessels	ASME VIII-1	• **Materials:** UG-4 to 15, listed in ASME II • **WPS:** PESR 18 - WPSs must be registered with ABSA. • **Welders:** PWR-2(1)-Only 'A', 'B' or 'C' pressure welders can weld on P.Vessels. • **NDE:** Personnel min. ASNT/CGSB II. • **Testing:** UG-99, Hydro test 1.3 x MAWP(Materials and Testing requirements for Fired Heaters shall be per API 530 and ASME B31.3)	Recommended	Yes	Yes, by ABSA	ASME VIII-1, U1 or U1A if code stamped. ABSA AB-25 if not code stamped.	The vessel should come stamped with an A-number when constructed in an Alberta shop. (Miniature vessels are not stamped with an A-number.)
Miniature Vessels	ASME VIII-1		Recommended	Yes (by Certified Individual)	No	U3 for code stamped. AB-24 non code stamp.	
Fired Heaters	Designed to API 530 & fabricated to B31.3		Recommended	Yes	Yes, by ABSA	ABSA Form AB-82	
Pressure Vessels	ASME VIII-2	Materials, WPS and Welders requirements are same as above. NDE requirements are extensive. Hydro test 1.25 x MAWP	Recommended	Yes	Yes, by ABSA	ASME VIII-2, A1	
Pressure Vessels	ASME VIII-3		Recommended	Yes	Yes, by ABSA	ASME VIII-3, K1	
Imported Vessels (from within Canada)	ASME VIII-1, 2, 3 (including miniature vessels)	Same as above except that the WPS and Welders may be registered with the local jurisdiction.	Recommended	Yes	Yes, by an A.I.	Same as above, rows 6-10.	Stamped in field by ABSA.
Imported Vessels (from outside Canada)		Same as above except that WPS + Welders must comply with ASME IX; no registration required.	Recommended	Yes	Yes, by an A.I.	Applicable ASME Data Report	Stamped in field by ABSA.

New Pressure Piping Construction Requirements

Category of Equipment	Code of Construction (PESR-6 - CSA B51)	ASME Code Stamp	ASME Code Stamp Requirement	Certificate of Authorization Permit Requirements (Required within Alberta only)	Design Registration Requirements	Certificate of Inspection Permit Required? [Blue Certificate. PESR 33]
Process Piping	ASME B31.3	N.A.	N.A.	Yes, Certificate of Authorization Permit is required for the construction of Pressure Piping in Alberta, PESR Section 11 (1) (a).	• PESR Sections 14: Design registration with ABSA required when internal volume of piping is over 0.5 m^3. All heater coils must be registered. • PESR Section 16(1)(h): Submission of AB-96 is required when registering the design with ABSA. • PESR Section 16(2): P.Eng. seal required for all piping designs over 0.5m^3 internal volume.	• No blue Certificate of Inspection is issued by ABSA for Piping. • A blue Certificate of Inspection is issued by ABSA for Unfired heater coils.
Unfired Heater Coils	ASME B31.3	N.A.	N.A.			
Imported Piping (From within Canada)	As applicable	PP / S for BEP	No	No. CSA B51: 4.9.1.1-QMS registration with the local jurisdiction required.	Same as above for Pressure Piping	
Imported Piping (From outside Canada)	As applicable		PP / S for BEP	No. Registration with ASME required for External piping only.	Design registration with ABSA required [PESR 14].	

Category of Equipment	Code of Construction (PESR-6 - CSA B51)	Manufacturing Requirements (Only parts of materials, welding, NDE and testing requirements are considered below. All other construction requirements of the QMS and applicable Codes/Standards must be complied with)	Inspection Requirements: By Owner	Inspection Requirements: By Manufacturer	Inspection Requirements: By an A.I.	Manufacturer's Certification Data Reports and ABSA Forms (PESR 29, 31)	A Number Stamping by ABSA (ABSA Identification)
Process Piping	ASME B31.3	• **Materials:** Per applicable Piping Code. • **WPS:** PESR 18 - WPSs registered with ABSA • **Welders:** WR-2(1)-Only 'A', 'B' or 'C' pressure welders can weld on P. Piping. • **NDE:** Per code of construction and ASME V. Personnel qualifications min. ASNT/CGSB II. • **Testing:** Hydro test 1.5 x MAWP Note: PESR 32, Submission of Form AB-81 to ABSA required when the job is completed (by contractor).	Yes	Yes	No	Submission of ABSA Form AB-83 to the owner is required for all Piping systems except Unfired Heater Coils. For Unfired Heater Coils complete and submit Form AB-28 to ABSA & to the Owner. For code stamped BEP: ASME I, P-4A/B required.	A Number is not stamped on Piping. A Number is stamped on Unfired Heater Coils by ABSA.
Unfired Heater Coils	ASME B31.3		Recommended	Yes	Yes		
Imported Piping (From within Canada)	As applicable	Same as above except that the WPS and Welders may be registered with local jurisdiction.	Recommended	Yes	May be required	AB-83/AB-83F/P-4A/P-4B (Requirements vary)	
Imported Piping (From outside Canada)	As applicable	Same as above except that WPS + Welders must comply with ASME IX; no registration required.	Optional	Yes	Yes	ASME 1, P4A for BEP, AB-83F for other applications.	

Legend: PESR: Pressure Equipment Safety Regulation; PWR: Pressure Welders Reg.; QMS: Quality Management System; A.I.: Authorized Inspector; C.I.: Certified Individual; WPS: Welding Procedure Specification; BP: Boiler Proper; BEP: Boiler External Piping;

New Fitting Requirements

New Construction of Fittings	Category of Equipment	Code of Construction [(Codes per PESR-6). CSA B51 code applies throughout]	ASME Code Stamp	ASME Code Stamp Requirement	Certificate of Authorization Permit Requirements (Required within Alberta only)	Design Registration Requirements	Certificate of Inspection Permit [Blue Certificate. PESR 33]
Cat. 'A'	Couplings, Tees, Elbows, Wyes. Plugs, unions…	• Standard Fittings may be manufactured to 'Component Standards' listed in the adopted codes & standards in DCR. • Non standard Fittings may be manufactured to ASME codes as applicable.	N.A.	N.A.	Yes, Certificate of Authorization Permit is required for the construction of Fittings in Alberta – PESR Section 11 (1) (a).	• PESR: Section 14(1) Design registration with ABSA required. • CSA B51: Clause 4.2-Design registration with the jurisdiction of installation required. • ASME: No registration requirement. CSA Clause 4.3: Design registration is signified by the CRN (Canadian Registration Number) which may look like 0B1234.246C. The number must include the digit '2' or letter 'C' after the period to be legal in Alberta CSA Clause 4.2.1: Design registration expires 10 years after first registration.	• No blue Certificate of Inspection is issued by ABSA for Fittings.
Cat. 'B'	Standard Flanges		N.A.	N.A.			
Cat. 'C'	All line Valves		N.A.	N.A.			
Cat. 'D'	Expansion Joints, Hoses, Flexible connections.		N.A.	N.A.			
Cat. 'E'	Strainers, Filters, Separators & Steam traps		N.A.	N.A.			
Cat. 'F'	Gages, Sight Glasses, Levels, P. Transmitters.		N.A.	N.A.			
Cat. 'G'	Pressure Relief Devices	• ASME 1 • ASME VIII-1, 2 • ASME VIII-3 • ASME IV	V UV UV3 HV	Yes (CSA B51, 5.3.1)			
Cat. 'H'	None of the above	As applicable	N.A.	No			
Any Category	Imported Fittings (From within Canada)	As applicable	N.A.	N.A. (Yes for Cat. G)	No. CSA B51: 4.9.1.1-QMS registration with the local jurisdiction required.	Yes-PESR, Section 14; CSA B51, Clause 4.2.1.	
Any Category	Imported Fittings (From outside Canada)	As applicable	N.A.	N.A. (Yes for Cat. G)	A registered QMS such as ISO 9001 or with ASME or oneacceptable to ABSA	Yes-PESR, Section 14; CSA B51, Clause 4.2.2.	

New Fitting Requirements (Continued)

New Construction of Fittings	Category of Equipment	**Code of Construction** [(Codes per PESR-6). CSA B51 code applies throughout]	**Manufacturing Requirements** (Only parts of Materials, Welding, NDE and Testing requirements are considered below. All other construction requirements of the QMS and applicable Codes/Standards must be complied with)	**Inspection Requirements**			**Manufacturer's Certification** Data Reports and ABSA Forms (PESR 29, 31)	**A Number Stamping by ABSA** (ABSA Identification)
				By Owner	**By Manufacturer**	**By an A.I.**		
Cat. 'A'	Couplings, Tees, Elbows, Wyes. Plugs, unions...	• Standard Fittings may be manufactured to 'Component Standards' listed in the adopted codes & standards in DCR. • Non standard Fittings may be manufactured to ASME codes as applicable.	• **Materials:** Per the code of construction. • **WPS:** PESR 18 - WPSs must be registered with ABSA. • **Welders:** WR-2(1)-Only 'A', 'B' or 'C' pressure welders can weld on Fittings. • **NDE:** Per code/standard of construction. Personnel qualifications min. ASNT/CGSB II. • **Proof Test**: When required, shall be per the code/standard of construction. • **Testing:** Hydro test per applicable code of construction.	Optional	Yes	No (CSA B51, Figs. 1 a, b, c: Some Cat. H Fittings are registered as vessels and inspected by an A.I.)	None specified except for PRVs.	A Number is not stamped on Fittings.
Cat. 'B'	Standard Flanges			Optional	Yes			
Cat. 'C'	All line Valves			Optional	Yes			
Cat. 'D'	Expansion Joints, Hoses, Flexible connections.			Optional	Yes			
Cat. 'E'	Strainers, Filters, Separators & Steam traps			Optional	Yes			
Cat. 'F'	Gages, Sight Glasses, Levels, P. Transmitters.			Optional	Yes			
Cat. 'G'	Pressure Relief Devices	• ASME 1 • ASME VIII-1, 2 • ASME VIII-3 • ASME IV		Optional	Yes by Certified Individual		ASME 1, P7, P8 for V Reqd., No Form for HV ASME UV-1, A-4 UV ASME K4 for UV3	
Cat. 'H'	None of the above	As applicable		Optional	Yes		None specified.	
Any Category	Imported Fittings (From within Canada)	As applicable	Same as above except that the WPS and Welders may be registered with local jurisdiction.	Optional	Yes		None specified except for PRVs.	
Any Category	Imported Fittings (From outside Canada)	As applicable	Same as above except that WPS + Welders must comply with ASME IX; no registration required.	Optional	Yes	No	None specified except for PRVs.	

ABSA Forms

www.absa.ca/Forms/Default.aspx

Design Registration Forms

- AB12 Pressure Vessel Inspection Report
- AB31 Design Registration Application
- AB40 Boilers and Pressure Vessels Repair/Alteration Report
- AB40a Guide for Completing Form AB-40
- AB41 Statutory Declaration Form for Registration of Fittings
- AB41a Guide For Completing Form AB-41

Pressure Equipment Forms

- AB76a Welder Qualification Record (WQR)
- AB76b Welding Operator Qualification Record (WOQR)
- AB81 Completion of Construction Declaration
- AB83 Construction Data Report for Piping Systems
- AB83a Guide for Completing Form AB-83
- AB83f Construction Data Report for Piping Systems Manufactured Outside Alberta
- AB506 Inspection and Servicing Requirements for Pressure Equipment, Rev 6
- AB513 Pressure Equipment Repair and Alteration Requirements
- AB516 PESR User Guide

Other Forms

- AB97 Accident Report Form

thoughness: ability to resist flaw propagation

BRITTLE FRACTURE

Characteristics

Steel is generally considered to be a ductile material. When overloaded, it usually gives warning before rupturing by flowing plastically, (i.e., bulging stretching, bending or necking). Contrary to expectation, however, steels sometimes rupture without prior evidence of distress. Such brittle failures are accompanied by little plastic deformation, and the energy required to propagate the fracture appears to be quite low. Under certain conditions, steel may shatter like glass. In piping, this extreme behavior generally occurs only at low temperatures.

Three conditions control this tendency for steel to behave in a brittle fashion, including:

1) high stress concentrations, (i.e., notches, nicks, scratches, internal flaws or sharp changes in geometry);
2) a high rate of straining; and
3) a low environmental temperature.

These three factors are so interrelated that the determination of the affect of any one of them provides an indication of how the steel will react to the intensification of either or both of the others. The effect of lowering the testing temperature is the condition most convenient to measure quantitatively. Consequently, the transition from ductile to brittle behavior of a steel is generally expressed in terms of temperature.

The transition temperature for any steel is the temperature above which the steel behaves in a predominantly ductile manner and below which it behaves in a predominantly brittle manner. Steel with a high transition temperature is more likely to behave in a brittle manner during fabrication or while in service.

In turn, a steel with a low transition temperature is more likely to behave in a ductile manner and, therefore, steels with low-transition temperatures are generally preferred for service involving severe stress concentrations, impact loading, low temperatures, or combinations of the three.

Metallurgical factors, (e.g., deoxidation practice, chemical composition, rolling, forging or extruding practice, grain size, subsequent heat treatment, etc.), influence the transition temperature of steel. In carbon steel materials that are under the worst conditions, the transition temperature may be above 200°F or under the best conditions, (i.e., below minus 100°F).

Steels treated in accordance with most favorable deoxidation practices are those which are fully killed. In plate and pipe steels, deoxidation is generally accomplished with sufficient silicon to provide about 0.10% to 0.20% of silicon in the steel. Aluminum is also used as a deoxidizer. The amount of aluminum normally used causes the retention of only a few hundredths of a per cent of residual aluminum in the steel. Such steels are sometimes referred to as being made in accordance with fine-grain steelmaking practices.

Book:
"Cracks and Fracture" by: K Bertram Broberg, Academic Press, 1999

Steels that have been fully annealed are in the poorest condition to resist embrittlement. Normalizing provides improvement. Frequently, further benefit is derived from tempering after normalizing or from stress relieving after welding. Optimum properties are obtained by fully quenching and tempering to moderate strength levels.

The presence of notches or other stress-concentration factors is of very considerable importance. Sharp notches in welded joints may encourage failure at loads well below those permitted by design. Any aggravated notch, just like a severe geometric shape change, can result in a crack at relatively low loads.

Low Temperature Service

Steels are commonly used below zero when they have Charpy V-notch impact values of at least 20 ft-lb. (27 J) at the lowest design temperature. Austenitic stainless steels with a limited carbon content, copper and copper alloys, and aluminum do not experience transitions in impact strength from ductile to brittle fracture and, therefore, may be used for low temperatures without pressure-rating penalties.

Low temperature piping is generally covered with thermal insulation, which helps provide protection from external impact blows or shock. This, however, is insufficient insurance against the type of damage that could result if a pipe should fracture.

Nature of Brittle Behavior

Brittle behavior in steel may result from a number of factors, including:

1) rapid rate of straining;
2) the presence of multidirectional stresses or notches causing restraint (e.g., surface defects, discontinuities, incomplete welds, underbead cracks, microcracks, sharp re-entrant corners, etc.);
3) low operating temperature; or
4) a combination of these factors.

The brittle behavior of a steel is generally evidenced by sudden fracture and sometimes by shattering. The initial cracking usually will propagate very rapidly and, under certain conditions, the rate of propagation is practically infinite. Relatively little energy is required for propagation. At the failure location, the surface of the fracture appears bright, granular, and crystalline with the cross section showing little or no evidence of necking or plastic deformation. Such fractures are generally called cleavage fractures.

In contrast, a steel that behaves in a ductile manner generally will fail gradually, (i.e., at a much slower rate). A high energy impact is required for crack propagation. Moreover, ductile failures in pressure vessels, pipes, or tubes usually are preceded by local bulging (i.e., by plastic deformation or flow in the material because of shearing forces). Such shear fractures will appear relatively dull and fibrous, and show a measurable and often considerable contraction of area across the fracture section.

Effects of Temperature

The transition from ductile to brittle behavior of carbon and low-alloy steels is not a phenomenon only occasionally noted; this transition is an inherent property that can be demonstrated by a number of accepted test methods. For example, Figure 1 illustrates this transition as brought about by a decrease in the testing temperature.

Note: Since several criteria may be employed to evaluate the transition temperature, its position with respect to the temperature scale may be expected to vary with the criterion selected.

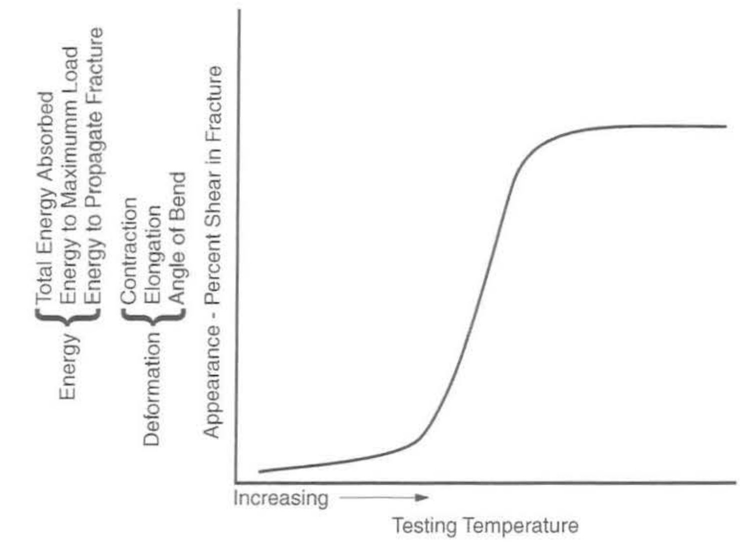


Figure 1 Schematic illustration of transition temperature range.

Transition Temperature

Various tests have been developed to determine whether a steel under certain test conditions will fail definitely in a ductile or brittle manner. Each of these conditions actually shows a scatter region or a transition-temperature range, within which a steel under the same set of test conditions will exhibit either ductile or brittle behavior, or both.

Usually, some empirically established point within the transition-temperature range is selected and is thereafter designated as the transition temperature for the steel tested. This temperature can be roughly defined as the temperature above which the steel under the particular test conditions will behave in a predominantly ductile manner and below which the steel will exhibit a predominantly brittle behavior.

For example, when the appearance of the fracture is the criterion, the transition temperature may be arbitrarily designated as the temperature at which half of the fracture surface shows a cleavage failure while the other half exhibits a shear failure.

0.2% off set Yeild Point For vessels
0.5% Proof Yeild Point use for pipes & Tubes

When impact energy absorption is the criterion representing the most widely accepted method, some arbitrary energy value is generally used. For example, in the Charpy test, the temperature corresponding to the 15 ft-lb value may be designated arbitrarily as the transition temperature.

Note: At this value, the fracture may be predominantly the cleavage type. This method is illustrated in Figure 2.

Other criteria are the temperature at which the initial appearance of cleavage (i.e., brittle) fracture is observed and the temperature at which the energy absorbed is half of the maximum energy value obtained over the testing range.

No one "transition temperature" exists for a given steel except for a particular set of conditions and one criterion of brittleness. Each particular forged or extruded pipe or plate thickness rolled from a given steel will exhibit a range of temperatures in which the fracture shifts from tough to brittle. This range may be varied considerably by changing the metallurgical and mechanical properties of a steel.

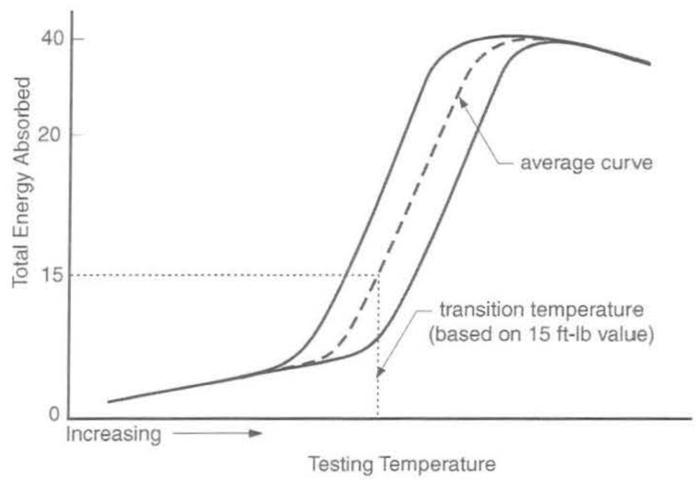


Figure 2 Transition temperature range and Charpy impact test.

Effects of Notches and Notch Sensitivity

The sudden brittle failures that occur without measurable deformation are generally ascribed to the notch sensitivity of the steel at the operating temperatures to which the steel was exposed. Although not always obvious, actual mechanical notches or notch effects are present in all structures. They may consist of minute surface or subsurface cracks, surface laps or scabs, visible scratches, abrupt shape changes (e.g., sharp corners, tool marks, grooves from drawing, dies, edges, etc.), or fabrication defects, (e.g., arc strikes, etc.).

Notch sensitivity is usually associated with an inability of the steel to deform in a plastic manner (i.e., to flow) underneath the notch. This resistance to flow is increased by the triaxial state induced by a tensile stress under a notch. The condition is accentuated as the thickness of the steel increases. Notches also are stress raisers. The greater the sharpness of the notch, the greater the degree of restraint will be; the more severe the degree of restraint, the more severe the triaxiality and magnitude of stresses will be and the higher the transition temperature will be. This is the basis of the general concept: the transition-temperature range or the arbitrarily-selected transition temperature will increase with the severity of the notch. In other words, a steel containing extremely severe notches will fail in a brittle manner at higher ambient temperatures than if less severe notches are present.

Note: In the instances where service conditions impose a triaxial state of stress, as is true of internally loaded vessels and piping, brittle behavior may be encountered even in the absence of notches.

Factors Determining Transition Temperatures

Factors influencing the transition-temperature range of a steel may be separated into metallurgical factors and mechanical factors. The metallurgical factors are characteristic of the steel itself, whereas the mechanical factors depend upon the service or testing environments, as well as many effects produced by fabricating procedures. An analysis and understanding of the various factors is often important, particularly when it is desirable to make the most efficient use of a particular steel.

Controlling Grain Size to Avoid Brittle Fracture

Controlling Grain Size by Normalizing

Grain growth occurs when higher austenitizing temperatures are reached while heat treating low-carbon and medium carbon steels, resulting in coarse grains, as defined in ASTM E7 as follows:

> *coarse grains*: grains either larger than normal for the particular wrought metal or alloy or grains of such a size that a surface roughening, popularly known as "orange peel" or" alligator skin," is produced.

Grain coarsening of austenite is reversible in silicon-deoxidized steels by re-austenitization. During re-austenitization several new grains of austenite can be nucleated within the volume occupied by a single pre-existing austenite grain, and the size to which the new austenite grains grow is dependent on the re-austenitizing temperature and time. Thus, the new austenite grain size will generally be smaller than the former grain size if the re-austenitizing temperature is lower than the previous one. This process is called *recrystallization* and is defined in ASTM E7 as follows:

> *recrystallization*: the formation of a new grain structure through nucleation and growth commonly produced by subjecting a metal that may be strained to suitable conditions of time and temperature.

However, an acceptably small austenite grain size may not be recovered in a single re-austenitization heat treatment if the initial austenite grains are very coarse. In such a case, several re-austenitizing heat treatments may be required to obtain a uniform and small final grain size, (e.g., double-normalizing heat treatment, etc.).

The austenite grain size of normalized or annealed medium-carbon steels can be readily observed because proeutectoid ferrite precipitates along the austenite grain boundaries during slow cooling. Thus, bands of ferrite outline the prior austenite grain boundaries.

However, recognizing the locations and paths of the prior austenite grain boundaries in low-carbon steels is not so easy when a large volume fraction of ferrite is present. Similarly, special etching techniques are required for quenched and tempered (i.e., martensitic) steels to reveal the prior austenite grain size. A picric acid etchant is suggested for revealing prior austenite grains in steels which have been fully hardened to martensite. See ASTM Standard E112, Appendix 3, for more details.

Normalizing is the most common heat treatment for carbon and alloy steels to control grain size. However, the austenitizing temperature during normalizing will define the final-room-temperature grain size and likewise the steel's mechanical properties. The most sensitive mechanical property in carbon and alloy steels affected by grain size is the notch-toughness (see Figure 3).

Generally, the smaller the ferrite grain size, the lower the transition temperature will be. Thus, the lower the final rolling temperature of the steel and the higher the cooling rate, the smaller the grain size and the lower the transition temperature, unless the final rolling temperature is so low that the steel is cold rolled to some degree.

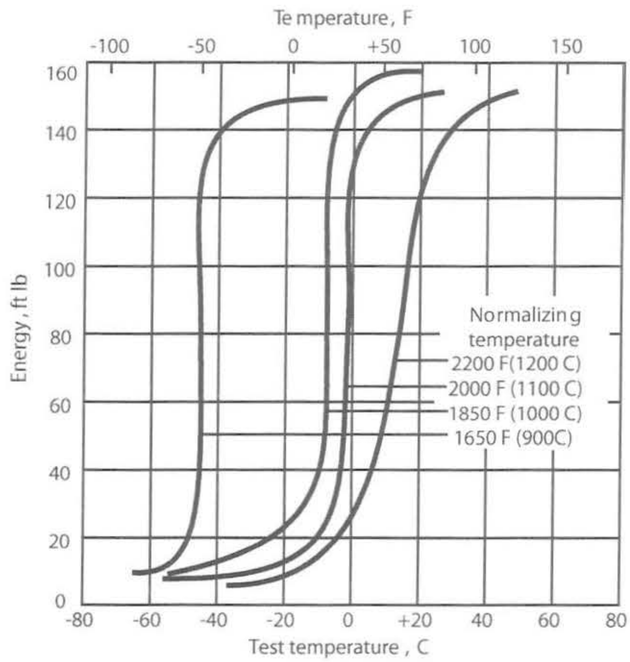


Figure 3 The effect of austenitizing temperature after normalizing on final grain size of a low-carbon steel and its reduction in notch toughness as measured by the transition temperature.

Controlling Grain Size by Chemical Composition

Another means of controlling grain size in carbon and alloy steels is through their chemical composition, by adding grain refining elements such as silicon (Si) and aluminum (Al). This is defined in ASTM A941 as follows:

> *fine grain practice*:a steelmaking practice for other than stainless steel that is intended to produce a killed steel that is capable of meeting the requirements specified for fine austenitic grain size.
>
> **Discussion**:
> Fine grain practice normally involves the addition of one or more austenitic grain-refining elements in amounts that have been established by the steel producer as being sufficient. Austenitic grain refining elements include, but are not limited to, aluminum, niobium (i.e., columbium), titanium, and vanadium.

Some steels are given small additions of such alloying elements as aluminum, niobium, vanadian, titanium, or zirconium during steelmaking to inhibit *austenitic grain growth*. This is accomplished by the formation of alloy carbides or carbonitrides, which are stable at austenitizing temperatures and impede with the migration of austenite grain boundaries, thus inhibiting grain coarsening. The result is *fine-grained austenite*, even after heating at normal austenitizing temperatures; the product is then called *fine-grained steel*, although the term *grain refined steel* has also been used.

Carbon influences the transition temperature of carbon steels unfavorably since it increases hardenability and the potential for martensite formation (see Figure 4). Most elements other than those used for deoxidation raise the transition temperature with the notable exception of nickel, which lowers appreciably the transition temperature of carbon steel. Austenitic chromium-nickel stainless steel and some high-nickel steels do not show transition at temperatures even as low as -325°F to -425°F.

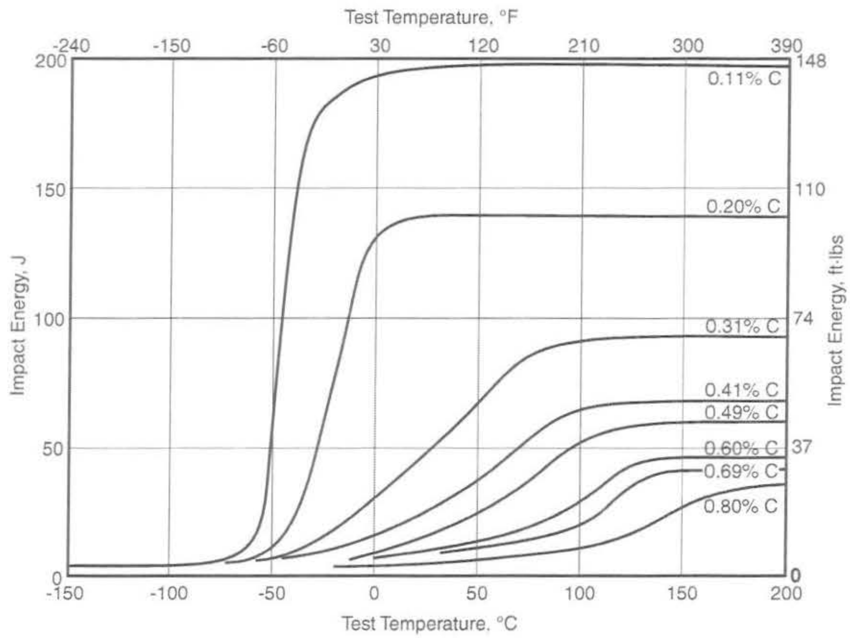


Figure 4 The effect of carbon content on notch-toughness in normalized steels.

Sulphur, phosphorous, and oxygen in quantities greater than normally tolerated and silicon in percentages greater than required for deoxidation also may raise the transition temperature. In fact, most additions usually made to steel raise the transition temperature.

Steels treated during the steel making process with grain refinement alloying elements, such as aluminum, niobium, vanadium, titanium and zirconium, inhibit austenitic grain growth. The austenitic grain size after heating at commercial austenitizing temperatures is then much smaller than for non-treated steels. The product then is commonly called *fine-grained steel*.

The additions of nickel and, under certain conditions, manganese will lower the transition temperature. Nickel is frequently added to low-carbon steel when a transition temperature below that obtainable with carbon steel is desired.

Commercial low-carbon steels, even those within the same grade, may exhibit considerable differences in their notch-sensitivity characteristics. These differences, which are not predictable from the conventional chemical analyses, may be attributed to various factors such as steel making practice, deoxidation, grain size, finishing temperature, thickness of section, heat treatment, and others.

Effect of Welding on Notch Toughness

The effect of two preheat temperatures on the toughness of simulated heat-affected zones in ASTM A514 or A517 steel plate that is 0.5in. thick is illustrated in Figure 5. The curves indicate the toughness of the grain-coarsened area in the heat-affected zone on a final pass or a multiple-pass weld or a single-pass weld. Such an area is considered to be the worst condition because it does not receive the benefits of tempering from additional weld passes. The toughness of the heat-affected zone of prior passes in multiple-pass welds is expected to be significantly better. Nevertheless, the higher preheat temperature (500°F) resulted in significantly decreased toughness when compared to that with the lower preheat temperature (200°F).

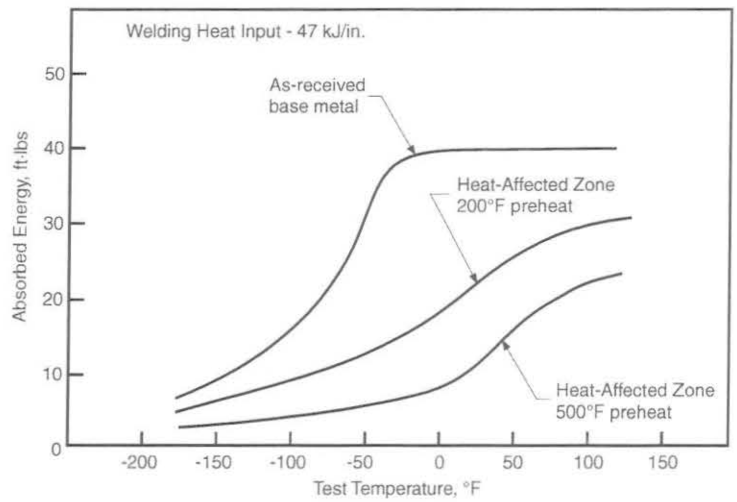


Figure 5 The effect of preheat temperature on the Charpy V-notch toughness of the heat-affected zone (2400°F) in a 0.5 inch thick ASTM A 514 or A 517 steel.

ASME Section VIII, Division 1

Hydrostatic Test Medium and Temperature – UG-99(h)

Provided the hydrostatic testing medium is a nonhazardous liquid, it may be used at any temperature only if it is below its boiling point. For example, combustible liquids with a flash point less than 110°F (43°C), (e.g., petroleum distillates may be used only for near atmospheric temperature tests, etc.).

UG-99(h) does not have a requirement for either minimum or maximum test temperature. However, maintaining the metal temperature during a hydrostatic test at a minimum of 30°F (17°C) above the minimum design metal temperature is recommended, but the design metal temperature should not exceed 120°F (48°C) to minimize the risk of brittle fracture.

UG-99(h) does specify that the test pressure shall not be applied until the vessel and its contents are at about the same temperature. If the test temperature exceeds 120°F (48°C), it further recommends inspection of the vessel required by UG-99(g) be delayed until the temperature is reduced to 120°F (48°C) or less.

Pneumatic Test Temperature – UG-100(c)

Unlike UG-99(h) for hydrostatic testing, UG-100(c) does specify that the metal temperature during pneumatic test shall be maintained at least 30°F (17°C) above the minimum design metal temperature to minimize the risk of brittle fracture. Again, the Code warns the user about the higher risk of performing a pneumatic test and avoiding brittle fracture.

ASME B31.3

General Requirements for Leak Tests - ¶345.2

Low Test Temperature - ¶345.2.2(c)

The Code makes no specific requirement of the metal temperature during pneumatic testing for either ambient or metal temperature. However, ¶345.2.2(c) does warn that the possibility of brittle fracture shall be considered when conducting leak tests at metal temperatures near the ductile-brittle transition temperature.

Mechanical Strength - 302.4.1

When necessary, the wall thickness shall be increased to prevent overstress, damage, collapse, or buckling due to superimposed loads from supports, ice formation, backfill, transportation, handling, or other causes.

Where increasing the thickness would excessively increase local stresses or the risk of brittle fracture, or is otherwise impracticable, the required strength may be obtained through additional supports, braces, or other means without an increasing wall thickness.

API 510 and API 570

Test Temperature and Brittle Fracture Considerations

The potential for a brittle failure must be evaluated prior to hydrostatic testing and especially prior to pneumatic testing because of the high potential energy in the vessel during the test. See API 510, ¶5.8.6, and API 570 and ¶5.8.3 for more details.

To minimize the risk of brittle fracture during a pressure test, API 510 and 570 suggest that the metal temperature should be maintained at least:

- 30°F (17°C) above the MDMT for vessels that are more than 2 in. (5 cm) thick and
- 10°F (6°C) above the MDMT for vessels that have a thickness of 2 in. (5 cm) or less.

The test temperature need not exceed 120°F (50°C) unless there is information on the brittle characteristics that indicate a risk of catastrophic fracture of the vessel material where a higher test temperature must be employed.

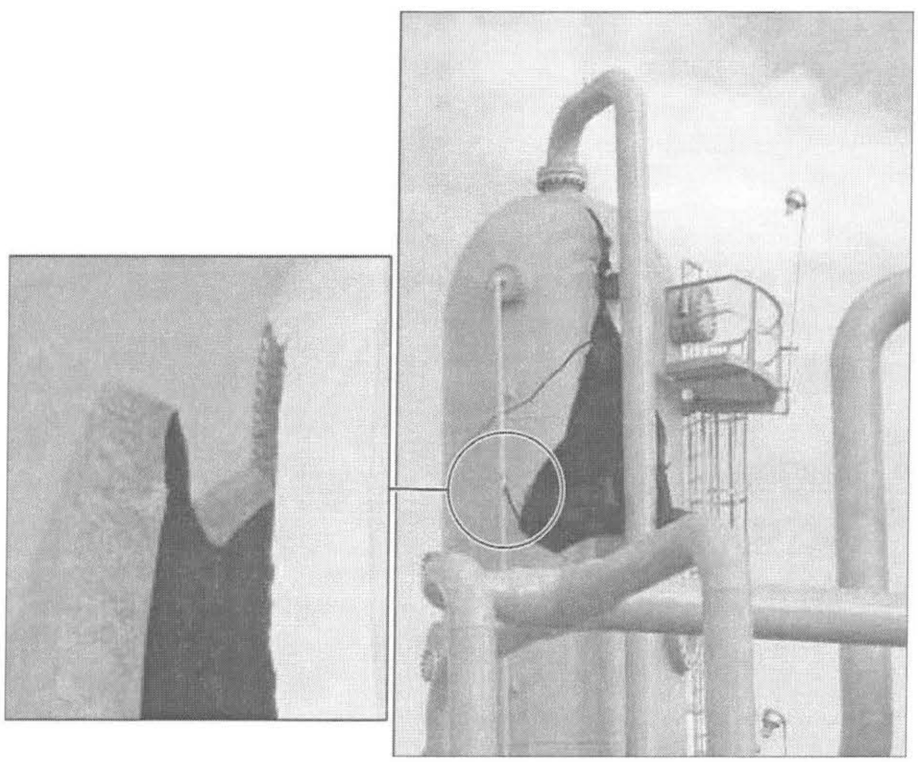


Figure 6 Hydrostatic pressure testing this new vertical vessel resulted in catastrophic brittle fracture — very cold water (i.e., temperature unknown) was a contributing factor. Fortunately, no injuries occurred.

The best book for pressure vessels design is:

"Pressure Vessele Design" by: Bednar

U: Unfired

Subsection B includes: Welding, Forging, and Brazing.

so we will have UW, UF and UB items.

UG: means includes General items.

UCS: includes carbon steel materials.

Interpretation: without interpretation code is not undrestand. suncor has access to the interpretation data base.

addenda: every 3 months ASME publishe a new addenda. This is about Typo or addition of new materials.

ASME is a "safety design code"

ASME SECTION VIII, DIVISION 1 – RULES FOR CONSTRUCTION OF PRESSURE VESSELS

The ASME Boiler and Pressure Vessel Code is made of up 29 code books, of which, Section VIII Division 1 is one of the code books, as shown in the list below. Typically, when the word "Code" (with an upper case C) is used within a code book, it refers to that particular code book and not to the entire ASME Boiler and Pressure Vessel Code. For example, when the word "Code" is used within ASME Section VIII Division 1, it is referring to that code book.

SECTIONS

I. I Rules for Construction of Power Boilers

II. II Materials
- Part A — Ferrous Material Specifications
- Part B — Nonferrous Material Specifications
- Part C — Specifications for Welding Rods, Electrodes, and Filler Metals
- Part D — Properties (Customary)
- Part D — Properties (Metric)

III. III Rules for Construction of Nuclear Facility Components
- Subsection NCA — General Requirements for Division 1 and Division 2
- Appendices
- Division 1
  - Subsection NB — Class 1 Components
  - Subsection NC — Class 2 Components
  - Subsection ND — Class 3 Components
  - Subsection NE — Class MC Components
  - Subsection NF — Supports
  - Subsection NG — Core Support Structures
  - Subsection NH — Class 1 Components in Elevated Temperature Service
- Division 2 — Code for Concrete Containments
- Division 3 — Containments for Transportation and Storage of Spent Nuclear Fuel and High Level Radioactive Material and Waste
- Division 5 — High Temperature Reactors

IV. Rules for Construction of Heating Boilers

V. Nondestructive Examination

VI. Recommended Rules for the Care and Operation of Heating Boilers

VII. Recommended Guidelines for the Care of Power Boilers

VIII. Rules for Construction of Pressure Vessels
- Division 1
- Division 2 — Alternative Rules
- Division 3 — Alternative Rules for Construction of High Pressure Vessels

IX. Welding, Brazing, and Fusing Qualifications

X. Fiber-Reinforced Plastic Pressure Vessels

XI. Rules for Inservice Inspection of Nuclear Power Plant Components

XII. Rules for Construction and Continued Service of Transport Tanks

my life is worth more than this.

Minimum Rules of Safety for Construction of New Pressure Vessels

The ASME Section VIII Division 1, specifies the minimum rules of safety for construction of new pressure vessels, which includes important warnings in the Forward, as follows.

Forward

- The Committee's function is to establish rules of safety, relating only to pressure integrity, governing the construction of boilers, pressure vessels, transport tanks...
- The user of the Code should refer to other pertinent codes, standards, laws, regulations, or other relevant documents.
- With few 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.
- Accordingly, it is not intended that this Section be used as a design handbook; rather, engineering judgment must be employed in the selection of those sets of Code rules suitable to any specific service or need.
- 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 designers 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 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 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 above safety warnings are a mandatory part of the Code, and likewise, must be always followed in order to meet the minimum requirements of the Code.

Each article in ASME Section VIII, Division 1, is identified with an alphanumeric label. This labeling system is common to all the Boiler and Pressure Vessel Code (BPVC) sections.

In Division 1, all article labels start with the letter U that symbolizes an article from the unfired vessel section of the Code. Another letter or letters symbolizing the information under discussion in the article follows this letter, as follows:

- UG – General Requirements for All Methods of Construction and All Materials
- UW – Requirements for Pressure Vessels Fabricated by Welding
- UCS – Requirements for Pressure Vessels Constructed of Carbon and Low Alloy Steels.

UHA: Unfired high Alloy
UHX: Unfired Heat exchanger

A sequential number follows the alpha descriptors for each article. These numbers are not necessarily consecutive. The Division is continually being reviewed. Articles that are no longer applicable to the current state of the technology may be deleted, or new articles may be inserted that reflect the current state of knowledge. For example, articles dealing with riveted construction of pressure vessels are no longer present in the Division, while additions have been made to include further refinements on the use of carbon and low alloy steel materials to reduce the risk of catastrophic failure by brittle fracture.

U-1 Scope

The scope of ASME Section VIII, Division 1 is presented on page 1 of the Division in article U-1. Any pressure retaining vessel, whether the pressure is internal or external to the container, can be designed to meet the requirements of the Division. However, there are specific pressure containers that are not considered under the scope of the Division. These specific pressure containers are:

- items covered by other sections of the Boiler and Pressure Vessel Code;
- fired process tubular heaters;
- pressure containers that are integral parts of rotating or reciprocating mechanical devices such as motors, pumps, compressors, hydraulic and pneumatic cylinders, and other similar mechanical devices;
- piping systems; and
- pressure containers designed for human occupancy.

Attachments made to the pressure container, even though they themselves may not be resisting pressure, are within the scope of the Division (Figure 1). The extent of a pressure container is defined by the first connection to that container and includes that connection. The application of the Division is shown in Figure 2.

Containers that are designed, fabricated, and inspected to meet the requirements of Division 1 can be marked by the letter U when the fabricator is so authorized by ASME (see Application of Section VIII, Division 1 later in this chapter). Smaller containers designed and fabricated in accordance with the requirements of the Division may be exempt from inspection by an independent inspector and as such will be marked by the fabricator with the letters UM when so authorized by ASME (see also UG-90). The size and pressure limits of these mass produced vessels is based on stored energy as defined by the following three volume and pressure points:

- U-1(j)(1): 5 cubic feet and 250 psi (0.14 cubic meters and 1.7 MPa)
- U-1(j)(2): 3 cubic feet and 350 psi (0.08 cubic meters and 2.4 MPa)
- U-1(j)(3): 1-1/2 cubic feet and 600 psi (0.04 cubic meters and 4.1 MPa)

Straight line interpolation for intermediate volumes and pressures is permitted.

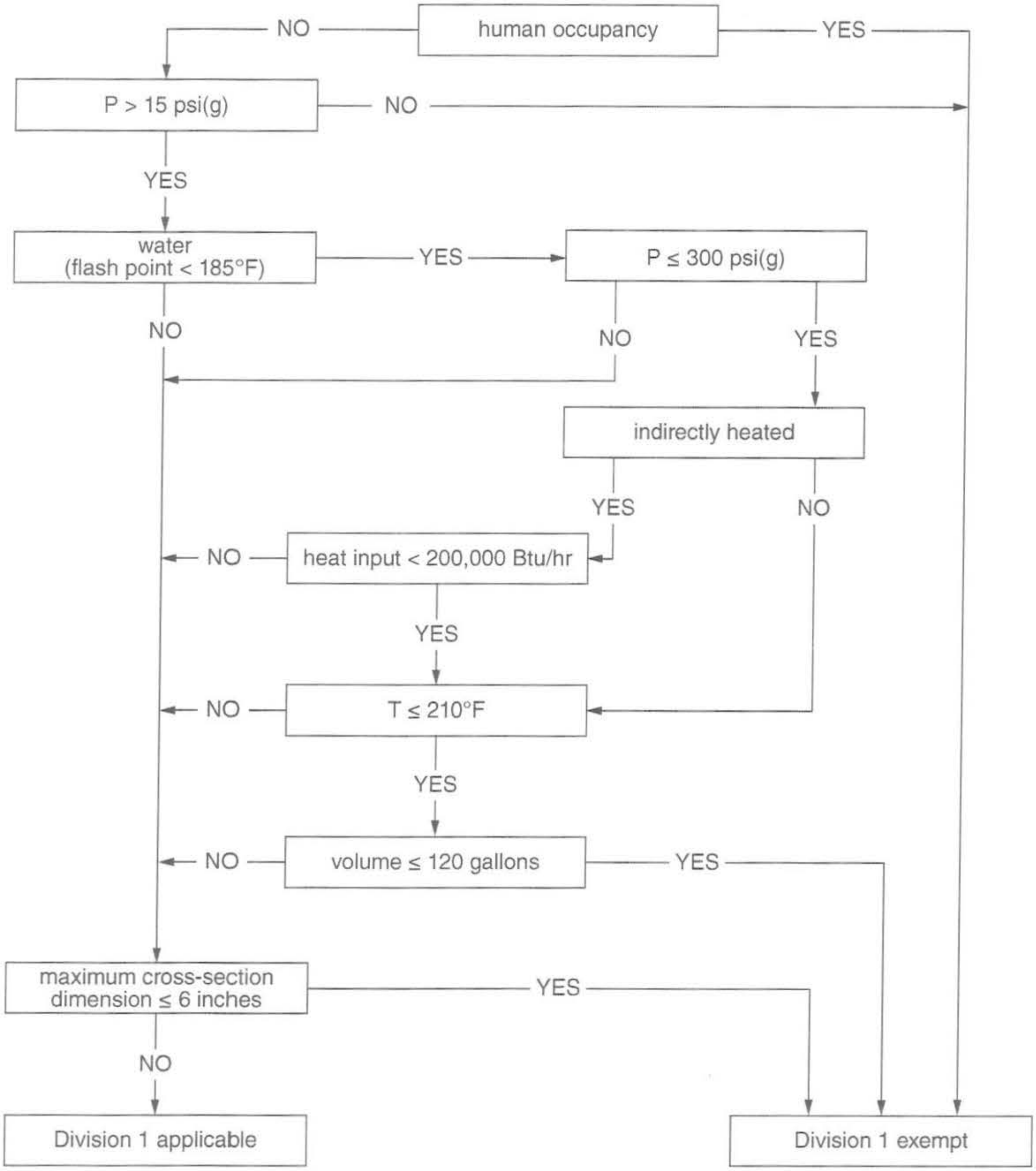


Figure 2 Application of Division 1.

Practice Problem Q1: Pressure Vessel Limitations

Which of the following classes of vessels are not included in the scope of Section VIII, Division 1?

a) a vessel for containing water with a design pressure of 330 psi
b) a vessel for containing water with a design pressure of 250 psi and design temperature of 200°F
c) vessels having an internal pressure of 20 psi
d) vessels with an inside diameter greater than 6 in.

U-2 GENERAL

U-2(a) Establishing Design Requirements

The responsibility for establishing the design requirements for pressure vessel construction is given in U-2(a) to be the user (i.e., typically the owner) or their designated agent (i.e., typically an engineering company). With this responsibility, the user of their designate must consider the design specific requirements for:

- normal operation,
- startups and shutdowns,
- abnormal conditions, and
- including the loading requirements in UG-22.

These design considerations must include, but are not be limited to:

U-2(a)
(1) the need for corrosion allowances;
(2) the definition of lethal services. For example, see UW-2(a).
(3) the need for postweld heat treatment beyond the requirements of this Division and dependent on service conditions;
(4) for pressure vessels in which steam is generated, or water is heated [see U-1(g) and U-1(h)], the need for piping, valves, instruments, and fittings to perform the functions covered by PG-59 through PG-61 of Section I.
(5) the degree of nondestructive examinations(s) and the selection of applicable acceptance standards, when such examinations are applied, are beyond the requirements of this Division.

U-2(b) Code User Responsibilities

The organization or individual making use of Section VIII, Division 1 may have externally applied business or legal responsibilities and requirements that are inferred in the Division. There are, however, distinct responsibilities given in the Division to the user of the pressure vessel, the manufacturer of the vessel, and the individual authorized to inspect the vessel.

U-2(b)(1) indicates that the user of the vessel is responsible for establishing the design requirements for the vessel, always bearing in mind that Division 1 states minimum safety requirements to meet rather than ideals to strive to meet. The manufacturer of the vessel is responsible for the design calculations that show that the maximum permitted material stresses have not been exceeded. In addition, manufacturers are responsible for their own workmanship as well as the workmanship of their subcontractors, including other services, materials, and components. The Authorized Inspector is responsible for ensuring that the vessel is designed and manufactured in accordance with the requirements of Division 1. These responsibilities are to be taken seriously.

U-2(g) Rules Not Covered by the Code

U-2(g) indicates that all details of design and construction cannot possibly be covered by the rules of the Division. In such instances, the manufacturer is responsible for developing the principles and techniques required. These are to be as safe as those given in the Division and are subject to approval by the Authorized Inspector.

Practice Problem Q2: Responsibilities

Who is responsible for assuring that a new pressure vessel complies with all the applicable requirements of ASME Section VIII, Division 1, and through proper certification, that all work done by others also complies?

a) the manufacturer
b) the fabricator
c) the design engineer
d) all of the above

Part UG - General Requirements for All Methods of Construction and All Materials

UG-4(a) Materials Subject to Stress Due to Pressure

Materials subject to stress due to pressure shall conform to one of the specifications given in Section II, Part D, Subpart 1, as required by UG-4(a).

Material may be identified as meeting more than one material specification and/or grade provided the material meets all requirements of the identified material specification(s) and/or grade(s) (see UG-23(a) and ASME Section II Part A - Guidelines on Multiple Marking of Materials).

UG-4(b) Materials Used for Nonpressure Parts

Materials used for nonpressure parts, such as skirts, supports, baffles, etc., do not need to conform to ASME Section II specifications, as in UG-4(a), but if attached to the vessel by welding they shall be of weldable quality (see UW-5(b)).

UG-4(f) Materials Suitable for the Intended Service

The user or their designated agent is responsible to select and use materials that are suitable for the intended service to ensure safe pressure retention within the vessel by considering:

- satisfactory mechanical properties,
- resistance to corrosion, erosion, oxidation, and
- other deterioration during the design service life.

ASME Section II, Part D, Appendix A,
Issues Associated with Materials Used in ASME Code Construction

The above reference provides guidance regarding metallurgical phenomena for pressure vessel material design considerations, with the main topics listed below.

A-200 Metallurgical Changes
A-300 Uniform Corrosion
A-400 Localized Corrosion
A-500 Metallurgically Influenced Corrosion
A-600 Mechanically Assisted Corrosion
A-700 Environmentally Induced Embrittlement and Cracking
A-800 Mechanical Damage Mechanisms

A complete list of all topics can be found the Reference chapter of this notebook.

Practice Problem Q3: Materials Subject to Stress Due to Pressure

Which of the following codes is applicable to pressure vessel materials that are subject to stress due to pressure?

a) ASME Section II, Part D
b) ASME Section III, Part D
c) NB-23
d) API 510

UG-9 Welding Materials

UG-9 is an exception to using a Code-given specification. This paragraph points out the advantages of using a welding material listed in ASME Section II, Part C. When the welding material does not comply with a specification in Section II, then the material marking or tagging must be identifiable with the welding material used in the welding procedure specification.

To be in compliance with ASME Section VIII, Division 1, Part UG-9, welding materials used for production must also comply with the requirements of ASME Section IX and the applicable qualified welding procedure specification (WPS).

Practice Problem Q4: Welding Materials

Where are the requirements found for welding materials used for new pressure vessel production?

a) ASME Section VIII, Division 1
b) ASME Section IX
c) the applicable qualified welding procedure specification
d) all of the above

UG-16 General

UG-16(b) Minimum Thickness of Pressure Retaining Components

As specified by UG-16(b), the minimum thickness of shells and heads after forming, regardless of material and product form, is 1/16 inch (1.5 mm) exclusive of corrosion allowance. Exceptions are:

- heat transfer plates of plate-type heat exchangers;
- inner pipe of double-pipe heat exchangers or tubes of shell type heat exchangers where the pipes or tubes are NPS 6 (DN 150) or less;
- unfired steam boilers where the minimum thickness shall be ¼ inch (6 mm) exclusive of corrosion allowance; and
- shells and heads in compressed air, steam, and water service made from materials listed in UCS-23 that shall have a minimum thickness of 3/32 inch (2.5 mm) exclusive of corrosion allowance.

UG-16(c) Mill Undertolerance

Mill undertolerance, as specified in UG-16(c), requires that plate vessels cannot be more than the smaller of 0.01 inch (0.25 mm) or 6% of the ordered thickness may be considered as full design thickness. This does not present a problem in most designs since the general specification for rolled plates, SA-20, limits the mill thickness undertolerance to 0.01 inch (0.25 mm) for all plates up to 15 inches (380 mm) thick.

UG-16(d) Pipe Undertolerance

Pipe and tube undertolerance specified in UG-16(d) allows materials to be ordered by its nominal wall thickness. However, the manufacturing undertolerance must be taken into account when designing or ordering the component. The undertolerance need not be considered when designing nozzle wall reinforcement.

UG-16(e) Corrosion Allowance

The formulas throughout the ASME VIII, Division 1, represent dimensions in the corroded condition [UG-16(e)]. That is, all formulas do not take into account corrosion allowance.

Corrosion Allowance

Nonmandatory Appendix E Suggested Good Practice Regarding Corrosion Allowance

E-1

From the standpoint of corrosion, pressure vessels may be classified under one of the following groups:

(1) vessels in which corrosion rates may be definitely established from information available to the designer regarding the chemical characteristics of the substances they are to contain. Such information may, in the case of standard commercial products, be obtained from published sources, or, where special processes are involved, from reliable records compiled from results of previous observations by the user or others under similar conditions of operation.

(2) vessels in which corrosion rates, while known to be relatively high, are either variable or indeterminate in magnitude;

(3) vessels in which corrosion rates, while indeterminate, are known to be relatively low;

(4) vessels in which corrosion effects are known to be negligible or entirely absent.

Carbon Steels

Corrosion allowance (mm) for carbon steels is commonly defined mathematically by selecting a corrosion rate (mm/year) and multiplying it by the design life (years), as follows.

Corrosion Allowance (mm) = corrosion rate (mm/year) x design life (years)

Corrosion allowance is the extra thickness that is added to the minimum required thickness to retain pressure and is designed to be consumed in service. Once the corrosion allowance is completely consumed, most codes and standards do not permit the continued use of this material since the further corrosion may reduce the thickness to retain pressure beyond safe limits.

Material manufacturing thickness under tolerance, e.g., -12.5% for ASTM A106, is a separate issue for consideration and is not included in this definition of corrosion allowance.

Note: Most corrosion allowance definitions assume general corrosion, without accounting for failure by localized corrosion (e.g., pitting, crevice corrosion, erosion-corrosion, etc.). Although there are several material selection software programs that are designed to address corrosion and corrosion allowance, they are not fool-proof. Consequently, it is suggested that knowledgeable people experienced in the field of corrosion be consulted.

Stainless Steels

The corrosion allowance approach for carbon steels of adding thickness for corrosion loss to a component beyond its minimum required thickness to retain pressure is typically inapplicable to stainless steels.

There are over xxx grades of stainless steels listed in ASTM material standards. So trying to place xxx grades into one category called stainless steels and simply treating them all similarly may not be practical. However, the ASTM A941 definition for *stainless steel* will be used for this text as shown below.

> *stainless steel*: a steel that conforms to a specification that requires, by mass percent, a minimum chromium content of 10.5 or more, and a maximum carbon content of less than 1.20.

The following are several considerations for establishing stainless steel corrosion allowance, although others may be required for specific applications.

1) Stainless steel relies on passivity for its corrosion resistance. When stainless steels are in the passive state, its corrosion rate is effectively zero, in which case applying a corrosion allowance to a design is unnecessary. This is unlike carbon steels, where active corrosion may always be occurring in service and a corrosion allowance is required in the design.
2) When stainless steels lose their passivity, they frequently corrode by pitting rather than by general corrosion. Corrosion allowance isn't a cost effective method of combatting pitting corrosion since its purpose would then be to add metal generally to counteract localized attack, which is not practical. In addition, the pitting corrosion rate may be high, causing rapid consumption of the corrosion allowance.
3) Designing for localized corrosion in stainless steels, much like in carbon steels, typically does not include using corrosion allowance, e.g., weld heat affected-zone corrosion due to sensitization that occurred from using a poorly qualified welding procedure that did not consider corrosion in service.
4) Designing to prevent environmental related cracking that may involve corrosion typically does not include using corrosion allowance, e.g., stress corrosion cracking of austenitic stainless steels.

In some cases, reducing the thickness when switching from coated carbon steels (e.g., painted, galvanized, etc.) to stainless steels may be appropriate. Overall, while a corrosion allowance on stainless steels may be chosen to cover short and infrequent periods of corrosion, a better practice would be to choose the appropriate stainless steel that has corrosion resistance in all predicted conditions for its intended application where a corrosion allowance would not be required (i.e., a corrosion allowance of zero).

Practice Problem Q5: Mill Undertolerance

What is the minimum allowable plate undertolerance for new pressure vessels that may be used at the full design pressure for the thickness ordered?

a) not more than the smaller value of 0.01 in. (0.25 mm) or 6% of the ordered thickness
b) not more than the smaller value of 0.1 in. (2.5 mm) or 10% of the ordered thickness
c) 12% of the ordered thickness
d) plate undertolerance does not apply

Practice Problem Q6: Corrosion Allowance

What do the dimensional symbols used in all design formulas throughout ASME Section VIII, Division 1, represent?

a) dimensions in the corroded condition
b) dimensions in the uncorroded condition
c) dimensions with the corrosion allowance
d) any of the above

UG-20 Design Temperature

Paragraph UG-20 establishes the requirement for maximum design temperature and minimum design metal temperature. This paragraph requires that UCS-66 be used for carbon and low alloy materials to determine if impact testing is required.

UG-20(a) Maximum Design Temperature

The maximum design temperature shall be equal to or greater than the mean metal temperature expected during operation. The maximum temperature at any point shall not exceed the maximum temperature listed in the stress tables for the specification, or the external pressure chart, if the vessel is under external pressure.

UG-20(b) Minimum Design Temperature

The minimum design metal temperature shall be the lowest temperature expected in service. The lowest metal temperature shall be the mean temperature of the metal and must consider the lowest operating temperature, operational upsets, autorefrigeration, atmospheric temperature, and other sources of cooling.

The governing thickness of each equipment shall be put for horizontal axis of the curve, not maximum thickne because this curve is for thoughess of the HAZ of the welds.

UG-20(f) Material Exemption to Impact Testing

The material parts in Subsection C, such as Part UCS or Part UHA, specify when to use impact testing. Part UCS materials are more prone to brittle fracture than other materials and therefore must often be impact tested. However, impact testing is not mandatory when all of the following are met in accordance with UG-20(f):

1) The material shall be limited to P-No. 1, Gr. No. 1 or 2, and the thickness, as defined in UCS-66(a) [see also Note (1) in Fig. UCS-66.2], shall not exceed that given in (a) or (b) below:
   (a) 1/2 in. (13 mm) for materials listed in Curve A of Fig. UCS-66;
   (b) 1 in. (25 mm) for materials listed in Curve B, C, or D of Fig. UCS-66.
2) The completed vessel shall be hydrostatically tested per UG-99(b) or (c) or 27-4.
3) Design temperature is no warmer than 650°F (345°C) nor colder than –20°F (–29°C). Occasional operating temperatures colder than –20°F (–29°C) are acceptable when due to lower seasonal atmospheric temperature.
4) The thermal or mechanical shock loadings are not a controlling design requirement. (See UG-22.)
5) Cyclical loading is not a controlling design requirement. (See UG-22.)

Practice Problem Q7: Design Temperature

How is the minimum metal temperature determined for pressure vessel design, not including the exceptions permitted by ASME Section VIII, Division 1,?

a) shall be the mean value expected in service
b) shall be the lowest expected in service
c) shall be the highest expected in service
d) as required for the MAWP

Practice Problem Q8: Material Exemption to Impact Testing

A hydrostatically tested pressure vessel is made from a P-No. 1, Group 1 material with a design temperature of 350°F, where thermal/mechanical shock and cyclic loading are not factors. Which of the following would be exempt from impact testing under this design?

a) 0.750 in. thick material on Curve A
b) 0.750 in. thick material on Curve B
c) 1.125 in. thick material on Curve C
d) 1.250 in. thick material on Curve D

UG-22 Loadings

UG-22 requires that the designer consider all loads acting on the vessel. Loads shall include those from:

- internal or external design pressure,
- weight of vessel plus normal and test contents including static head,
- weights of attachments (see Figure 3.3),
- internal attachments,
- vessel support attachments,
- cyclic and dynamic reactions due to pressure, thermal, or mechanical loads,
- wind, snow, and seismic loads,
- impact reactions such as those due to fluid shock, and
- temperature gradients and differential thermal expansion.

This is a commonly overlooked requirement of the Division. Since the Code does not provide design guidance or formulas for loads other than internal and external pressure, many designers overlook this requirement.

Practice Problem Q9: Loadings
Which of the following loadings are mandatory in designing a pressure vessel? a) internal design pressure b) external design pressure c) internal or external design pressure d) internal and external design pressure, not including snow, wind, and seismic loading

UG-24 Castings

UG-24(a) Castings Quality Factors

A casting quality factor is required to recognize the relative high concentration of imperfections that may be present in a casting as compared to a wrought product. However, at a welded joint in a casting, only the lesser of the casting quality factor or the weld joint efficiency specified in UW-12 applies, but not both.

UG-24(a) also details the supplementary machining and examinations that must be performed before using a casting quality factor greater than 80%. The casting quality factor must be used in the Division 1 equations that require an efficiency or E value. The requirements for using a quality factor greater than 80% are listed in UG-24(a)(1) to UG-24(a)(6).

UG27 : thickness Calculation

Required thickness = thickness due to pressure + thickness due to other Loading such as weigth, wind, Earthquick, and . . . . (UG-22)

Practice Problem Q10: Casting Quality Factor
At a welded joint in a casting, what is the appropriate factor to be applied to the allowable stress value for the cast material? a) either the casting quality factor or the weld joint efficiency may be selected b) the lesser of the casting quality factor or the weld joint efficiency c) the larger of the casting quality factor or the weld joint efficiency d) the mean value of the casting quality factor or the weld joint efficiency

UW-2 Service Restrictions

UW-2(a) Lethal Service for Unfired pressure Vessels

UW-2 and its footnote definition contain important information on special requirements for vessels containing lethal substances. When the substance in the vessel is designated as lethal, all butt welds used to manufacture the vessel shall be fully examined using radiographic techniques. See UW-2(a)(2), UW-2(a)(3), UW-11(a)(4) for some exceptions.

UW-2(a)(1) restricts weld types that are designated for lethal service; these are listed in Table UW-12 as follows:

- Category A – Type 1 weld only
- Category B – Type 1 or Type 2 welds only
- Category C – Type 1 or Type 2 welds only
- Category D – Type 1 or Type 2 welds only

Some other important liquid or gaseous lethal service restrictions listed in UW-2(a) are as follows:

- ERW pipe or tube is not permitted to be used as a shell or nozzle.
- When fabricated of carbon or low alloy steel, postweld heat treated is required.

UW-2(d) Lethal Service for Direct Fired Pressure Vessels

Pressure vessel subjected to direct firing have a set of different rules that unfired vessels, as specified in UW-2(d) as follows.

- Category A – Type No. (1) of Table UW-12
- Category B, when the thickness exceeds 5/8 in. (16 mm) – Type No. (1) or No. (2)
- No welded joints of Type No. (3) of Table UW-12 are permitted for either Category A or B joints in any thickness.
- PWHT is required when the thickness at welded joints exceeds 5/8 in. (16 mm) for carbon (P-No. 1) steels and for all thicknesses for low alloy steels (other than P-No. 1 steels).

Practice Problem Q11: Lethal Service

What examination is required when pressure vessels are to contain lethal substances, either liquid or gaseous, for all ERW pipe or tube to be used as a shell or nozzle?

a) full RT
b) full UT
c) full RT and MT
d) ERW pipe or tube is not permitted in lethal service applications

Practice Problem Q12: Lethal Service

What is the maximum thickness at welded joints for carbon (P-No. 1) steels that postweld heat treatment is not required for pressure vessels that are subject to direct firing?

a) 1/2 in. (13 mm)
b) 5/8 in. (16 mm)
c) 3/4 in. (19 mm)
d) all thicknesses

UW-3: weld Joint Category

UW-5 Materials

UW-5(a) specified that pressure parts materials for welded pressure vessels must be proven of weldable quality, in which satisfactory qualification of Section IX welding procedure is considered as proof.

UW-5(b) requires that non-pressure parts materials welded to pressure vessels must be of proven weldable quality, as follows:

1) For material identified in accordance with UG-10, UG-11, UG-15, or UG-93, satisfactory qualification of Section IX welding procedure is considered as proof of weldable quality.
2) For materials not identifiable in accordance with UG-10, UG-11, UG-15, or UG-93, satisfactory qualification of Section IX welding procedure is considered as proof of weldable quality, provided the material is identifiable by:

    - nominal chemical analysis and mechanical properties or
    - a material specification not permitted in this Division.

3) Unidentifiable material may be proved as being of weldable quality by:

    - preparing a butt-joint test coupon from each piece of nonidentified material to be used, and
    - passing the tests specified in QW-451 of Section IX for guided bend test specimens made from the test coupon.

UW-5(c) specifies that two materials of different specifications may be joined by welding provided the requirements of Section IX, QW-250, are met.

Practice Problem Q13: Materials

Which of the following is a Category D welded joint in a pressure vessel?

a) welded joint connecting a flange to main shell
b) longitudinal joint within the main shell
c) circumferential joint within the main shell
d) welded joint connecting a nozzle to main shell

Practice Problem Q14: Materials

What type of materials shall be used for nonpressure parts which are welded to a pressure vessel?

a) materials received with a certified test report
b) materials received with a certified test report referencing ASME Section II Part A or B
c) material proven of weldable quality
d) material proven of weldable quality with a carbon equivalent < 0.35

UW-9 Weld Joint Designs

Various weld joint configurations are permitted for arc and gas welding. These configurations include:

- butt joints,
- lap joints,
- corner joints,
- tee joints, and
- edge joints.

Unacceptable joint configurations are those that leave a crack-like configuration that would be subjected to tensile loading. The risk of failure at such configurations is significant.

Note: UW-9(b) makes it clear that groove welds must be designed to provide complete fusion and penetration. The term *groove weld* is defined in AWS A3.0 as follows.

> *weld groove*, fusion welding. A channel in the surface of a workpiece or an opening between two joint members providing space to contain weld metal.

There are very few restrictions on the joint detail in a WPS developed in accordance with Section IX of the Code. Inexperienced Code users are advised to restrict their designs to joint details presented pictorially in the figures of Subsections B and C of the Division as given here in Table 1.

Table 1 Weld Joint Details Given in ASME Section VIII, Division 1

Typical Joint Connection	Applicable Figures in Division 1
butt weld, plates of unequal thickness	UW-9, UW-13.1, ULW-17.1
butt weld, weld necks to materials of unequal thickness	UW-13.4, ULW-17.1
head to shell	UW-13.1, ULW-17.2, ULW-17.3
nozzle or other appurtenance abutting a shell or head	UW-13.2, UW-13.3, UW-13.5, UW-16.1, UW-16.2, UHT-18.1, UHT-18.2, ULW-17.3, ULW-18.1
stay bolts to shell or flange	UW-19.1
tube to tubesheet	UW-20, ULW-17.3
small fittings and couplings to shell or head	UW-16.1, UW-16.2

UW-9(c) Weld Joints with Taper Transition

UW-9(c) specifies a minimum taper transition of 3 to 1, where $\ell \geq 3y$, when joining materials of unequal thickness. This is illustrated in Fig. UW-9 where unequal thickness is quantified as two materials differing in thickness by 1/4 the thickness of the thinner part, or by 1/8 inch (3 mm), whichever is less.

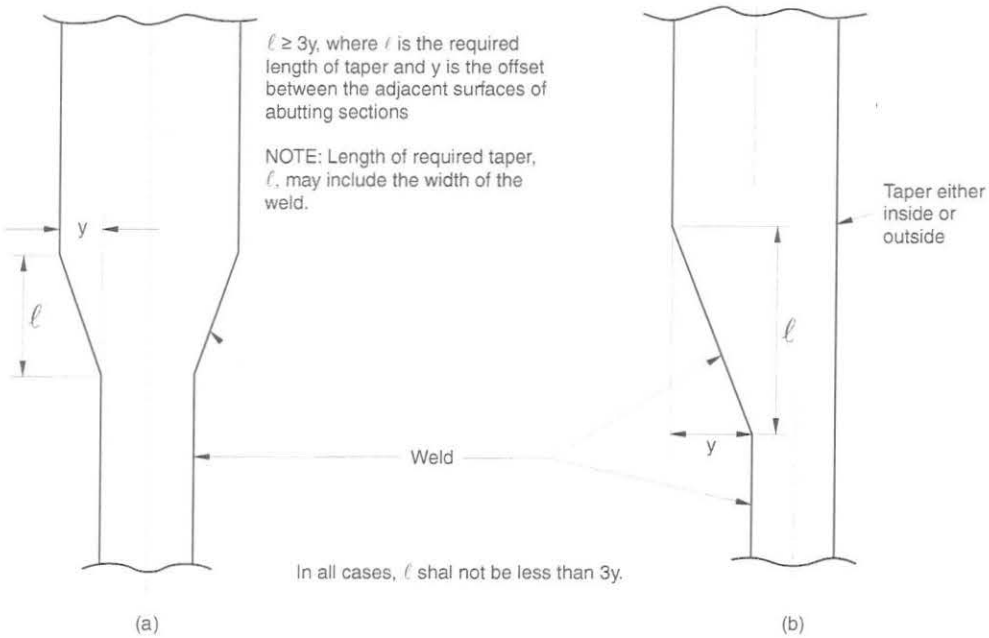


Figure 3 Butt-Welding of Plates of Unequal Thickness (Fig. UW-9 from ASME VIII-1)

Any change in material continuity serves to magnify the stress at the change; the more abrupt the change, the greater the stress magnification. In addition, stress concentrators in close proximity have a multiplying effect. A weld represents an interruption in metallurgical continuity and is therefore a stress magnifier.

Weld reinforcement is an interruption in the geometry of the material surface, so a butt weld joining two materials of different thickness can be a very highly stressed area in a pressure vessel. Fig. UW-13.1(l) and (m) further illustrates the taper transition requirement.

Practice Problem Q15: Tapered Transition

When a pressure vessel weld joint is tapered, what is the required transition, where ℓ is the required length of taper and y is the offset between adjacent surfaces of abutting sections?

a) $\ell \geq y$
b) $\ell \geq 2y$
c) $\ell \geq 3y$
d) $\ell \geq 4y$

UW-3 Weld Joint Classification System

In Section VIII, weld requirements are given in accordance with the nature of the principal stress at the weld joint due to internal pressurization. Four conditions of stress geometry are defined and termed as Category A, Category B, Category C, and Category D joints.

UW-3 and its accompanying figure, Figure UW-3, reproduced below, give the definitions for the various joint locations.

UW-3 Brief Summary of Categories

Category A joints include longitudinal-welded and spiral-welded joints within the main shell and are generally transverse to the maximum stress created by the pressure containment.

Category B joints include circumferential-welded joints within the main shell and are generally oriented parallel to the direction of maximum stress created by pressure containment and, as well, join parts of one dimension symmetry whose axes of symmetry are parallel.

Category C joints include welded joints connecting flanges and are generally oriented parallel to the direction of maximum stress created by pressure containment and join parts of generally one dimension symmetry whose major axes of symmetry are not parallel.

Category D joints include welded joints connecting nozzles to main shells and are generally the joints between an appurtenance and the main pressure containment vessel or vessel subcomponent.

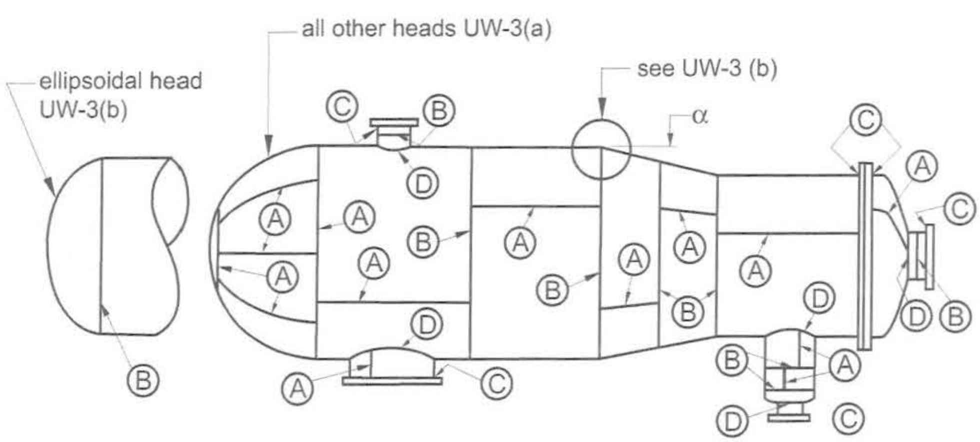


Figure 4 Illustrations Depicting Welded Joint Locations Typical of Categories A, B, C, and D (Fig. UW-3 from ASME VIII-1)

Practice Problem Q16: Weld Joint Classifications

What is the correct category for longitudinal and spiral welded joints within the main shell of a pressure vessel?

a) Category A
b) Category B
c) Category C
d) Category D

Type 1 Weld Joint

Type 1 welds are butt joints detailed to ensure high structural quality through the depth of the weld. They incorporate a detail requiring gouging or grinding of the root area of the second side of the weld. This is done to achieve sound metal before making the weld on the second side.

Type 1 joints can be used to make all joint categories of butt welds and are shown pictorially in Figure 5. If these welds are examined radiographically for their entire length and they meet the quality requirements of the Division with or without repairs, they can be considered structurally equivalent to a forging and are accordingly assigned a joint efficiency factor of 1.

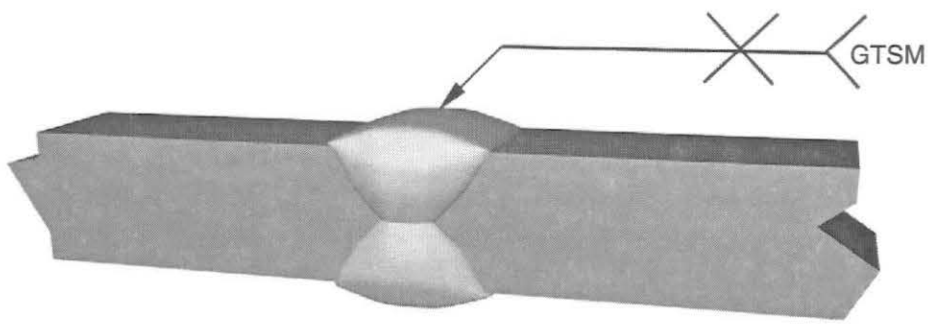


Figure 5 Typical Type 1 weld joint; GTSM—gouge to sound metal.

If only a portion of the weld length is examined radiographically, then a maximum joint efficiency of 0.85 can be used in required thickness calculations. A maximum joint efficiency of 0.70 is to be used if only visual examination is carried out on the weld.

Type 2 Weld Joint

Type 2 butt welds are also capable of providing good structural integrity. In this instance, weld metal is deposited on backing to make the weld from one side only. The backing material to be used must be specified in the qualified weld procedure. This weld detail leaves a stress concentrator at the weld root as shown in Figure 6. This detail can be used for all weld categories.

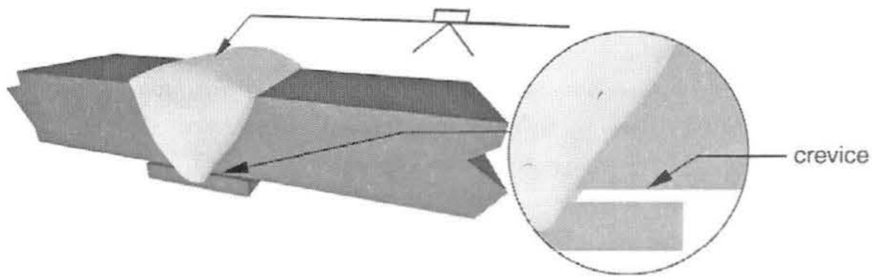


Figure 6 Typical Type 2 weld joint.

Because of reduced radiographic sensitivity and the stress concentration at the weld root, this detail has a lower efficiency. For full radiographic examination, a maximum value of 0.90 can be used. A maximum value of 0.80 can be used for spot radiographic examination. With no radiographic examination, the maximum efficiency shall be 0.65.

The backing strip detail is not good in corrosive environments regardless of the concentration of the corrodant. The crevice at the weld root can trap corrodants and this could result in concentration cell corrosion.

Type 3 Weld Joint

Type 3 welds are limited to circumferential butt welds for category A, B, and C joints. These welds are made by welding from only one side of the joint with no backing. This requires the molten deposited weld metal to freeze in the air to make a bridge between the two sides of the butt joint. As such, this type of joint is susceptible to poor or incomplete fusion of the weld metal at the root. This imperfection has the features of a crack and can be difficult to detect.

Category D joints have low inspection sensitivity, and therefore welds made from one side without a backing strip (Type 3 welds) are not to be used for joining nozzles and communication chambers to the main vessel. A typical Type 3 weld is shown in Figure 7.

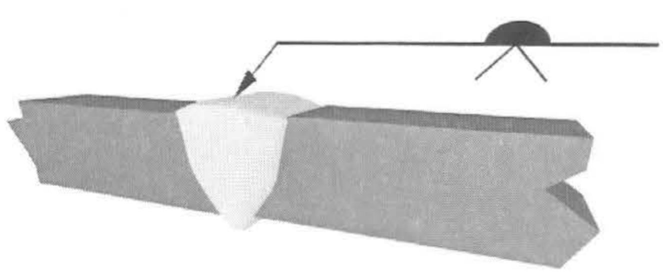


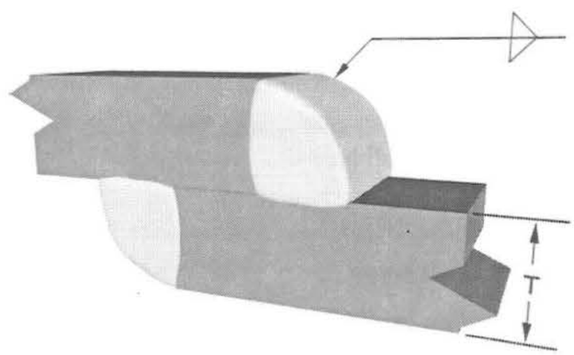
Figure 7 Typical Type 3 weld joint.

Type 4 Weld Joint

Type 4 welds are restricted to category A, B, and C joints and are made by overlapping material and placing fillet welds at either end face of the lap. This configuration, as illustrated in Figure 8, results in a radiographic film image that is difficult to interpret because of the thickness gradation in the area of interest. Accordingly, Type 4 joints are not considered radiographically examinable and the risks of incomplete weld root penetration, along with the possibility of lamellar tearing, limit the maximum weld joint efficiency to 0.55.

Type 4 weld joints can only be used with materials that have sufficient working, which is caused by thickness reduction, to break up nonmetallic grain boundary films. Accordingly, maximum thicknesses are specified in Table UW-12 to ensure sufficient working.

For Type 4 joints used to make circumferential welds on thicknesses over ½ inch (13 mm), the Code user may wish to take extra precautions and follow the nondestructive examination (NDE) requirements for corner joints given in UG-93(d)(3).



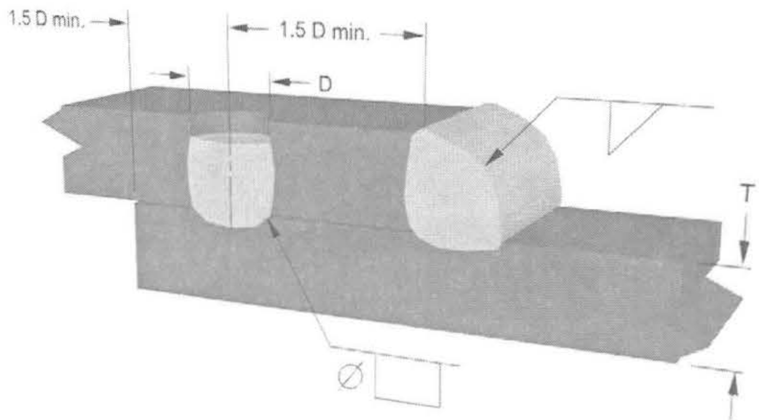
T = 3/8 inch (10 mm) maximum for longitudinal joints
T = 5/8 inch (16 mm) maximum for circumferential joints

Figure 8 Typical Type 4 weld joint.

The requirement for weld root penetration is stated in UW-36. Lamellar tearing results from residual weld stress in the thickness direction of wrought materials causing cracking along the grain boundaries, particularly when the material has been cold worked, when it contains a significant concentration of nonmetallic contaminants, or when both conditions exist.

Type 5 Weld Joint

Type 5 joints are also lap joints, but are restricted to category B and C joint locations. They use a plug weld instead of a second fillet weld to secure one end of the lap. The plug weld does not make the joint stiff, and this permits some stressing of the fillet weld root area. Therefore, Type 5 joints are assessed for a maximum efficiency of 0.5.



T = ½ inch (13mm) maximum for category B joint configurations
T = ⅝ inch (16mm) maximum for category C joint configurations

Figure 9 Typical Type 5 weld joint.

The maximum diameter for attaching a head to a shell using a Type 5 joint is restricted to 24 inches (600 mm) (category B configuration).

A Type 5 joint is not to be used for attaching hemispherical heads to shells. Hemispherical heads are made by weld construction and therefore have intersecting head and shell-to-head seam welds. This construction would cause additional stress magnification at the Type 5 shell-to-head joint. Minimum size requirements for a plug weld are given in UW-17.

Type 6 Weld Joint

A Type 6 weld joint is a lap joint with a single fillet weld and is applicable to either category A or B configurations. Because there is no resistance to bending at the weld root, the maximum efficiency is 0.45.

When a single fillet lap joint is used to attach a head that is pressurized only on the convex side of the head, the maximum shell thickness shall be 5/8 inch (16 mm) or less and the fillet weld shall be inside the shell as shown in Figure 10.

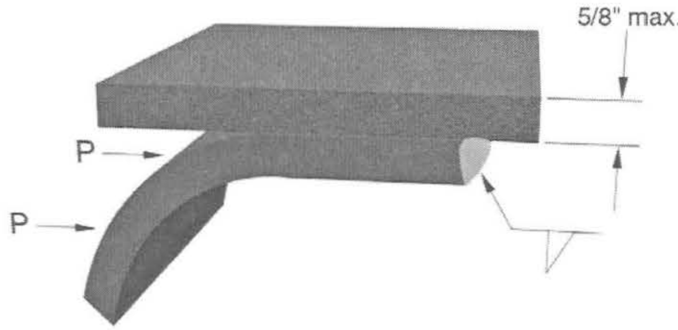


Figure 10 Typical Type 6 weld joint for shell-to-head.

Alternatively, if the shell diameter is 24 inches (600 mm) or less and the shell thickness is ¼ inch (6 mm) or less, then the weld can be on the flange of the head as shown in Figure 11.

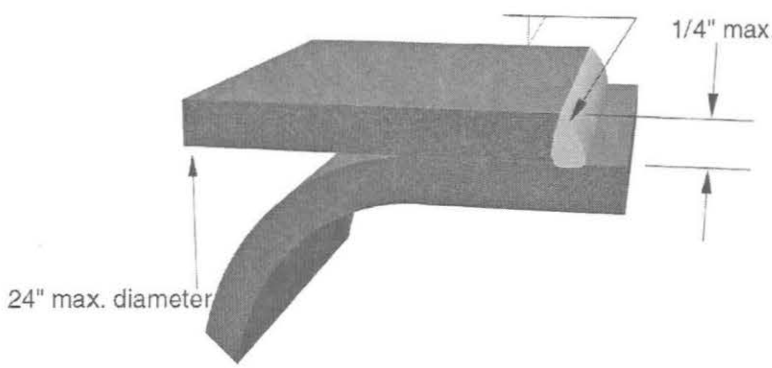


Figure 11 Alternative shell-to-head Type 6 weld joint.

Example Q17: Joint Efficiency

What is the maximum allowable joint efficiency for a Category A Type No. (1) joint with visual examination?

From Table UW-12:

TABLE UW-12
MAXIMUM ALLOWABLE JOINT EFFICIENCIES FOR ARC AND GAS WELDED JOINTS

Type No.	Joint Description	Limitations	Joint Category	Degree of Radiographic Examination (a) Full [Note(1)]	(b) Spot [Note(2)]	(c) None
(1)	Butt joints as attained by double-welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside weld surfaces to agree with the requirements of UW-35. Welds using metal backing strips which remain in place are excluded.	None	A, B, C & D	1.00	0.85	0.70
(2)	Single-welded butt joint with backing strip other than those included under (1)	*(a)* None except as in (b) below	A, B, C & D	0.90	0.80	0.65
		(b) Circumferential butt joints with one plate offset; see UW-13(b)(4) and Fig. UW-13.1, sketch (i)	A, B & C	0.90	0.80	0.65
(3)	Single-welded butt joint without use of backing strip	Circumferential butt joints only, not over 5/8 in. (16 mm) thick and not over 24 in. (600 mm) outside diameter	A, B & C	NA	NA	0.60
(4)	Double full fillet lap joint	*(a)* Longitudinal joints not over 3/8 in. (10 mm) thick	A	NA	NA	0.55
		(b) Circumferential joints not over 5/8 in. (16 mm) thick	B & C [Note (3)]	NA	NA	0.55
(5)	Single full fillet lap joints with plug welds conforming to UW-17	*(a)* Circumferential joints [Note (4)] for attachment of heads not over 24 in. (600 mm) outside diameter to shells not over 1/2 in. (13 mm) thick	B	NA	NA	0.50
		(b) Circumferential joints for the attachment to shells ofj ackets not over 5/8 in. (16 mm) in nominal thickness where the distance from the center of the plug weld to the edge of the plate is not less than 1 1/2 times the diameter of the hole for the plug.	C	NA	NA	0.50

The maximum allowable joint efficiency is 0.70.

Practice Problem Q18: Joint Efficiency

What is the maximum allowable joint efficiency for a Category D Type No. (2) joint with spot radiographic examination?

a) 0.60
b) 0.70
c) 0.80
d) 1.00

UW-11 Radiography of Welds

UW-11 specifies radiographic requirements for welds mandated to be radiographed beyond the considerations given for weld joint efficiency in Table UW-12. These requirements are for weld quality, and they consider the fracture toughness of the weld. The more sensitive a weld filler metal or weld heat affected zone is to brittle fracture, the more significant is the requirement for the weld to have fewer imperfections.

The purpose of radiography is to identify imperfections so that those that may reduce the integrity of the weld can be removed, such as by grinding. As the thickness of most materials increases, so does the propensity for brittle fracture.

UW-11(a)(1) Lethal Service

All butt welds of vessels in lethal service are required to be radiographed.

UW-11(a)(2) Butt Welds Over 1½ inch (38 mm)

All butt welds over 1½ inch (38 mm) are to be radiographically examined, although there is a long list of exceptions in UW-11(a)(2).

UW-11(a)(2) also exempts radiography for Category B and C welds of nozzles and communication chambers provided they are ≤ NPS 10 (DN 250) and 1 1/8 inch (29 mm) thickness. Smaller diameter and thinner wall appurtenances usually do not represent a significant failure risk when considered with the other Division mandated quality controls—see UW-52 and UG-97(c)—and are therefore exempt.

UW-11(a)(3) Unfired Steam Boilers

Unfired steam boilers exceeding 50 psi (345 kPa) are to be radiographically examined along their entire length.

UW-11(a)(4) Butt Welds in Nozzles and Communicating Chambers

All butt welds (e.g., in nozzles, communicating chambers, etc.) attached to vessel sections or heads are required to be fully radiographed; however, see exceptions in UW-11(a)(4).

UW-11(a)(5) Category A and D Butt Welds

Full radiography is required for all Category A and D butt welds in vessel sections and heads where the design of the joint or part is based on a joint efficiency permitted by UW-12(a), in which case:

(a) Category A and B welds connecting the vessel sections or heads shall be of Type No. (1) or Type No. (2) of Table UW-12;

(b) Category B or C butt welds—but not including those in nozzles or communicating chambers except as required in UW-11(a)(2) above—that intersect the Category A butt welds in vessel sections or heads or connect seamless vessel sections or heads shall, as a minimum, meet the requirements for spot radiography in accordance with UW-52.

Note: Spot radiographs required by this paragraph shall not be used to satisfy the spot radiography rules as applied to any other weld increment.

UW-11(b) Spot Radiography

Butt welded joints made in accordance with Type No. (1) or (2) of Table UW-12 that are not required to be fully radiographed by UW-12(a) may be examined by spot radiography, except as required in UW-11(a)(5)(b).

If spot radiography is specified for the entire vessel, radiographic examination is not required of Category B and C butt welds in nozzles and communicating chambers that exceed neither NPS 10 (DN 250), nor 1-1/8 in. (29 mm) wall thickness.

Spot radiography shall be in accordance with UW-52.

UW-11(c) No Radiography

Pressure vessels or their parts that are designed for external pressure (i.e., vacuum service) do not require radiographic examination of welded joints.

Practice Problem Q19: Radiography

Which of the following welded joints shall be examined radiographically for their full length?

a) Category B butt weld in a NPS 8 nozzles
b) Category C butt weld in a nozzle with a 1 in. (25 mm) wall thickness
c) all butt welds in vessels in which the nominal thickness at the welded joint exceeds 1-1/2 in. (38 mm)
d) all of the above

UW-12 Weld Joint Efficiency

The weld joint efficiency is a reliability factor assigned to the joint based on the joining process, the joint type and detail, and the degree of joint examination. This factor is based on the structural integrity of the material, with a forged product as the basis for E = 1.

UW-12, and in particular Table UW-12, lists the joint efficiencies to be used for various types of welds, joint details, and extent of radiographic examination. Table UW-12 identifies six types of arc or gas weld details and two forms of radiographic examination:

- full radiography in column (a) and
- spot radiography in column (b).

Note: All welds are to be visually examined whether or not they are also examined by other means. For weld joints loaded only in compression, radiographic examination is not required and the joint efficiency is a maximum of 1.

UW-12(d) Weld Joint Efficiency for Seamless Vessel Sections or Heads

Seamless vessel sections or heads are considered by the Code to be equivalent to welded parts of the same geometry in which all Category A welds are Type No. 1.

For calculations involving circumferential stress in seamless vessel sections or for thickness of seamless heads:

- E = 1.0 when the spot radiography requirements of UW-11(a)(5)(b) are met;
- E = 0.85 when the spot radiography requirements of UW-11(a)(5)(b) are not met; and
- E = 0.85 when the Category A or B welds connecting seamless vessel sections or heads are Type No. 3, 4, 5, or 6 of Table UW-12.

Table 2 ASME VIII-1 Code Excerpt of Table UW-12

TABLE UW-12
MAXIMUM ALLOWABLE JOINT EFFICIENCIES FOR ARC AND GAS WELDED JOINTS

Type No.	Joint Description	Limitations	Joint Category	Degree of Radiographic Examination (a) Full [Note (1)]	(b) Spot [Note (2)]	(c) None
(1)	Butt joints as attained by double-welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside weld surfaces to agree with the requirements of UW-35. Welds using metal backing strips which remain in place are excluded.	None	A, B, C & D	1.00	0.85	0.70
(2)	Single-welded butt joint with backing strip other than those included under (1)	*(a)* None except as in (b) below	A, B, C & D	0.90	0.80	0.65
		(b) Circumferential butt joints with one plate offset; see UW-13(b)(4) and Fig. UW-13.1, sketch (i)	A, B & C	0.90	0.80	0.65
(3)	Single-welded butt joint without use of backing strip	Circumferential butt joints only, not over ⅝ in. (16 mm) thick and not over 24 in. (600 mm) outside diameter	A, B & C	NA	NA	0.60
(4)	Double full fillet lap joint	*(a)* Longitudinal joints not over ⅜ in. (10 mm) thick	A	NA	NA	0.55
		(b) Circumferential joints not over ⅝ in. (16 mm) thick	B & C [Note (3)]	NA	NA	0.55
(5)	Single full fillet lap joints with plug welds conforming to UW-17	*(a)* Circumferential joints [Note (4)] for attachment of heads not over 24 in. (600 mm) outside diameter to shells not over ½ in. (13 mm) thick	B	NA	NA	0.50
		(b) Circumferential joints for the attachment to shells ofj ackets not over ⅝ in. (16 mm) in nominal thickness where the distance from the center of the plug weld to the edge of the plate is not less than 1½ times the diameter of the hole for the plug.	C	NA	NA	0.50
(6)	Single full fillet lap joints without plug welds	*(a)* For the attachment of heads convex to pressure to shells not over⅝ in. (16 mm) required thickness, only with use of fillet weld on inside of shell; or	A & B	NA	NA	0.45
		(b) for attachment of heads having pressure on either side, to shells not over 24 in. (600 mm) inside diameter and not over ¼ in. (6 mm) required thickness with fillet weld on outside of head flange only	A & B	NA	NA	0.45
(7)	Corner joints, full penetration, partial penetration, and/or fillet welded	As limited by Fig. UW-13.2 and Fig UW-16.1	C & D [Note (5)]	NA	NA	NA
(8)	Angle joints	Design per U-2(g) for Category B and C joints	B, C & D	NA	NA	NA

GENERAL NOTES:
(a) The single factor shown for each combination ofj ointcategory and degree of radiographic examination replaces botthe stress reduction factor and the joint efficiency factor considerationspreviously used in this Division.
(b) E = 1.0 for butt joints in compression.

NOTES:
(1) See UW-12(a) and UW-51.
(2) See UW-12(b) and UW-52.
(3) For Type No. 4 Category C joint, limitation not applicable for bolted flange connections.
(4) Joints attaching hemispherical heads to shells are excluded.
(5) There is no joint efficiency E in the design formulas of this Division for Category C and D corner joints. When needed, a value of E not greater than 1.00 may be used.

UG-116 Markings and Nameplates

All pressure equipment built in accordance with Section VIII, Division 1 by an ASME certified fabricator must be permanently marked in accordance with the requirements of UG-115, UG-116, UG-118, UG-119, UG-129, and UG-130 as applicable.

UG-116(a) Required Markings

Figure 12 is an example of an approved form of marking for a full-size vessel fabricated to Division 1 U requirements.

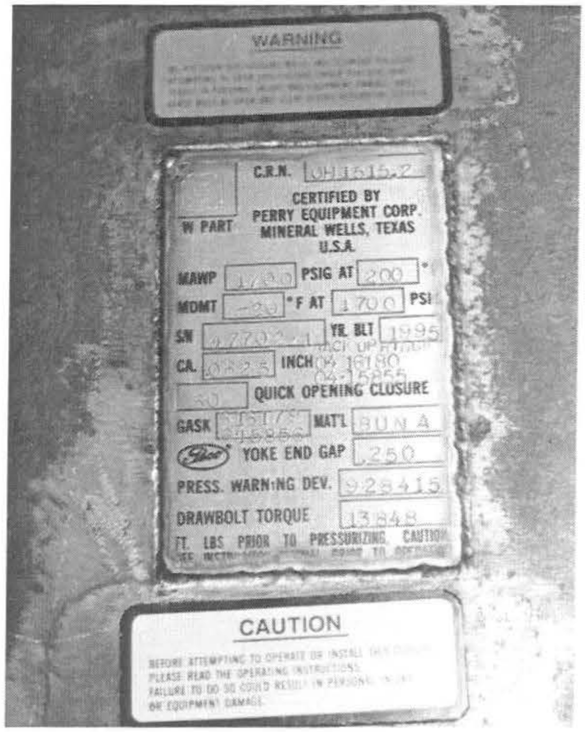


Figure 12 Data plate welded to vessel shell.

UG-116(a) requires markings on the equipment are U and UG-116(b) for vessels that are UM. these marking are ASME registered trademark symbols. As an aside, UV is used for pressure relief valves, and UD for rupture disks.

UG-116(a) requires that each pressure vessel is marked with the following:

(1)(a) the official Code U Symbol
(1)(b) the official UM Symbol for U-1(j) vessels
(2) name of the Manufacturer of the pressure vessel preceded by the words "certified by";
(3) maximum allowable working pressure at temperature;
(4) maximum allowable external working pressure at temperature;
(5) minimum design metal temperature at maximum allowable working pressure;
(6) Manufacturer's serial number; and
(7) year built.

UG-116(b)(1) Vessel Type of Construction Markings

The type of construction used for the vessel is a requirement and is placed directly under the Code Symbol with the appropriate letter(s) as follows: vessels having Category A, B, or C joints (except nozzles or other openings and their attachment) in or joining parts of the vessels:

Type of Construction	Letter(s)
arc or gas welded	W
pressure welded (except resistance)	P
brazed	B
resistance welded	RES

UG-116(c) Markings for Special Service

When a vessel is intended for special service and the special requirements have been complied with based on UG-120(d), the appropriate lettering shall be applied as listed below:

Type of Service	Letter(s)
lethal service	L
unfired steam boiler	UB
direct firing	DF

This lettering shall be separated by a hyphen and applied after the lettering of UG-116(b) for the type of construction.

UG-116(e) Markings for Radiographic Examination

UG-116(e) specifies that when radiographic or ultrasonic examination has been performed on a vessel in accordance with UW-11, marking shall be applied under the Code Symbol as follows:

1) "RT 1" when all pressure-retaining butt welds, other than Category B and C butt welds associated with nozzles and communicating chambers that neither exceed NPS 10 (DN 250) nor 1-1/8 in. (29 mm) wall thickness—except as required by UHT-57(a)—satisfy the full radiography requirements of UW-11(a) for their full length; full radiography of the above exempted Category B and C butt welds, if performed, may be recorded on the Manufacturer's Data Report; or

2) "RT 2" when the complete vessel satisfies the requirements of UW-11(a)(5) and when the spot radiography requirements of UW-11(a)(5)(b) have been applied; or

3) "RT 3" when the complete vessel satisfies the spot radiography requirements of UW-11(b); or

4) "RT 4" when only part of the complete vessel has satisfied the radiographic requirements of UW-11(a) or where none of the markings "RT 1," "RT 2," or "RT 3" are applicable.

Note: The extent of radiography and the applicable joint efficiencies shall be noted on the Manufacturer's Data Report.

UG-116(f) Markings for Heat Treatment

UG-116(f)(1) specifies that the letters HT shall be applied under the Code Symbol when the complete vessel has been postweld heat treated as provided in UW-10.

The letters PHT shall be applied under the Code Symbol when only part of the complete vessel has been postweld heat treated as provided in UW-10—see UG-116(f)(2).

Practice Problem Q20: Radiography

When a Category A butt weld in a vessel head is designed with a joint efficiency permitted by UW-12(a), which of the following designations may be applied to this weld?

a) RT 1
b) RT 2
c) RT 3
d) RT 1 or RT 2

Practice Problem Q21: Vessel Type of Construction Markings

What type of construction was used for a vessel that was marked with the letter P directly under the Code Symbol?

a) arc welded
b) gas welded
c) pressure welded
d) GMAW-Pulse arc welded

Practice Problem Q22: Markings for Special Service

When a pressure vessel is intended for lethal service and the special requirements in UG-120(d) have been complied with, what is the appropriate lettering that shall be applied to the markings?

a) L
b) LS
c) L-S
d) any of the above

Practice Problem Q23: Markings for Radiographic Examination

When radiographic examination has been performed on a pressure vessel in accordance with UW-11, what marking shall be applied to the nameplate when the complete vessel satisfies the requirements of UW-11(a)(5) and when the spot radiography requirements of UW-11(a)(5)(b) have been applied?

a) RT 1
b) RT 2
c) RT 3
d) RT 4

Practice Problem Q24: Markings for Heat Treatment

When only part of the complete pressure vessel has been postweld heat treated as provided in UW-10, what letters shall be applied under the Code Symbol?

a) HT
b) PHT
c) PWHT
d) UW-P

UG-119 Nameplates

UG-119(a) Material and Location

UG-119 specifies that nameplates are to be used on vessels, except when markings are directly applied on the vessel wall according to UG-118.

Nameplates must be made from a metal suitable for the intended service with the markings specified in UG-116. Nameplates must also be located in an obvious location on the vessel to allow for easy reading.

UG-119(b) Nameplate Thickness

The nameplate thickness must be sufficient to:

- resist distortion from being marked;
- resist distortion from the method of attachment; and
- the nominal thickness shall not be less than 0.020 in.

UG-119(c) Nameplates Characters

Nameplates must contain characters as follows:

- UG-119(c)(1) – The required markings on a nameplate shall be in characters not less than 5/32 in. (4 mm) high, except characters for pressure relief device markings may be smaller.
- UG-119(c)(2) – Characters shall be either indented or raised at least 0.004 in. (0.10 mm) and shall be legible and readable.

Practice Problem Q25: Nameplates

What is the required thickness of a pressure vessel name plate?

a) > 0.020 in.
b) ≥ 0.025 in.
c) ≥ 0.100 in.
d) shall be sufficient to resist distortion due to the application of the marking and to be compatible with the method of attachment

UW-51 Radiographic Examination of Welded Joints

UW-51(a)(1) requires that a complete set of radiographs and records, as described in Article 2 of Section V, for each vessel or vessel part must be retained by the Manufacturer. However, although UG-120(a)(3)(c) requires data reports to be retained for 3 years, radiograph examination records are only required to be retained until the Data Reports are signed by the Authorized Inspector—see UW-51(a)(1)(a). No other NDE records need be retained for Code compliance.

UW-51(a)(2) does not require that radiographic examination be conducted to a written procedure. However, satisfactory evidence of compliance with Article 2 of Section V is satisfactory if a demonstration of density and image quality indicator (IQI) image requirements on production or technique radiographs is made.

Keep in mind, UW-51(a)(3) states that although the requirements of T-285 of Article 2 of Section V are to be used only as a guide, final acceptance of radiographs must be based on the ability to see the prescribed IQI image and the specified hole or the designated wire of a wire IQI.

UW-51(b) requires indications shown on radiographs of welds and characterized as imperfections are unacceptable under the following conditions:

1) any indication characterized as a crack or zone of incomplete fusion or penetration;
2) any other elongated indication on the radiograph with length greater than:
   (a) 1/4 in. (6 mm) for t up to 3/4 in. (19 mm)
   (b) 1/3t for t from 3/4 in. (19 mm) to 2-1/4 in. (57 mm)
   (c) 3/4 in. (19 mm) for t over 2-1/4 in. (57 mm), where:

   t = the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in t.

3) any group of aligned indications that have an aggregate length greater than t in a length of 12t, except when the distance between the successive imperfections exceeds 6L where L is the length of the longest imperfection in the group;
4) rounded indications in excess of that specified by the acceptance standards given in Appendix 4.

Mandatory Appendix 4 – Rounded Indications Charts Acceptance Standard for Radiographically Determined Rounded Indications in Welds

Appendix 4-2 Terminology includes definitions for *rounded indications*, *aligned indications*, and *thickness t*, that are be applied to UW-51(b), as follows.

> Appendix 4-2 Terminology
> (a) Rounded Indications. Indications with a maximum length of three times the width or less on the radiograph are defined as rounded indications. These indications may be circular, elliptical, conical, or irregular in shape and may have tails. When evaluating the size of an indication, the tail shall be included. The indication may be from any imperfection in the weld, such as porosity, slag, or tungsten.
> (b) Aligned Indications. A sequence of four or more rounded indications shall be considered to be aligned when they touch a line parallel to the length of the weld drawn through the center of the two outer rounded indications.
> (c) Thickness t. t is the thickness of the weld, excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in t .

UW-51(b) also permits ultrasonic examination of repairs provided the original imperfection was also detected by ultrasonics. Appendix paragraph 12–4 requires that the inspection technique and all examination findings be available for review by the Authorized Inspector.

Practice Problem Q26: Radiographic Examination

How shall satisfactory evidence of compliance with Article 2 of Section V be attained to ensure radiographic image requirements of the pressure vessel manufacturing welding was met?

a) by a written radiographic examination procedure
b) by demonstration of density and penetrameter image
c) by a qualified radiographic examination procedure
d) any one of the above

Practice Problem Q27: Radiographic Examination

What is the maximum size of acceptable rounded (random) weld slag inclusion in a pressure vessel that is 1/2 in. thick?

a) 1/16 in.
b) 1/8 in.
c) 1/4 in.
d) 3/8 in.

UG-120 Data Reports

For each pressure vessel marked with the Code U Symbol, the vessel Manufacturer must complete a data report (Form U-1 or U-1A) and it must be signed by the Manufacturer and the Inspector.

UG-120(a)(3) Manufacturer's Responsibilities for Data Reports

UG-120(a)(3) requires the vessel Manufacturer to:

1) furnish a copy of the Manufacturer's Data Report to the user and, upon request, to the Inspector;
2) submit a copy of the Manufacturer's Data Report to the appropriate enforcement authority in the jurisdiction in which the vessel is to be installed, where required by law; and
3) keep a copy of the Manufacturer's Data Report on file in a safe repository for at least 3 years.

Practice Problem Q28: Data Reports

How long shall the Manufacturer of a pressure vessel keep a copy of the Manufacturer's Data Report on file in a safe repository?

a) 3 years minimum
b) 3 years maximum
c) 5 years minimum
d) 5 years maximum

UG-27 Thickness of Shells Under Internal Pressure

Code paragraph UG-27 gives the Code formulas for determining the thickness of cylindrical and spherical vessel shells designed to resist internal pressure.

For circumferential (hoop) stress and for longitudinal stress, UG-27 provides two formulas:

- one for determining the minimum thickness based on the design pressure, and
- another for determining the pressure based on a given thickness.

Code Formulas for Circumferential (Hoop) Stress

$$t = \frac{PR}{SE - 0.6P} \text{ or } P = \frac{SEt}{R + 0.6t} \qquad \text{UG-27(c)(1)}$$

where:

t = minimum required thickness of shell in inches
P = internal design pressure, in pounds per square inch (psi)
R = inside radius of the shell course under consideration in inches
S = maximum allowable tensile stress value in psi as given in Section II, Part D
E = joint efficiency of the appropriate joint in the shell or the efficiency of the ligaments between openings, whichever is less. Use Code Table UW-12 for welded joints.

The 0.6 factor is the correction that extends the applicability of the thin wall formula for circumferential stress to a thickness equal to one-half the inside radius. The formulas in Appendix 1 of the Code must be used if the thickness exceeds one-half the radius or P exceeds 0.385SE.

Code Formulas for Longitudinal Stress

$$t = \frac{PR}{2SE + 0.4P} \text{ or } P = \frac{2SEt}{R - 0.4t} \qquad \text{UG-27(c)(2)}$$

where:

t = minimum required thickness of shell in inches
P = internal design pressure, in pounds per square inch (psi)
R = inside radius of the shell course under consideration in inches
S = maximum allowable tensile stress value in psi as given in Section II, Part D
E = joint efficiency of the appropriate joint in the shell or the efficiency of the ligaments between openings, whichever is less. Use Code Table UW-12 for welded joints.

These longitudinal stress formulas are limited to use when the thickness is less than or equal to one-half of the inside radius or P does not exceed 1.25SE. The variables are the same as in the circumferential stress formula and reflect the fact that the longitudinal joint must be stronger than the circumferential joint of a cylindrical vessel. Footnote 16 of Part UG points out that, normally, the circumferential stress acting on the longitudinal joint will govern. However, this is not the case when the circumferential joint efficiency is less than one-half the longitudinal joint efficiency or when nonpressure loads cause high stresses in the longitudinal direction.

Practice Problem Q29: Formulas for Circumferential (Hoop) Stress

What does the symbol E define when used to calculate the minimum required thickness of shells under internal pressure?

a) inside radius of the shell course under consideration
b) maximum allowable stress value
c) joint efficiency in cylindrical or spherical shells
d) internal design pressure

Practice Problem Q30: Formulas for Circumferential (Hoop) Stress

What does the symbol R define when used to calculate the minimum required thickness of shells under internal pressure?

a) external radius of the shell course under consideration
b) inside radius of the head course under consideration
c) joint efficiency in cylindrical or spherical shells
d) inside radius of the shell course under consideration

Practice Problem Q31: Formulas for Circumferential (Hoop) Stress

What does the symbol t define when used to calculate the minimum required thickness of shells under internal pressure?

a) maximum required thickness of shell
b) maximum shell tensile strength
c) minimum shell tensile strength
d) minimum required thickness of shell

Example Q32: Minimum Thickness of Shells Under Internal Pressure

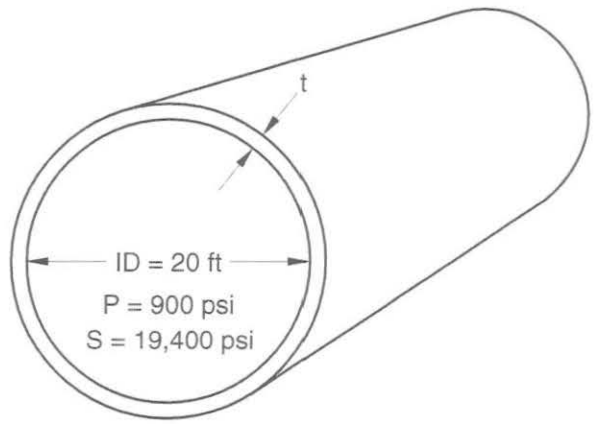
What is the minimum thickness for a pressure vessel having a cylindrical shell with an inside diameter of 20 ft., an internal design pressure of 900 psi, made of SA-516 grade 70, normalized, operating at 600°F, with an allowable stress value of 19,400 psi, that was constructed with Type (1) weld joints and full radiography?

Formula:

From UG-27(c)(1) for cylindrical shells with circumferential stress:

$$t = \frac{PR}{SE - 0.6P}$$

Diagram:



Required Variables:

$P = 900 \text{ psi}$

$R = \frac{ID}{2} = \frac{20}{2} = 10 \text{ ft.}$

$= 10 \text{ ft.} \times 12 \text{ in./ft.} = 120 \text{ in.}$

$S = 19{,}400 \text{ psi}$

from ASME Section VIII-1, Table UW-12 for Type (1) with full radiography:

$E = 1.00$

$$t = \frac{PR}{SE - 0.6P}$$

$$= \frac{(900 \text{ psi})(120 \text{ in.})}{(19{,}400 \text{ psi})(1.00) - (0.6)(900 \text{ psi})}$$

$$= \frac{108{,}000 \text{ psi} \cdot \text{in.}}{19{,}400 \text{ psi} - 540 \text{ psi}}$$

$$= \frac{108{,}000 \text{ psi} \cdot \text{in.}}{18{,}860 \text{ psi}}$$

$$= 5.726 \text{ in.}$$

Practice Problem Q33: Minimum Thickness of Shells Under Internal Pressure

A 150 foot vertical vessel is designed to have a cylindrical shell with an inside radius of 8 ft., an internal design pressure of 1,100 psi, made of SA-516 Gr. 70, normalized, operating at 500°F, with an allowable stress value of 20,000 psi, that was constructed with Type (2) weld joints and spot radiography. The content has the same specific gravity as water. What is the minimum thickness required for this design?

a) 7.283 in.
b) 6.884 in.
c) 7.309 in.
d) 5.460 in.

UG-32 Formed Heads and Sections, Pressure on Concave Side

The most common type of end closure for a cylindrical shell is a formed head. Paragraph UG-32 contains the design requirements for formed heads subjected to internal pressure. There are five types of formed heads:

- ellipsoidal,
- torispherical,
- hemispherical,
- conical, and
- toriconical.

Conical and toriconical sections are also used as transition sections between shell sections of different diameters.

UG-32(a) Minimum Required Thickness of Heads

For ellipsoidal, torispherical, hemispherical, conical, and toriconical heads that are used for internal pressure, the minimum required thickness at the thinnest point in the head after forming is calculated by the appropriate formulas in UG-32.

UG-32(d) Ellipsoidal Heads

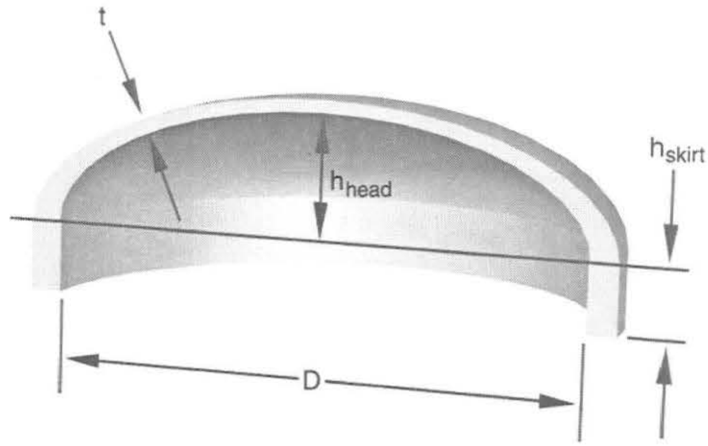


Figure 13 Ellipsoidal head (Figure 8.1 in ASME VIII-1).

The required minimum thickness for a 2:1 ellipsoidal head is:

$$t = \frac{PD}{2SE - 0.2P}$$

or

$$P = \frac{2SEt}{D + 0.2t} \qquad (8.1)$$

where:

t = minimum required thickness of head after forming, inches or mm
P = internal design pressure, psi or kPa
D = inside diameter of skirt or inside length of the major axis of the head, inches or mm
S = maximum allowable tensile stress from Section II, Part D, psi or kPa
E = lowest efficiency of any point in the head.

A 2:1 ellipsoidal head has one-half the minor axis, h, equal to one-fourth of the inside diameter of the head skirt, D.

$$h_{head} = \frac{D}{4}$$

h_{skirt} is the skirt length required by UG-32(l).

UG-32(f) Hemispherical Heads

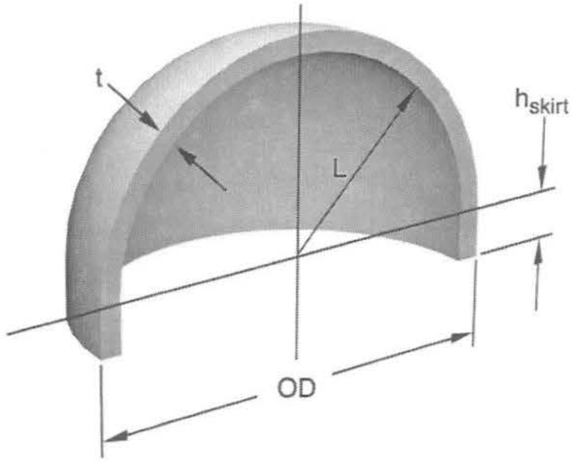


Figure 14 Hemispherical head (Figure 8.4 from ASME VIII-1).

The minimum required thickness after forming and the maximum allowable working pressure for hemispherical heads are:

$$t = \frac{PL}{2SE - 0.2P}$$

or

$$P = \frac{2SEt}{L + 0.2t}$$

Both formulas are applicable only when the thickness is less than or equal to 0.356L or P does not exceed 0.665SE.

UG-81 Tolerance for Formed Heads

UG-81(a) Deviation of Formed Heads

Deviation of the inner surface of a torispherical, toriconical, hemispherical, or ellipsoidal head shall not be greater than:

- the specified shape by more than 1-1/4% of D;
- nor inside the specified shape by more than 5/8% of D; and
- where D is the nominal inside diameter of the vessel shell at point of attachment.

All deviations must be measured perpendicular to the specified shape and shall not be abrupt, although UG-81 does not quantify the abruptness.

The knuckle radius must not be less than that specified in the design.

UG-81(c) Measuring Deviation of Formed Heads

When measuring deviations, they must be taken from the surface of the base metal and not from welds.

UG-81(d) Tolerance of Head Skirts

The tolerance of head skirts must be kept within the difference between the maximum and minimum inside diameters not to exceed 1% of the nominal diameter.

Practice Problem Q34: Tolerance
What is the allowable deviation of the inner surface of a torispherical head? a) ≤ 5/8% of D outside deviation of the specified shape b) ≤ 7/8% of D inside deviation of the specified shape c) ≤ 1-1/4% of D inside deviation of the specified shape d) ≤ 1-1/4% of D outside deviation of the specified shape

UG-37 Reinforcement Required for Openings in Shells and Formed Heads

UG-37 contains the reinforcement requirements for openings. The requirements are based on the area replacement rule and apply for both internal and external pressure. The area replacement rule states that excess or extra metal must be available to carry the load that would normally be carried by the missing metal. This excess material must also be within certain limits in order to be effective.

The excess metal can be surplus material in the shell and nozzle or an extra reinforcing pad. The reinforcement pad may be placed inside or outside of the vessel. The amount of missing metal that must be replaced equals the minimum required thickness of the shell times the diameter of the opening.

The area of replacement for an opening in a pressure vessel is governed by the following equation from Fig. UG-37.1:

$$A = d\, t_r\, F + 2\, t_n\, t_r\, F\,(1 - f_{r1})$$

where:

- A = total cross-sectional area of reinforcement required in the plane under consideration
- d = finished diameter of circular opening or finished dimension
- t_r = required thickness of a seamless shell based on the circumferential stress, or of a formed head
- t_n = nozzle wall thickness
- c = corrosion allowance
- t = specified vessel wall thickness
- F = a correction factor that compensates for the variation in internal pressure stresses on different planes with respect to the axis of a vessel
- f_r = a strength reduction factor.

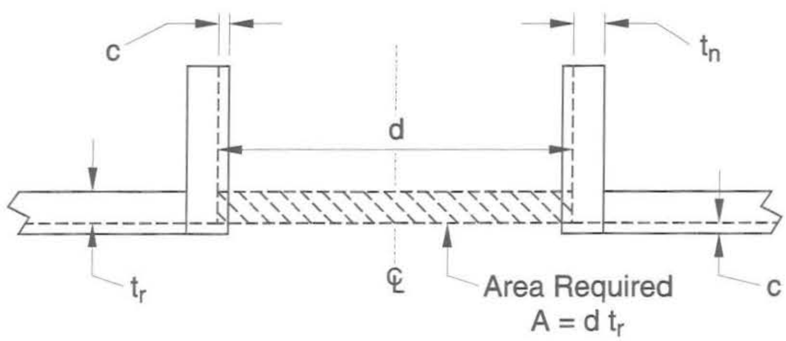


Figure 15 Showing A, the total cross-sectional area of reinforcement required for an opening in a shell or formed head (Figure UG-37.1 from ASME VIII-1).

Example Q35: Minimum Required Area of Replacement

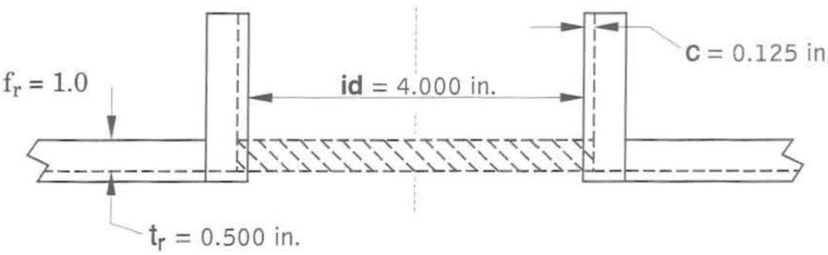
What is the total cross-sectional area of reinforcement required for the following conditions? A vertical vessel has a 36 in. diameter seamless shell with a required wall thickness of 0.500 in., made from SA-516 grade 70, as-rolled, with an allowable stress of 20,000 psi, with an internal design pressure of 350 psi at 400°F. The inlet nozzle has a finished diameter of 4.000 in. and required thickness of 0.375 in.

Formula:

From Fig. UG-37.1:

$A = d\,t_r$, since $F = 1.0$ and $f_r = 1.0$

Diagram:



Required Variables:

$d = 4.000$ in.
$t_r = 0.500$ in.

$$A = d\,t_r$$
$$= 4.000 \text{ in.} \times 0.500 \text{ in.}$$
$$= 2.000 \text{ in.}^2$$

Practice Problem Q36: Minimum Required Area of Replacement

A vertical vessel has a 36 in. diameter seamless shell with a required wall thickness of 0.500 in., made from SA-516 grade 70, as-rolled, with an allowable stress of 20,000 psi at 400°F with an internal design pressure of 350 psi. The inlet nozzle has an inside diameter of 4.000 inches in the uncorroded condition and required thickness of 0.375 in. The entire vessel, including all heads and nozzles, has a corrosion allowance of 0.125 in. What is the total cross-sectional area of reinforcement required for the corroded condition?

a) 1.500 in.^{2}
b) 2.000 in.^{2}
c) 2.625 in.^{2}
d) 2.125 in.^{2}

UG-99 Standard Hydrostatic Test

UG-99(a)(1) requires that hydrostatic testing is done only after all fabrications, heat treatment, inspections, and other tests have been done.

The pressure of the hydrostatic test is defined in UG-99(b) as 1.3 times the maximum allowable working pressure for the design temperature, multiplied by the ratio of the material permitted stress value at the test temperature to that at the vessel design temperature. The stress value is made to account for the reduction in strength of metallic materials with increasing temperature.

Unfortunately, ASME Section VIII, Division 1, does not include the above hydrostatic test pressure definition as a mathematical equation, so for your convenience, the following equation is given.

$$P_T = 1.3 \times MAWP \times \left(\frac{S_T}{S_D}\right)$$

where:

P_T = minimum hydrostatic test pressure
S_T = permitted stress value at the test temperature
S_D = permitted stress value at the design temperature
MAWP =maximum allowable working pressure

Since P_T is the minimum hydrostatic test pressure, this means that the equipment may actually be tested at a pressure greater than 1.3 times the design pressure.

Vessels designed to operate under vacuum conditions are also required to be hydrostatically tested by UG-99(f). In this instance the test pressure is 1.3 times the difference between atmospheric pressure and the minimum internal pressure.

Multi-chamber vessels shall have each chamber separately tested, or, in instances where the design is based on a pressure differential between chambers, the test shall be based on the maximum pressure differential as required by UG-99(e) (1) and (2).

UG-99(g) Hydrostatic Test Acceptance Criterion

The acceptance criterion for a hydrostatic test is the absence of leaks at all joints and connections as determined by a visual examination.

UG-99(h) Hydrostatic Test Medium and Temperature

Provided the hydrostatic testing medium is a nonhazardous liquid, it may be used at any temperature only if it is below its boiling point. For example, combustible liquids with a flash point less than 110°F (43°C), (e.g., petroleum distillates,, etc.) may be used only for near atmospheric temperature tests.

UG-99(h) does not have a requirement for either minimum or maximum test temperature. However, it does recommend that the metal temperature during hydrostatic test be maintained at least 30°F (17°C) above the MDMT, but need not exceed 120°F (48°C) to minimize the risk of brittle fracture.

UG-99(h) does specify that the test pressure shall not be applied until the vessel and its contents are at about the same temperature. It further suggests that if the test temperature exceeds 120°F (48°C), delaying the inspection of the vessel required by UG-99(g) is recommended until the temperature is reduced to 120°F (48°C) or less.

Practice Problem Q37: Hydrostatic Test Medium and Temperature

What type of liquid may be used at any temperature for a pressure vessel hydrostatic test, if below its boiling point?

a) water
b) water and anti-freeze if below 32°F
c) petroleum distillates
d) any nonhazardous liquid

Practice Problem Q38: Hydrostatic Test Medium and Temperature

When a nonhazardous combustible liquid is used during a hydrostatic test, what is the maximum permitted flash point temperature?

a) < 110°F
b) < 130°F
c) < 120°F
d) < 125°F

Example Q39: Hydrostatic Test Pressure

A pressure vessel design conditions are: MAWP of 400 psi at 900°F, material is SA-387 grade 2 and the test fluid is water at 100°F, S at test temperature is 15.7 ksi and S at design temperature is 14.3 ksi. What is the minimum required pressure for a hydrostatic test? Round to the nearest whole number.

Formula:

from ASME Section VIII-1, ¶UG-99(b):

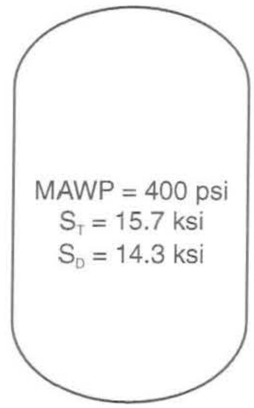
$$P_T = 1.3 \times MAWP \times \left(\frac{S_T}{S_D}\right)$$

Required Variables:

MAWP = 400 psi
S_T = 15.7 ksi
S_D = 14.3 ksi

$$P_T = 1.3 \times MAWP \times \left(\frac{S_T}{S_D}\right)$$
$$= 1.3 \times 400 \text{ psi} \times \left(\frac{15.7\,\text{ksi}}{14.3\,\text{ksi}}\right)$$
$$= 1.3 \times 400 \text{ psi} \times 1.098$$
$$= 571 \text{ psi}$$

Diagram:



ASME SA-387 Grade 2

Practice Problem Q40: Hydrostatic Test Pressure

For design pressure and temperature limits of 1,100 psig and 700°F using SA-106 grade B as the shell material, what is the minimum hydrostatic test pressure required with a test fluid of water at 75°F? S at design temperature is 15.6 ksi and S at test temperature is 17.1 ksi. Round to the nearest whole number.

a) 1,305 psi
b) 1,430 psi
c) 1,568 psi
d) 1,600 psi

Static Head During Hydrostatic Testing

Always including a static head calculation is important when determining the minimum required hydrostatic test pressure to ensure that the added static head pressure does not undermine the design. For example, towers are typically not completely filled with the process liquid since there is commonly a gas phase at the top. Additionally, some process liquids are less dense than water. Consequently, the static head of water during hydrostatic test has to be included in the design in accordance with UG-22 as follows.

UG-22 LOADINGS

The loadings to be considered in designing a vessel shall include those from:

(b) weight of the vessel and normal contents under operating or test conditions;

Note: There is no additional pressure due to static head at the top of a vessel; however, its effect is maximized at the bottom of the vessel where 100% of the static head pressure is applied.

Example Q41: Pressure on Concave Side of Ellipsoidal Head

A 2 ft. diameter, 115 ft. tall vertical pressure vessel has ellipsoidal heads that are under pressure on the concave side. The water used in a hydrostatic test has a static head of 0.433 psi/ft. What is the static head pressure at the bottom of the pressure vessel?

Formula:

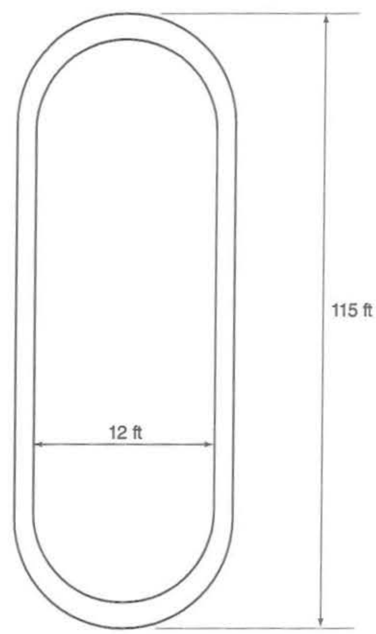
$$P_{\text{static head}} = h_{\text{vessel}} \times \text{static head}$$

Required Variables:

h_{vessel} = 115 ft.
static head = 0.433 psi/ft.

$$\begin{aligned} P_{\text{static head}} &= h_{\text{vessel}} \times \text{static head} \\ &= 115 \text{ ft.} \times 0.433 \text{ psi/ft.} \\ &= 49.80 \text{ psi} \end{aligned}$$

Diagram:



UG-100 Pneumatic Test

Wherever possible, pneumatic testing should be avoided because the expansive nature of a gas could maintain stress on a leak and cause it to grow, thus creating the potential for an explosive failure during the test. Specifically, UG-100(a) only gives two possible reasons for performing a pneumatic test in lieu of hydrostatic testing for vessels:

- UG-100(a)(1) – that are so designed and/or supported that they cannot safely be filled with water;
- UG-100(a)(2) – not readily dried, that are to be used in services where traces of the testing liquid cannot be tolerated and the parts of which have, where possible, been previously tested by hydrostatic pressure to the pressure required in UG-99.

For this reason the pre-inspection requirements for a pneumatic test are rigorous; the rate of pressurization must be controlled—see UG-100(d).

UG-100(b) Pneumatic Test Pressure

The minimum pneumatic test pressure is 1.1 times the maximum allowable operating pressure, multiplied by the ratio of the material permitted stress value at the test temperature to that at the vessel design temperature.

Unfortunately, ASME Section VIII, Division 1, does not include the above pneumatic test pressure definition as a mathematical equation, so for your convenience, the following equation is given.

$$P_T = 1.1 \times MAWP \times \left(\frac{S_T}{S_D}\right)$$

where:

P_T = minimum pneumatic test pressure
S_T = permitted stress value at the test temperature
S_D = permitted stress value at the design temperature
MAWP =maximum allowable working pressure

UG-100(c) Pneumatic Test Temperature

Unlike UG-99(h) for hydrostatic testing, UG-100(c) does specify that the metal temperature during pneumatic test shall be maintained at least 30°F (17°C) above the MDMT to minimize the risk of brittle fracture. Again, the Code is warning the user about the higher risk of performing a pneumatic test and avoiding brittle fracture.

UG-100(d) Pneumatic Test Acceptance Criterion

Leakage is not allowed at the time of the required visual inspection, except for leakage that might occur at temporary test closures for those openings intended for welded connections.

Leakage from temporary seals shall be directed away so as to avoid masking leaks from other joints.

Test Procedure:

(a) The pneumatic pressure must be gradually increased in the pressure vessel being tested up to one-half of the test pressure.
(b) The pneumatic test pressure is required to be increased in steps of approximately 1/10th of the test pressure until the required test pressure has been reached.
(c) The pneumatic pressure is reduced by 1.1 of the test pressure and then held for a sufficient time to permit visual inspection for leaks.

Practice Problem Q42: Pneumatic Test

Under what condition(s) may a pneumatic test be used in lieu of the standard hydrostatic test prescribed in UG-99 for vessels?

a) when the pressure vessel is designed such that it cannot safely be supported when filled with water
b) when the pressure vessel cannot be readily dried
c) when the pressure vessel is to be used in services where traces of the testing liquid cannot be tolerated
d) all of the above

Practice Problem Q43: Pneumatic Test

What is the maximum time allotted to perform the visual inspection during pneumatic testing of a vessel?

a) 1 hour
b) 4 hour
c) 8 hours
d) a sufficient time to permit inspection of the vessel

Example Q44: Pneumatic Test Pressure

What is the pneumatic test pressure for a vessel where the design conditions are: MAWP of 400 psi at 900°F, material is SA-387 grade 2 and the test temperature is 100°F? S at test temperature is 15.7 ksi and S at design temperature is 14.3 ksi. Round to the nearest whole number.

Formula:

from ASME Section VIII-1, ¶UG-100(b):

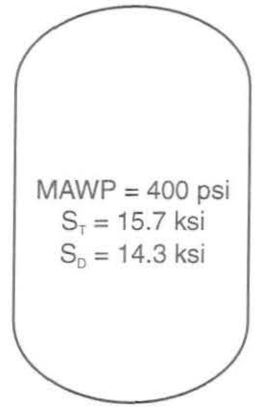
$$P_T = 1.1 \times MAWP \times \left(\frac{S_T}{S_D}\right)$$

Required Variables:

MAWP = 400 psi
S_T = 15.7 ksi
S_D = 14.3 ksi

$$P_T = 1.1 \times MAWP \times \left(\frac{S_T}{S_D}\right)$$
$$= 1.1 \times 400 \text{ psi} \times \left(\frac{15.7\text{ ksi}}{14.3\text{ ksi}}\right)$$
$$= 1.1 \times 400 \text{ psi} \times 1.098$$
$$= 483 \text{ psi}$$

Diagram:



ASME SA-387 Grade 2

Practice Problem Q45: Pneumatic Test Pressure

For design pressure and temperature limits of 1,100 psi and 700°F using SA-106 grade B as the shell material, what is the minimum pneumatic test pressure required with a test temperature at 75°F? S at design temperature is 15.6 ksi and S at test temperature is 17.1 ksi. Round to the nearest whole number.

a) 1,103 psi
b) 1,210 psi
c) 1,326 psi
d) 1,416 psi

UG-102 Test Gages

An indicating gage must be connected directly to the vessel, and if not visible without difficulty to the test operator, an additional indicating gage is required to be visible to the operator during the entire test. UG-102(a) suggests that for large vessels a recording gage should be used in addition to indicating gages.

UG-102(b) specifies that dial indicating pressure gages used in hydrostatic and pneumatic testing:

- must be graduated over a range of about 2 times the intended maximum test pressure; but
- in no case be less than 1-1/2 times nor greater than 4 times the maximum test pressure.

Digital reading pressure gages having a wider range of pressure are permitted by UG-102(b) provided the readings give the same or greater degree of accuracy as obtained with dial pressure gages.

Calibration of pressure gages in accordance with UG-102(c) is required to be made against a standard deadweight tester or a calibrated master gage. Recalibration of pressure gages is required any time there is reason to believe that they are in error.

Practice Problem Q46: Test Pressure Gages

What must be done when an indicating pressure gage is not visible to the hydrostatic test operator?

a) A digital pressure gage is required to be visible to confirm the maximum pressure.
b) The operator may at their discretion, use their best judgment to establish the test pressure.
c) An additional indicating gage is required to be visible to the operator during the entire test.
d) A recording digital pressure gage must be used.

Practice Problem Q47: Test Pressure Gages

What is the pressure gage graduated range that is required for used in hydrostatic testing?

a) up to 2 times the intended maximum test pressure
b) 1-1/2 to 4 times the intended maximum test pressure
c) up to 2 times the MAWP
d) 1-1/2 to 4 times the MAWP

UW-16 Minimum Requirements for Attachment Welds at Openings

Figure UW-16.1 illustrates 68 different acceptable types of welded nozzles and other connections to shells, heads, and so on. As an example of sizing a nozzle to shell weld, UW-16(c)(2)(d) states:

> The weld at the inner edge of the reinforcement plate when the reinforcement plate is not full penetration welded to the nozzle neck shall be a continuous fillet weld with a minimum throat dimension of $t_w = 0.7t_{min}$ [see Fig. UW-16.1(h) below].

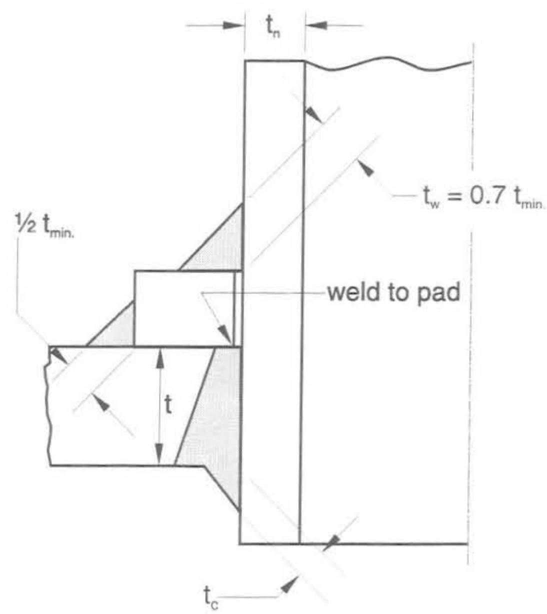


Figure 16 Acceptable Types of Welded Nozzles
and other Connections to Shells, Heads, etc. [Fig. UW-16.1(h) in ASME VIII-1]

Convert a Fillet Weld Throat Dimension to Leg Dimension

The relationship between weld leg and weld throat can be approximated by examining the weld cross section. A right-angle isosceles triangle is formed by the weld leg and throat as shown in Figure 17.

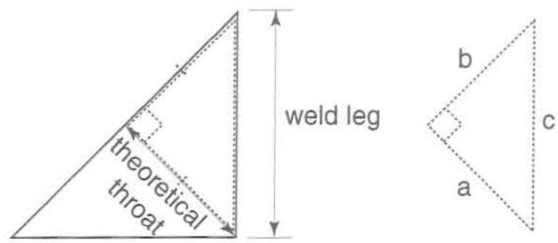


Figure 17 Relationship between weld leg and throat dimensions.

For a right-angle triangle, where 'a' and 'b' are the sides adjacent to the right angle, and 'c' is the side opposite the right angle:

$$a^2 + b^2 = c^2$$

where:

a = weld throat
c = weld leg

Since we have an isosceles triangle:

$$a = b$$

Then:

$$a^2 + a^2 = c^2$$
$$2a^2 = c^2$$
$$a^2 = \frac{1}{2}c^2$$
$$\sqrt{a^2} = \sqrt{\frac{1}{2}c^2}$$
$$a = \frac{1}{\sqrt{2}}c$$
$$a = 0.707\ c$$

Therefore, the length of the weld throat is 0.707 times the length of the weld leg.

$$\text{throat size} = 0.707 \times \text{leg size}$$

and

$$\text{leg size} = \frac{\text{throat size}}{0.707}$$

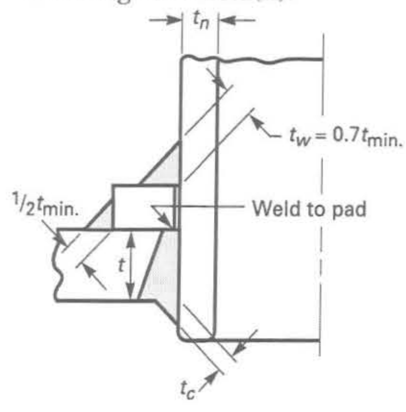
Example Q48: UW-16 Minimum Requirements for Attachment Welds at Openings

What is the outer nozzle-to-weld pad leg size in a Fig. UW-16.1 (h) design, where t_{min} is 0.500 in., and the nozzle is made from SA-335 grade P22 alloy steel?

Formula:

leg size = throat size/0.707 from Body of Knowledge: 8(a) weld size throat to leg conversion, where the throat size in Fig. UW-16.1(h) is t_w

$t_w = 0.7t_{min}$ from Fig. UW-16.1(h):



(h)

Solving for t_w:

$t_{min} = 0.500$ in.

$$t_w = 0.7t_{min} = 0.7\ (0.500\ \text{in.}) = 0.350\ \text{in.}$$

$t_w = 0.707$ leg size

Solving for the leg size:

$$\text{leg size} = \frac{t_w}{0.707} = \frac{0.350\ \text{in.}}{0.707} = 0.495\ \text{in.}$$

Practice Problem Q49: UW-16 Minimum Requirements for Attachment Welds at Openings

What is the outer fillet weld leg size in a nozzle designed to Fig. UW-16.1 (d), where t_c is 0.500 in., the nozzle thickness is 0.375 in., and made from SA-333 grade 6?

a) 0.354 in.
b) 0.495 in.
c) 0.595 in.
d) 0.707 in.

UW-21 Slip-On and Socket Welded Flanges

Typical weld details for ASME B16.5 slip-on and socket welded flanges are shown in Fig. UW-21, as follows.

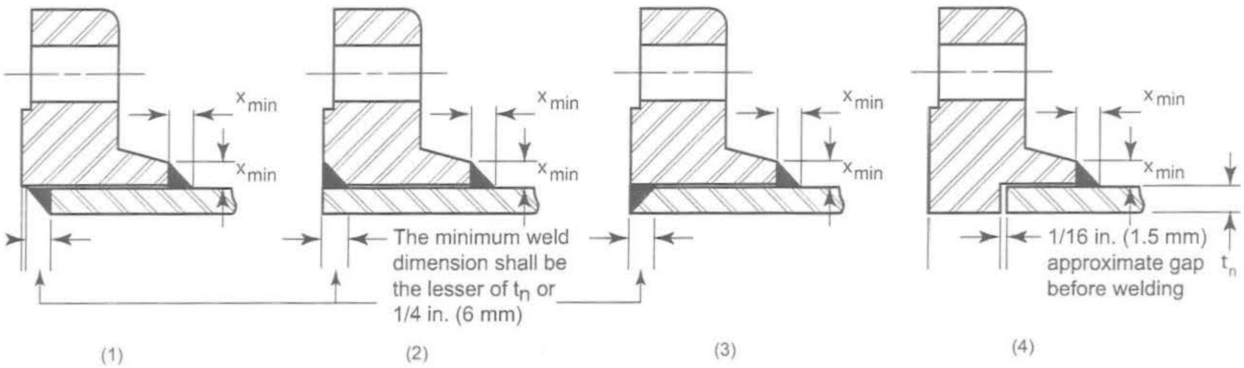


Fig. UW-21, General Note: X_{min} = the lesser of $1.4t_n$ or the thickness of the hub.

Sizing the fillet welds for ASME B16.5 slip-on and socket flange is given in UW-21(a) and (b), as follows.

(a) ASME B16.5 socket weld flanges shall be welded using an external fillet weld. The minimum fillet weld throat dimension shall be the lesser of the nozzle wall thickness or 0.7 times the hub thickness of the socket weld flange. See Figure UW-21, illustration (4).

(b) ASME B16.5 slip-on flanges shall be welded using an internal and an external weld. See Figure UW-21, illustrations (1), (2), and (3).

Example Q1: UW-21 Slip-On and Socket Welded Flanges

What is the socket welded flange-to-pipe leg size, where nominal wall thickness of pipe is 0.375 in. with a hub thickness of 0.625 in., and made from A333 grade 6?

Formula:

From Fig. UW-21:

X_{min} = the lesser of $1.4t_n$ or the thickness of the hub

Diagram:

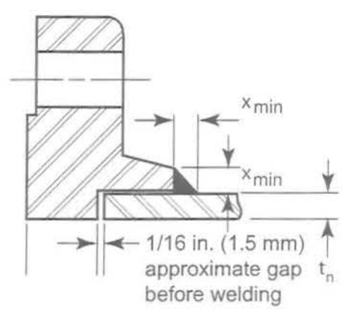


Fig. UW-21(4)

Required Variables:

t_n = 0.375 in.

hub thickness = 0.625 in.

leg size = X_{min} = the lesser of $1.4t_n$ or the thickness of the hub.

= lesser of 1.4 × 0.375 in. or 0.625 in.

= lesser of 0.525 in. or 0.625 in.

= 0.525 in.

Practice Problem Q2: Flange Attachment Weld Size - Fig. 328.5.2B

What is the socket welded flange-to-pipe leg size, where nominal wall thickness of pipe is 0.500 in. with a hub thickness of 0.600 in., and made from A381 Grade Y48?

e) 0.500
f) 0.600
g) 0.700
h) 0.250

Measuring Fillet Weld Sizes

Each of the fillet weld gages have notched corners to correspond with the measurement markings. These notched corners measure fillet weld leg and throat size.

When properly applying a concave gage to a concave fillet weld (see Figure 12), the throat of the weld will contact the notched portion of the corresponding gage with the gage itself resting squarely between both members of the joint. If the throat of the weld does not touch the gage or if the gage is not resting squarely between both members of the joint, a different size gage should be tried.

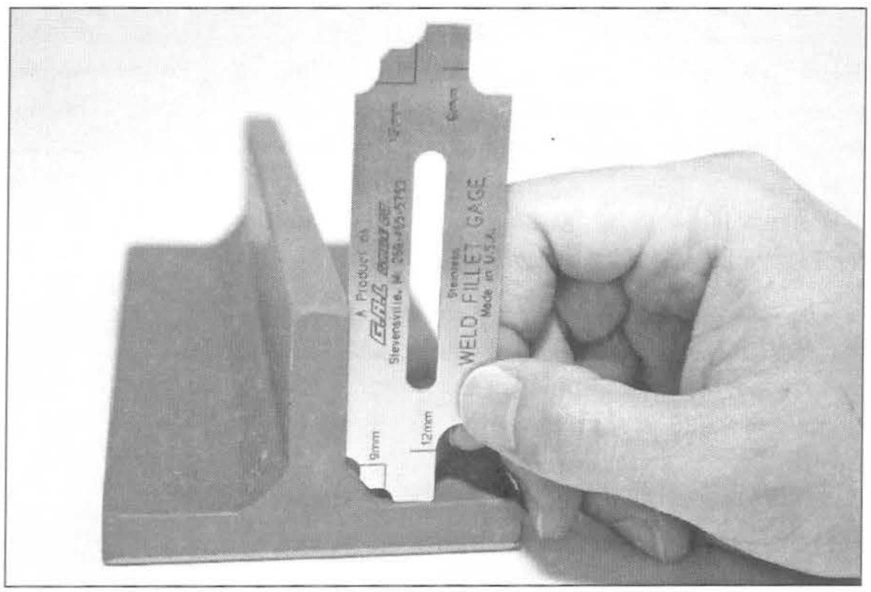


Figure 18 A concave fillet weld gage is used to determine weld size of a concave fillet weld.

When properly applying a convex gage to a convex fillet weld (see Figure 19), the legs of the weld can be measured in two ways:

1) positive contact of the upper weld toe with the tip of the corresponding gage, and
2) visualizing the black line extending downward toward the lower toe.

For testing, the positive contact method of measuring is more accurate and should be used for measuring both legs. To do this, the gage will have to be rotated to measure each leg with positive contact of the toe and the tip of the gage.

Note: Whenever a fillet weld gage is applied to a weld, the gage itself must always rest squarely between both members of the joint.

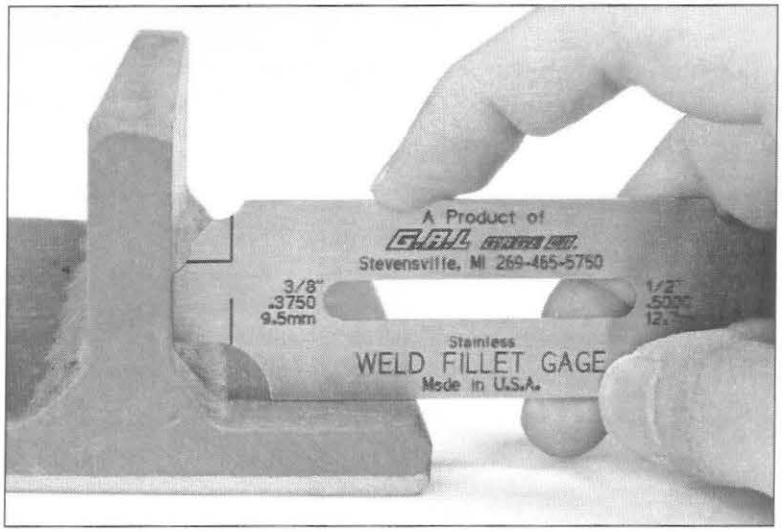


Figure 19 A convex fillet weld gage is used to determine weld size of a convex fillet weld.

UW-30 Lowest Permissible Temperatures for Welding

The Code in UW-30 does not specify a minimum ambient temperature for welding. Rather, it only recommends that no welding of any kind be done when the temperature of the base metal is lower than 0°F (–20°C).

UW-30 also recommends that at temperatures between 32°F (0°C) and 0°F (–20°C), the surface of all areas within 3 in. (75 mm) of the point where a weld is to be started should be preheated to a temperature that is at least warm to the hand—estimated to be above 60°F (15°C)—before welding is started.

When surfaces are wet or covered with ice, when snow is falling on the surfaces to be welded, during periods of high wind, or unless the welders or welding operators and the work are properly protected, UW-30 again only recommends that no welding be done.

UW-33 Welding Alignment Tolerance

Alignment tolerances for butt welded edges are listed in Table UW-33.

Practice Problem Q50: Temperatures for Welding

During the construction of a pressure vessel outside, what should not be done if welders and the work are not properly protected?

a) no welding be done when surfaces are wet or covered with ice
b) no welding be done when snow is falling on the surfaces to be welded
c) no welding be done during periods of high wind
d) all of the above

Practice Problem Q51: Alignment

During the construction of a pressure vessel, what is the maximum allowable offset for a shell to hemispherical head weld joint, where the nominal shell and head thicknesses (t) are 2.00 in. each?

a) 1/4t
b) 1/8t
c) 1/8 in.
d) 3/16 in.

UW-35 Finished Longitudinal and Circumferential Joints

UW-35(a) requires that butt welded joints must have complete penetration and full fusion. The welded surfaces may remain as-welded.

The welded surfaces must be sufficiently free from coarse ripples, grooves, overlaps, and abrupt ridges and valleys to permit proper interpretation of radiographic and other required nondestructive examinations. If there is a question regarding the surface condition of the weld when interpreting a radiographic film, the film shall be compared to the actual weld surface for determination of acceptability.

UW-35(b) requires that any reduction in thickness resulting from welding process is permitted when all of the following are satisfied:

1) The reduction in thickness shall not reduce the material of the adjoining surfaces below the minimum required thickness at any point.
2) The reduction in thickness shall not exceed 1/32 in. (1 mm) or 10% of the nominal thickness of the adjoining surface, whichever is less (see footnote 8).

Footnote 8: It is not the intent of this paragraph to require measurement of reductions in thickness due to the welding process. If a disagreement between the Manufacturer and the Inspector exists as to the acceptability of any reduction in thickness, the depth shall be verified by actual measurement.

Practice Problem Q52: Welded Surface

What shall be done when there is a question regarding the surface condition of a longitudinal or circumferential butt welded joint in a pressure vessel when interpreting a radiographic film?

a) the film shall be compared to the actual weld surface for determination of acceptability
b) the film shall be reviewed by a 2nd qualified examiner
c) the radiograph shall be retaken with an adjusted procedure to accommodate the circumstance for the question
d) the film shall be interpreted as best as possible

UW-35(d) Maximum Allowable Reinforcement

For ASME Section VIII, Division 1, welds, there are minimum requirements for joint throat and maximum requirements for weld reinforcement. The weld must develop the strength of the base material. Weld reinforcement is a change in surface contour and therefore is a stress concentrator: the more severe the build-up, the greater the stress magnification. Although the Code does not require weld reinforcement, but does require complete joint fill.

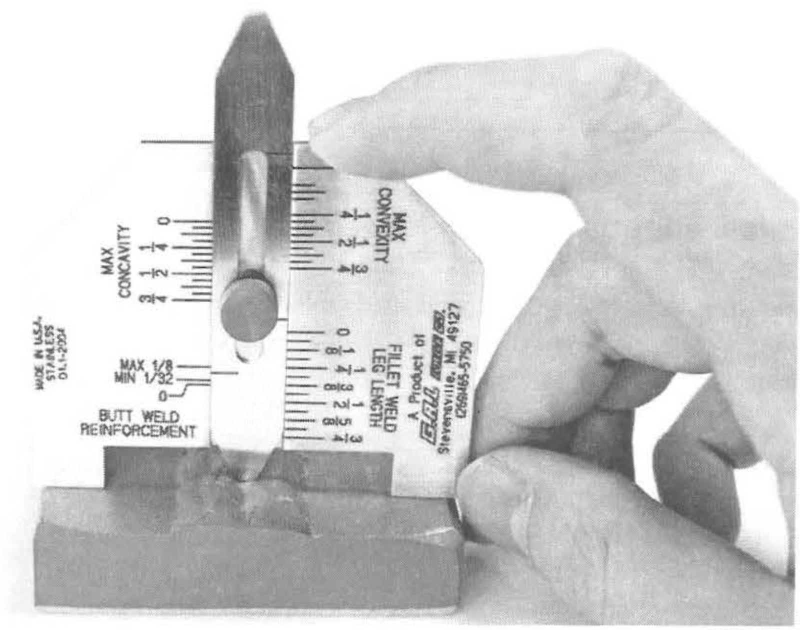


Figure 20 Palmgren weld reinforcement gage.

UW-35(d) states that limitations for the thickness of the weld reinforcement on each face shall not exceed those listed in Table 3.

Table 3 Maximum Reinforcement per ASME Section VIII, Division 1, UW-35(d)

Material Nominal Thickness, in.	Maximum Reinforcement, in.	
	Category B and C Butt Welds	Other Welds
Less than 3/32	3/32	1/32
3/32 to 3/16, incl.	1/8	1/16
Over 3/16 to 1/2, incl.	5/32	3/32
Over 1/2 to 1, incl.	3/16	3/32
Over 1 to 2, incl.	1/4	1/8
Over 2 to 3, incl.	1/4	5/32
Over 3 to 4, incl.	1/4	7/32
Over 4 to 5, incl.	1/4	1/4
Over 5	5/16	5/16

Practice Problem Q53: Weld Reinforcement

What is the maximum thickness of the weld reinforcement on each face for a welded joint connecting flange to nozzle with a nominal thickness of 0.750 in.?

a) 3/32 in.
b) 1/8 in.
c) 5/32 in.
d) 3/16 in.

UW-37 Miscellaneous Welding Requirements

UW-37(a) requires that the reverse side of double-welded joints must be prepared appropriately before applying weld metal from the reverse side. This may be done by chipping, grinding, or melting out to ensure that first back-pass has proper fusion.

Practice Problem Q54: Completing Double-Welded Joints

What is the reason for chipping, grinding, or melting out the reverse side of double-welded joints during the construction of a pressure vessel before applying weld metal from the reverse side?

a) to secure sound metal at the base of weld metal first deposited
b) to increase weld metal properties on the reverse side
c) to strengthen the back-pass weldment
d) to improve low temperature impact properties of the back-pass

UW-28 Qualification of Welding Procedure

Each welding procedure specification (WPS) used to weld pressure parts, including load-carrying non-pressure parts (e.g., clips, lugs, etc.) welded to pressure parts, must be qualified in accordance with Section IX, as described in UW-28(b).

In accordance with UW-28(c)(1), the WPS used to weld non-pressure bearing attachments which have essentially no load-carrying function to pressure parts (e.g., ladders or insulation support pins attached to a shell) when welded with a manual, machine, or semiautomatic process, the WPS is required to be qualified to Section IX. When welding these same parts using any automatic welding process with a WPS in compliance with Section IX "as far as applicable", then the WPS qualification testing is not required, see UW-28(c)(2).

Welding and testing of all test coupons, accordance with UW-28(d), is the sole responsibility of the Manufacturer.

Alternatively, UW-28(d) permits AWS Standard Welding Procedure Specifications that have been accepted by Section IX, Appendix E, may be used provided they meet all other requirements of Section VIII Div. 1.

Note: UW-28(d) does not permit qualification of a welding procedure by one Manufacturer to be used or shared by any other Manufacturer, except as provided in QW-201 of Section IX, where two or more companies that are owned by the same mother-company that has a quality control program that specifically addresses sharing of WPSs between them.

Preheat – Non-Mandatory Appendix R

Mandatory welding preheating rules are not given in ASME Section VIII Division 1, except as required in the footnotes that provide for exemptions to postweld heat treatment (PWHT) in Tables UCS-56 and UHA-32. In essence, this code requires all carbon and alloy steel welds to be PWHT, except when preheated and within thickness limits, and other limitations.

In general, the requirements for preheating, temperature, time at temperature, method of application and such are dependent on many factors, including:

- chemical analysis of the base metal and filler metal, and deposited weld metal,
- degree of restraint of the parts being joined,
- elevated physical properties, and
- section thickness(es).

Non-mandatory Appendix R lists some practices used for preheating as a general guide for the materials listed by P-Numbers in Section IX, as shown in the following table.

Table 4 Non-mandatory Appendix R

Non-Mandatory Appendix R	
Base Material P-Number	**Preheat Practice Guide**
P-No. 1 Group Nos. 1, 2, 3	(a) 175°F (79°C) for material which has both a specified maximum carbon content in excess of 0.30% and a thickness at the joint in excess of 1 in. (25 mm); (b) 50°F (10°C) for all other materials in this P-Number.
P-No. 3 Group Nos. 1, 2, 3	(a) 175°F (79°C) for material which has either a specified minimum tensile strength in excess of 70,000 psi (480 MPa) or a thickness at the joint in excess of 5/8 in. (16 mm); (b) 50°F (10°C) for all other materials in this P-Number.
P-No. 4 Group Nos. 1, 2	(a) 250°F (121°C) for material which has either a specified minimum tensile strength in excess of 60,000 psi (410 MPa) or a thickness at the joint in excess of 1/2 in. (13 mm); (b) 50°F (10°C) for all other materials in this P-Number.
P-Nos. 5A and 5b Group No. 1	(a) 400°F (204°C) for material which has either a specified minimum tensile strength in excess of 60,000 psi (410 MPa), or has both a specified minimum chromium content above 6.0% and a thickness at the joint in excess of 1/2 in. (13 mm); (b) 300°F (149°C) for all other materials in these P-Numbers.
P-No. 6 Group Nos. 1, 2, 3	400°F (204°C)
P-No. 7 Group Nos. 1, 2	None
P-No. 8 Group Nos. 1, 2	None

The following Example and Practice Problem illustrate how to determine the suggested preheat requirement given a pipe material and size.

Example Q55: Preheat Requirement

What is the Section VIII, Division 1, suggested preheat requirement for 2 in. O.D., ¼ in. thick, ASME SA-335/SA-335M Grade P11 seamless piping material?

The P-No. for this material can be read from ASME Section IX, Table QW/QB-422

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	Nominal Composition	Product Form
SA-335	P1	K11522	55 (380)	3	1	101	C–0.5Mo	Smls. pipe
SA-335	P2	K11547	55 (380)	3	1	101	0.5Cr–0.5Mo	Smls. pipe
SA-335	P12	K11562	60 (415)	4	1	102	1Cr–0.5Mo	Smls. pipe
SA-335	P15	K11578	60 (415)	3	1	101	1.5Si–0.5Mo	Smls. pipe
SA-335	P11	K11597	60 (415)	4	1	102	1.25Cr–0.5Mo–Si	Smls. pipe
SA-335	P22	K21590	60 (415)	5A	1	102	2.25Cr–1Mo	Smls. pipe
SA-335	P21	K31545	60 (415)	5A	1	102	3Cr–1Mo	Smls. pipe
SA-335	P5c	K41245	60 (415)	5B	1	102	5Cr–0.5Mo–Ti	Smls. pipe
SA-335	P5	K41545	60 (415)	5B	1	102	5Cr–0.5Mo	Smls. pipe
SA-335	P5b	K51545	60 (415)	5B	1	102	5Cr–0.5Mo–Si	Smls. pipe

Using the P-No., the required minimum preheat temperature can be read from Appendix R.

P-No. 4 Group Nos. 1, 2

(a) 250°F (121°C) for material which has either a specified minimum tensile strength in excess of 60,000 psi (410 MPa) or a thickness at the joint in excess of 1/2 in. (13 mm);
(b) 50°F (10°C) for all other materials in this P-Number.

The suggested preheat is 250°F (121°C) based on a MSTS not exceeding 60,000 psi (410 MPa) and a section thickness of 1/4 in.

Practice Problem Q56: Preheat Requirement

What is the Section VIII, Division 1, suggested preheat requirement for NPS 10, Sch 80, 0.594 inch, ASME SA-335/SA -335M Grade P1 seamless piping material with an ambient temperature of 0°F?

a) 50°F
b) 150°F
c) 175°F
d) 200°F

UW-40 Procedures for PWHT

In accordance with UW-40(a) the PWHT soak band must contain:

- the weld,
- heat affected zone, and
- a portion of base metal adjacent to the weld being heat treated for a minimum distance of the widest width of weld plus 1t or 2 in. (50 mm), whichever is less, on each side or end of the weld.

Note: The above term, t, is the nominal thickness of the weld at the point of attachment.

Note: For a fully completed pressure vessel, all heat treatment must be done after all weld repairs and prior to hydrostatic testing; see UW-40(e).

UW-40(a)(2) PWHT with Multiple Heats

When heating the vessel in more than one heat in a furnace, the overlap of the heated sections of the vessel must be at least 5 ft. (1.5 m). The vessel portion outside of the furnace must be shielded to prevent any harmful temperature gradient.

Practice Problem Q57: PWHT Procedures

What is the minimum width of a PWHT soak band in the construction of a new pressure vessel?

a) a minimum of 2 in. from the center line of the weld in all directions
b) a minimum of 3 in. from the center line of the weld in all directions
c) shall extend at least 1 in. (25 mm) beyond each edge of the weld or 2 in., whichever is less
d) widest width of weld plus 1t or 2 in. (50 mm), whichever is less, on each side or end of the weld

Practice Problem Q58: PWHT Procedures

What is the preferable procedure for PWHT a new pressure vessel?

a) by locally PWHT with electric blankets
b) by locally PWHT with electric blankets that are insulated with ceramic
c) heating the vessel in more than one heat in a furnace, provided the overlap of the heated sections of the vessel is at least 5 ft (1.5 m)
d) as a whole in an enclosed furnace

UCS-56 Heat Treatment of Carbon and Low Alloy Steels

UCS-56 presents the minimum requirements for PWHT of carbon and low alloy steels. While this article of the Code is labeled PWHT, the heat treatments prescribed are used in achieving stored internal energy redistribution and reduction. This energy results not only from welding, but from other fabrication means as well (e.g., forging or rolling, etc.).

Part UCS-85 of the Code defines *heat treatment* as follows.

> *heat treatment*: a controlled exposure to a temperature greater than 900°F (480°C), but less than the lower transformation temperature for the steel (i.e., 1333°F from the Body of Knowledge) for carbon steel but slightly higher for alloy steels with greater alloy additions having a higher transformation temperature.

At these temperatures, the metal will be red hot as shown in Figure 21.

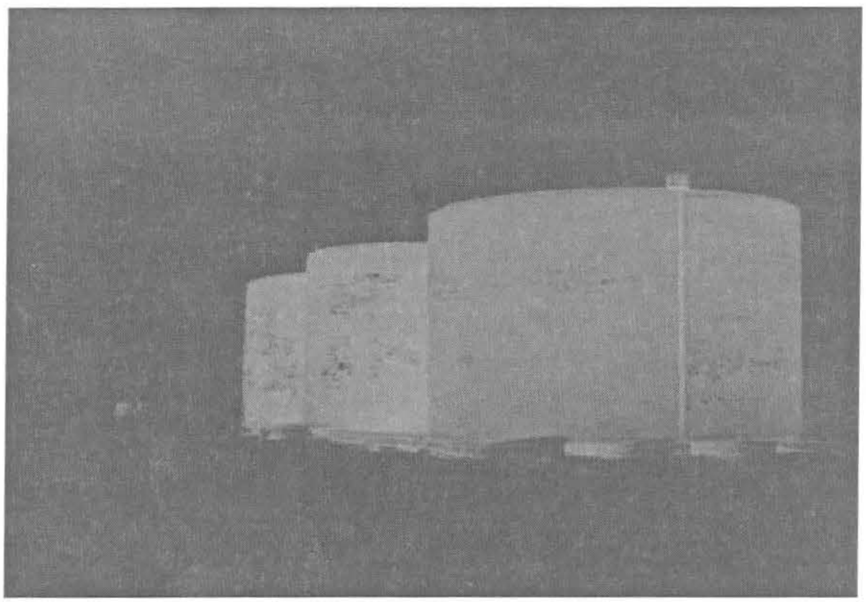


Figure 21 Thick wall shell sections glow red upon their removal from the heat treatment furnace.

For C.S materials

Half bead method:

1- low Hydrogen electode. (First layer)
1-5- Pre heat apply.
2- Small Electrod (more heat/lb of metal deposit) 3mm thickness
3- Remove half thickness of the first layer.
4- weld out using larger diameter electrod
5- Over weld one Pass and remove the weld.
6- Increase preheat to 450°F and keep upto 4hours

UCS-56 provides a set of heat treating rules that represents good practice for heat treating carbon and alloy steel products other than just pressure vessels; these are described below.

- UCS-56(d)(1) – The heat treated item shall not be placed in a furnace hotter than 800°F (427°C).
- UCS-56(d)(2) – Above 800°F (425°C), the rate of heating shall be not more than 400°F/hr (222°C/ h) divided by the maximum metal thickness of the shell or head plate in inches, but in no case more than 400°F/hr (222°C/h).
- UCS-56(d)(2) – During the heating period there shall not be a greater variation in temperature throughout the portion of the vessel being heated than 250°F (120°C) within any 15 ft. (4.6 m) interval of length.
- UCS-56(d)(2) footnote 3 – The rates of heating and cooling need not be less than 100°F/hr (56°C/h). However, in all cases consideration of closed chambers and complex structures may indicate reduced rates of heating and cooling to avoid structural damage due to excessive thermal gradients.
- UCS-56(d)(3) – During the holding period the furnace temperature shall not vary by more than 150°F (83°C) between the hottest and coldest areas in the furnace.
- UCS-56(d)(4) – Furnace atmospheres shall be controlled to limit the amount of high temperature oxidation.
- UCS-56(d)(4) – The flame shall not directly impinge on the material.
- UCS-56(d)(5) – Above 800°F (425°C), cooling shall be done in a closed furnace or cooling chamber at a rate not greater than 500°F/hr (280°C/h) divided by the maximum metal thickness of the shell or head plate in inches, but in no case more than 500°F/hr (280°C/h). (see footnote 3)
- UCS-56(d)(5) – Cooling from 800°F (425°C) the vessel may be cooled in still air.
- Table UCS-56 – The time at temperature (1 hour per inch (25 mm) of thickness up to 2 inches (50 mm), 15 minutes minimum) and the stated temperatures in Table UCS-56 are minimums.
- Table UCS-56.1 – For P-Number 1 Groups 1 and 2 materials, Table UCS-56.1 presents alternative lower temperatures with corresponding longer times at temperature.
- UCS-56(f) – Weld repairs during fabrication made to P-No. 1 Group Nos. 1, 2, and 3 and to P-No. 3 Group Nos. 1, 2, and 3 materials may be made after the final PWHT but prior to the final hydrostatic test, without additional PWHT, provided that PWHT is:
  - not required as a service requirement in accordance with UW-2(a)
  - not an exemption in Table UCS-56, or
  - as a service requirement in accordance with UCS-68.
- UCS-56(f)(1) through to (6) – These six paragraphs specify the weld repair requirements, (see the Code). These requirements do not apply when the welded repairs are minor restorations of the material surface, such as those required after removal of construction fixtures, and provided that the surface is not exposed to the vessel contents.
- UW-40 – Heat treatment shall be done after all weld repairs and prior to hydrostatic testing.
- UW-40 – The thickness of the weld throat, exclusive of permitted reinforcement, shall govern the time at the specified temperature.

These rules allow the material to achieve a reduction in internal energy without introducing stress caused by thermal gradients. When components of a vessel are restricted from moving during heat treatment, such as might be encountered during a local heat treat procedure, or when large thermal gradients are present, then stress equal to or greater than that already in the part may be created by the process. The Code user is cautioned to consider the potential for creating this condition, particularly on treatments where the entire object is not being heated.

Practice Problem Q59: PWHT

What is the maximum permitted temperature of a PWHT furnace at the time a pressure vessel is placed in it?

a) 400°F (205°C)
b) 500°F (260°C)
c) 800°F (425°C)
d) 100°F (56°C) above room temperature

Practice Problem Q60: PWHT

Above 800°F (425°C) in a PWHT furnace, what is the maximum rate of heating for a pressure vessel made from SA-516 grade 70, normalized, with a nominal thickness of 1.0 in.?

a) 100°F/hr (56°C/h)
b) 200°F/hr (111°C/h)
c) 400°F/hr (222°C/h)
d) 500°F/hr (280°C/h)

Practice Problem Q61: PWHT

During PWHT heating and holding periods for pressure vessels, why is it mandatory to control furnace atmosphere, other than for temperature?

a) to avoid excessive condensation of the surface of the vessel
b) to avoid excessive thermal expansion of the surface of the vessel
c) to avoid excessive thermal contraction of the surface of the vessel
d) to avoid excessive oxidation of the surface of the vessel

Practice Problem Q62: PWHT

What is the permitted total weld repair depth after PWHT for the construction of a pressure vessel with a P-No. 1 Group No. 3 material?

a) shall not exceed 1 in. (25 mm)
b) shall not exceed 1-1/4 in. (32 mm)
c) shall not exceed 1-1/2 in. (38 mm)
d) as required to make the repair

Practice Problem Q63: PWHT

A pressure vessel is being constructed of SA-387 Gr. 2, Cl. 2 material, where after welding and PWHT, NDE has revealed several cracks that need to be repaired. In addition to the requirements in ASME Section IX, what welding process and filler metal shall be used?

a) SMAW using low hydrogen electrodes
b) SMAW using low hydrogen electrodes or GMAW
c) SMAW using low hydrogen electrodes or GMAW (excluding short-circuiting)
d) by the same welding process originally used

Practice Problem Q64: PWHT

When repair welding a pressure vessel nozzle made from SA-335 grade P1 material during construction and after PWHT, what welding technique is required?

a) stringer welds only
b) stringer welds with controlled heat input
c) temper bead stringer welds only
d) weld temper bead reinforcement

Table UCS-56 Postweld Heat Treatment (PWHT)

The PWHT details for each material used to fabricate pressure vessels are listed in Table UCS-56. The Code takes the approach that all materials shall be PWHT, except as provided in the "Notes" below each individual UCS-56 Table.

The factors that affect weldability and result in ASME classifying materials in P-Number groupings also apply to PWHT. Therefore, the heat treatment dwell times and temperatures are given in Table UCS-56 in accordance with P-Number classifications.

The Code user should keep in mind that the heat treatment requirements listed in Table UCS-56 are minimum requirements and while a number of exemptions are given for each P-Number listing in the Table UCS-56 Notes, using the exemptions may not represent the lowest risk or the lowest cost for the pressure vessel.

Table UCS-56 exemptions are not applicable for some cold service vessels as defined in UCS-68 (i.e., service temperature less than -55°F (-48°C)).

Example Q65: Table UCS-56 Heat Treatment of Carbon and Low Alloy Steels

What is the minimum PWHT temperature and minimum holding time for SA-516 grade 60 with a nominal wall thickness of 3.00 in.?

From ASME IX, Table QW/QB-422, the P-No. for SA-516 Grade 60 is P-No. 1

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS AND S-NUMBERS (CONT' D)
Grouping of Base Metals for Qualification

Ferrous (CONT' D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Welding S-No.	Welding Group No.	Brazing P-No.	Brazing S-No.	Nominal Composition	Product Form
SA-516	55	K01800	55 (380)	1	1	...	...	101	...	C-Si	Plate
SA-516	60	K02100	60 (415)	1	1	...	...	101	...	C-Mn-Si	Plate
SA-516	65	K02403	65 (450)	1	1	...	...	101	...	C-Mn-Si	Plate
SA-516	70	K02700	70 (485)	1	2	...	...	101	...	C-Mn-Si	Plate

From ASME VIII-1 Table UCS-56, the minimum normal holding temperature is 1100°F

TABLE UCS-56
POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)] Up to 2 in. (50 mm)	Over 2 in. to 5 in. (50 mm to 125 mm)	Over 5 in. (125 mm)
P-No. 1 Gr. Nos. 1, 2, 3	1,100 (595)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)
Gr. No. 4	NA	None	None	None

NOTES:
(1) When it is impractical to postweld heat treat at the temperature specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with Table UCS-56.1.
(2) Postweld heat treatment is mandatory under the following conditions:
(a) for welded joints over $1\frac{1}{2}$ in. (38 mm) nominal thickness;

Based on ASME VIII-1 Table UCS-56, 15 minutes must be added to the minimum holding time per inch greater than 2 in.

Holding time = 2 hours + [15 minutes × (3 in. – 2 in.)]
= 2 hours + [15 minutes × 1 in.]
= 2 hours + 15 minutes
= 2.25 hours

The minimum PWHT temperature is 1100°F (595°C) and held for a minimum of 2.25 hours.

Example Q66: Table UCS-56 Heat Treatment of Carbon and Low Alloy Steels

What is the minimum PWHT temperature and minimum holding time for SA-335 grade P22 with a nominal wall thickness of 6.00 in.?

Table UCS-56 lists heat treatment requirements that are organized by P-No. The P-No. for all B&PV materials are found in ASME Section IX, QW/QB-422, as follows.

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-335	P1	K11522	55 (380)	3	1	101	1.1	C-0.5Mo	Smls. pipe
SA-335	P2	K11547	55 (380)	3	1	101	4.2	0.5Cr-0.5Mo	Smls. pipe
SA-335	P12	K11562	60 (415)	4	1	102	5.1	1Cr-0.5Mo	Smls. pipe
SA-335	P15	K11578	60 (415)	3	1	101	...	1.5Si-0.5Mo	Smls. pipe
SA-335	P11	K11597	60 (415)	4	1	102	5.1	1.25Cr-0.5Mo-Si	Smls. pipe
SA-335	P22	K21590	60 (415)	5A	1	102	5.2	2.25Cr-1Mo	Smls. pipe
SA-335	P21	K31545	60 (415)	5A	1	102	5.2	3Cr-1Mo	Smls. pipe
SA-335	P5c	K41245	60 (415)	5B	1	102	5.3	5Cr-0.5Mo-Ti	Smls. pipe
SA-335	P5	K41545	60 (415)	5B	1	102	5.3	5Cr-0.5Mo	Smls. pipe
SA-335	P5b	K51545	60 (415)	5B	1	102	5.3	5Cr-0.5Mo-Si	Smls. pipe

Since SA-335 grade P22 has an ASME P-No. 5A, then find the required PWHT values in Table UCS-56 for P-No. 5A, with a thickness of 6 in, as follows:

TABLE UCS-56
POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS (CONT'D)

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)] Up to 2 in. (50 mm)	Over 2 in. to 5 in. (50 mm to 125 mm)	Over 5 in. (125 mm)
P-Nos. 5A, 5B Gr. No. 1, and 5C Gr. No. 1	1,250 (675)	1 hr/in. (25 mm), 15 min minimum	1 hr/in. (25 mm)	5 hr plus 15 min for each additional inch (25 mm) over 5 in. (125 mm)

Minimum PWHT:

temperature = 1250°F

holding time for over 5 inches = 5 hours + 15 minutes for each additional inch

= 5 hours + 15 minutes × 1 additional inch

= 5.25 hours

The minimum PWHT temperature is 1250°F (675°C) and held for a minimum of 5.25 hours.

Practice Problem Q67: Table UCS-56 Heat Treatment of Carbon and Low Alloy Steels

What is the minimum PWHT temperature and minimum holding time for SA-335 grade P11 with a nominal wall thickness of 2.50 in.?

a) 1100°F for 2 hours
b) 1200°F for 2 hours
c) 1100°F for 2.5 hours
d) 1200°F for 2.5 hours

Table UCS-56.1 Alternative Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels

Table UCS-56.1 presents alternative lower temperatures with corresponding longer times at temperature; see Table UCS-56.1 Note (1). Postweld heat treatment temperatures of 150°F or 200°F lower than permitted in Tables UCS-56 are only permitted for P-No. 1 Gr. No. 1 and 2 materials; see Table UCS-56.1 Note (2).

Example Q68: Table UCS-56.1 Alternative Heat Treatment of Carbon and Low Alloy Steels

What is the minimum PWHT holding time for a 6 in. thick nozzle attached to a pressure vessel made from SA-516 grade 60 and PWHT at 900°F?

Since SA-516 grade 60 is listed in ASME Section IX, QW-422, as a P-No. 1 Group 1, C–Mn–Si steel, then Table UCS-56.1 applies. The minimum required temperature for P-No. Group 1 material in Table UCS-56 is 1100°F.

TABLE UCS-56
POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]		
		Up to 2 in. (50 mm)	Over 2 in. to 5 in. (50 mm to 125 mm)	Over 5 in. (125 mm)
P-No. 1 Gr. Nos. 1, 2, 3	1,100 (595)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)

Since the minimum holding temperature in Table UCS-56 is 1100°F:

then the adjusted holding time = 1100°F – 900°F
= 200°F

From Table UCS-56.1, minimum holding time for a decrease of 200°F:

= 20 hours + 15 minutes for each inch above 1 in.
= 20 hours + (6 in. – 1 in.) (15 minutes)
= 20 hours + (5 in. × 15 minutes)
= 21.25 hour

TABLE UCS-56.1
ALTERNATIVE POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS
Applicable Only When Permitted in Table UCS-56

Decrease in Temperature Below Minimum Specified Temperature, °F (°C)	Minimum Holding Time [Note (1)] at Decreased Temperature, hr	Notes
50 (28)	2	...
100 (56)	4	...
150 (83)	10	(2)
200 (111)	20	(2)

NOTES:
(1) Minimum holding time for 1 in. (25 mm) thickness or less. Add 15 minutes per inch (25 mm) of thickness for thicknesses greater than 1 in. (25 mm).
(2) These lower postweld heat treatment temperatures permitted only for P-No. 1 Gr. Nos. 1 and 2 materials.

UG-84 Charpy Impact Tests

UG-84(b) and UG-84(c) specifies that Charpy impact testing consists of a set of three specimens that are prepared and tested in accordance with SA-370 from ASME Section II, Part A.

UG-84(c)(2) establishes the standard size specimen (i.e., full-size) is 10 x 10 mm in cross section and 55 mm in length. The standard 10 mm x 10 mm specimens are used for nominal base metal thicknesses of 7/16 in. (11 mm) or greater, except when otherwise permitted in UG-84(c)(2)(a) as follows.

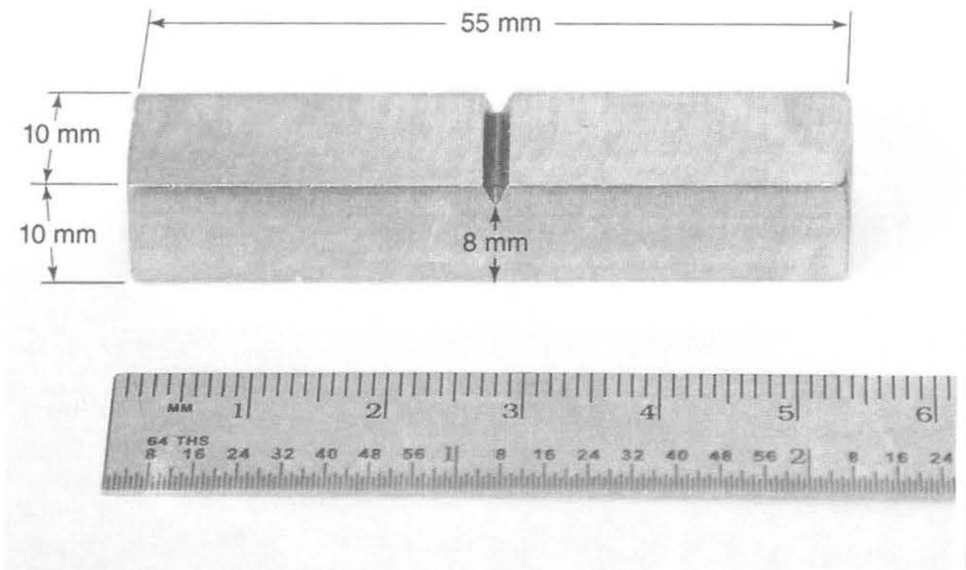


Figure 22 Full-size Charpy specimen 10 mm x 10 mm x 55 mm with 2 mm "V" notch depth (UG-84 from ASME VIII-1).

UG-84(c)(2)(a) allows for the use of a sub-size Charpy impact test specimen (i.e., less than 10 mm width) for materials that normally have absorbed energy in excess of 180 ft-lbf (240 J).

UG-84(c)(3) also permits the use of sub-size specimens when the material being tested is less than 10 mm thick or the shape is not conducive to extract a full-size specimen; however, the sub-size specimens must be either:

- the largest possible standard sub-size specimens obtainable, or
- specimens of full material nominal thickness that may be machined to remove surface irregularities.

In such instances, Table UG-84.2 may apply and a reduction in test temperature may be required to compensate for the reduced test specimen size.

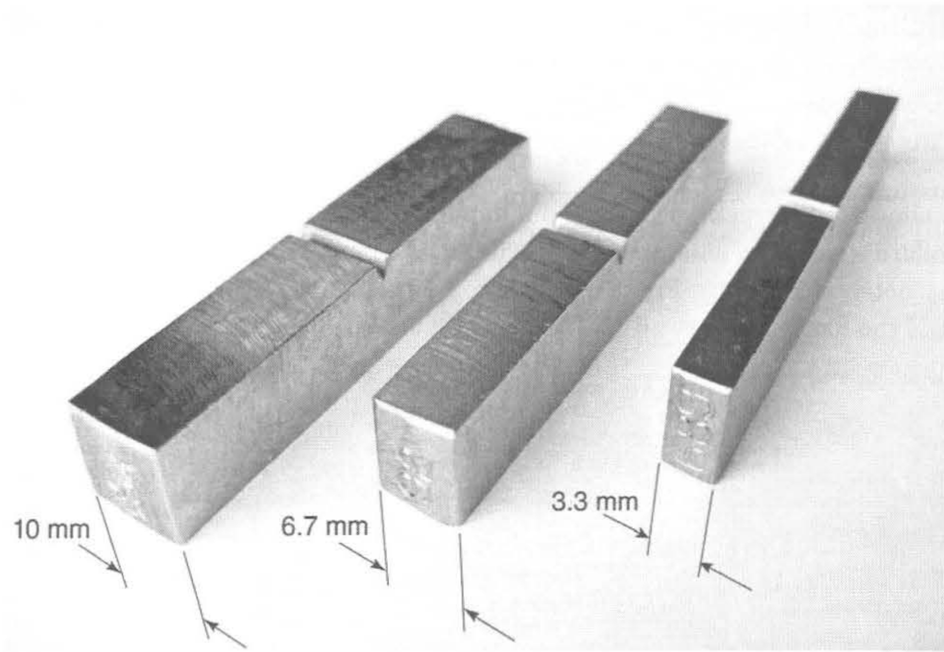


Figure 23 Full-size, 2/3 size, and 1/3 size Charpy V-notch specimens.

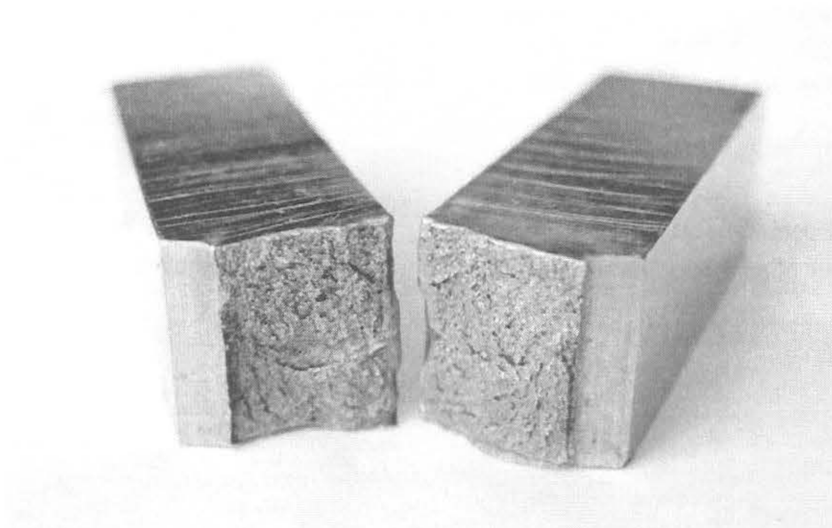


Figure 24 Broken Charpy V-notch specimen after testing.

Fig. UG-84.1 Minimum Absorbed Energy Requirement for Charpy Impact Specimens

UG-84(c)(4)(a) directs users to Fig. UG-84.1, which shows the minimum energy requirement for all Charpy impact test specimen sizes for Table UCS-23 materials that have a specified minimum tensile strength of less than 95,000 psi (655 MPa).

If a sub-size specimen is used in the test, then the value in Fig. UG-84.1 is multiplied by the ratio of the actual specimen width along the notch to the width of a full-size (i.e., 10 mm x 10 mm) specimen. However, there are two exceptions in UG-84(c)(4)(a) that must be noted, as follows:

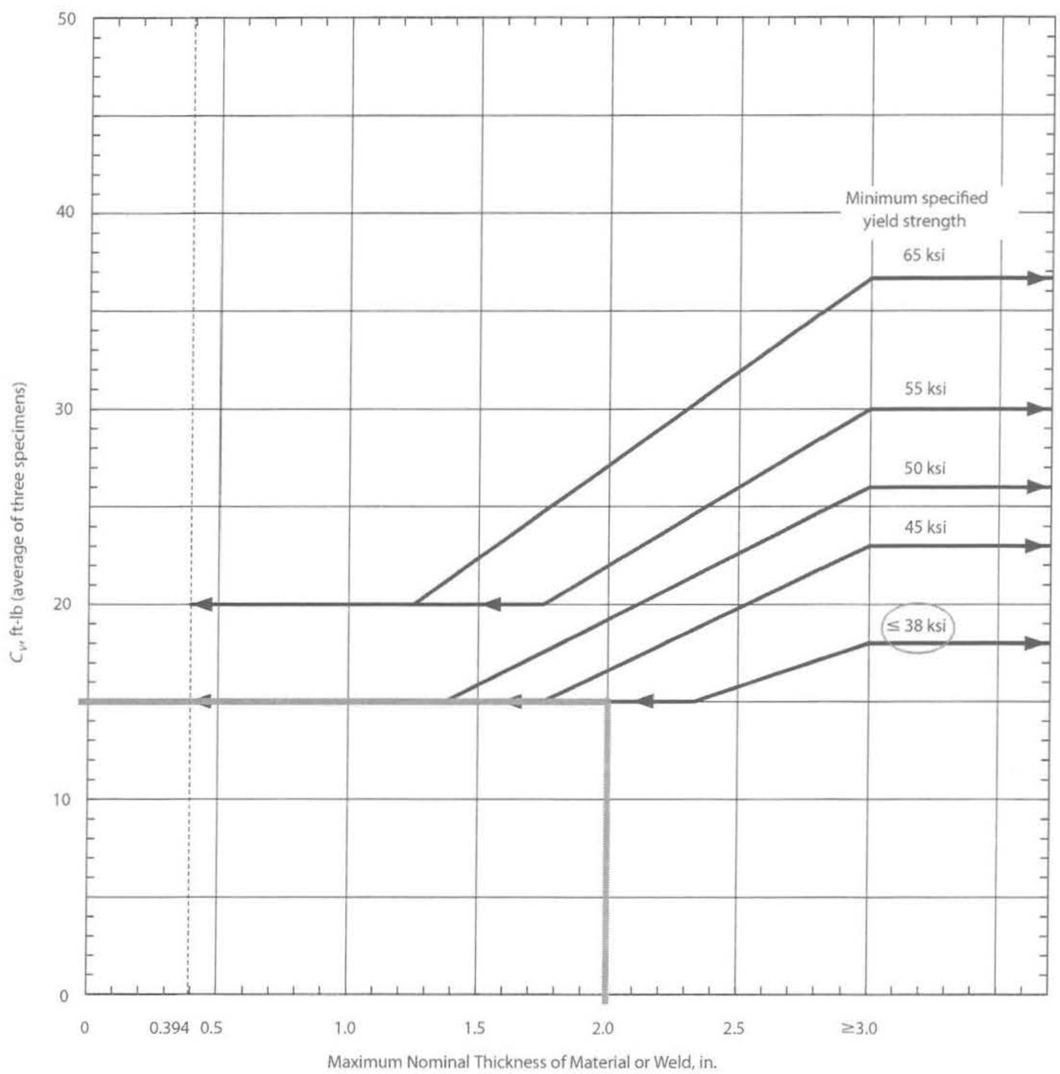
- see General Note (c) of Fig. UG-84.1, and
- as provided in UG-84(c)(2)(a) for materials that normally have absorbed energy in excess of 180 ft-lbf (240 J).

Example Q71: Minimum Absorbed Energy Requirement

What are the minimum single and average values for a Charpy impact test specimen using 2 in. thick carbon steel with a minimum specified yield strength of 36 ksi for a pressure vessel application?

From ASME Section VIII, Division 1, Fig. UG-84.1 and Footnote (b):

FIG. UG-84.1 CHARPY V-NOTCH IMPACT TEST REQUIREMENTS FOR FULL SIZE SPECIMENS FOR CARBON AND LOW ALLOY STEELS, HAVING A SPECIFIED MINIMUM TENSILE STRENGTH OF LESS THAN 95 ksi, LISTED IN TABLE UCS-23



GENERAL NOTES:

(a) Interpolation between yield strengths shown is permitted.

(b) The minimum impact energy for one specimen shall not be less than $\frac{2}{3}$ of the average energy required for three specimens. The average impact energy value of the three specimens may be rounded to the nearest ft-lb.

(c) Material produced and impact tested in accordance with SA-320, SA-333, SA-334, SA-350, SA-352, SA-420, impact tested SA/AS 1548 (*L* impact designations), SA-437, SA-540 (except for materials produced under Table 2, Note 4 in SA-540), and SA-765 do not have to satisfy these energy values. See UCS-66(g).

(d) For materials having a specified minimum tensile strength of 95 ksi or more, see UG-84(c)(4)(b).

The minimum average value Charpy impact test value is 15 ft-lb.

The minimum single value is:

$$15 \text{ ft-lb} \times 2/3 = 10 \text{ ft-lb}.$$

UCS-66 Rules for Determining Lowest Minimum Design Metal Temperature (MDMT) Without Impact Testing

UCS-66 gives the toughness design requirements for carbon and low alloy steels. Unless they are exempted by this item of the Code or item UG-20(f), materials require verification of toughness by Charpy impact testing. The exemption requirements are based on service temperature, material thickness, material chemistry, and steel making practice.

UCS-66(a) specifies that listed UCS materials may be exempt from impact testing when the MDMT and thickness combination is on or above the curve from Fig. UCS-66 or above the tabular value in Table UCS-66.

If the governing thickness at any welded joint exceeds 4 in. and the MDMT is colder than 120°F (50°C), UCS-66(a)(1)(d) requires that impact tested material shall be used.

UCS-66(d) permits materials less than 0.10 inches thick to be exempt from impact testing at temperatures no colder than -55°F. Materials impact tested as per the material specification are exempt at temperatures no colder than the specification temperature.

There are many detailed requirements and exemptions in UCS-66 to obtain the MDMT without impact testing. One of the more common exemptions is by calculating the "coincident ratio" permitted by UCS-66(b) and defined in Fig. UCS-66.1 and related footnotes, as follows:

$$\text{Coincident Ratio} = \frac{t_r \times E^*}{t_n - c}$$

where:

t_r = required thickness of the component under consideration in the corroded condition for all applicable loadings, based on the applicable joint efficiency E, in.

E^* = as defined in General Note (c) of Fig. UCS-66.2

t_n = nominal thickness of the component under consideration before corrosion allowance is deducted, in.

c = corrosion allowance, in.

Fig. UCS-66.1 can then be used to obtain a reduction to the MDMT without impact testing that can be applied to Fig. UCS-66 or Table UCS-66.

For P–Number 1 materials, two further means of lowering the exemption requirement can be realized. From Fig. UCS-66 or Table UCS-66, a temperature reduction of 30°F (17°C) may be realized by postweld heat treating the vessel—provided that other articles of the Code do not require it as indicated in UCS-68(c). UG-20(f) provides impact test exemption for P-Number 1, Groups 1 and 2 materials, which also must meet all of the other five requirements listed in this code paragraph.

UCS-66(b)(2) requires all carbon and low alloy steel materials be impact tested when the minimum design temperature is less than -55°F (-48°C) with the exception that the material is exempt down to -155°F (-104°C) if the coincident ratio is 0.35 or less.

Example Q73: Temperature Reduction (continued)

The temperature reduction for a given material thickness and impact specimen width can be obtained from Table UG-84.2.

TABLE UG-84.2
CHARPY IMPACT TEST TEMPERATURE REDUCTION BELOW MINIMUM DESIGN METAL TEMPERATURE
For Table UCS-23 Materials Having a Specified Minimum Tensile Strength of Less Than 95,000 psi (655 MPa) When the Subsize Charpy Impact Width Is Less Than 80% of the Material Thickness

Actual Material Thickness [See UG-84(c)(5)(b)] of Charpy Impact Specimen Width Along the Notch (1)	
Thickness, in. (mm)	Temperature Reduction, °F (°C)
0.394 (Full-size standard bar) (10)	0 (0)
0.354 (9)	0 (0)
0.315 (8.00)	0 (0)
0.295 (3/4 size bar) (7.5)	5 (3)
0.276 (7)	8 (4)
0.262 (2/3 size bar) (6.7)	10 (6)
0.236 (6)	15 (8)
0.197 (1/2 size bar) (5.00)	20 (11)
0.158 (4)	30 (17)
0.131 (1/3 size bar) (3.3)	35 (19)
0.118 (3.00)	40 (22)
0.099 (1/4 size bar) (2.5)	50 (28)

NOTE:
(1) Straight line interpolation for intermediate values is permitted.

Step 1: temperature reduction for 5 mm material = 11°C

Step 2: temperature reduction for 4 mm impact specimen = 17°C

Step 3: test temperature reduction = design minimum temperature + TR_{amt} – TRs
= -40°C + 11°C – 17°C
= -46°C

Practice Problem Q74: Temperature Reduction

An ASTM A671 Gr CC70 pipe has an actual thickness of 6.32 mm from which a 5 mm Charpy impact test specimen was machined. If the design minimum temperature is -46°C, what is the required Charpy impact test temperature?

a) -46.0°C
b) -50.1°C
c) -41.9°C
d) -60.2°C

UCS-66 Rules for Determining Lowest Minimum Design Metal Temperature (MDMT) Without Impact Testing

UCS-66 gives the toughness design requirements for carbon and low alloy steels. Unless they are exempted by this item of the Code or item UG-20(f), materials require verification of toughness by Charpy impact testing. The exemption requirements are based on service temperature, material thickness, material chemistry, and steel making practice.

UCS-66(a) specifies that listed UCS materials may be exempt from impact testing when the MDMT and thickness combination is on or above the curve from Fig. UCS-66 or above the tabular value in Table UCS-66.

If the governing thickness at any welded joint exceeds 4 in. and the MDMT is colder than 120°F (50°C), UCS-66(a)(1)(d) requires that impact tested material shall be used.

UCS-66(d) permits materials less than 0.10 inches thick to be exempt from impact testing at temperatures no colder than -55°F. Materials impact tested as per the material specification are exempt at temperatures no colder than the specification temperature.

There are many detailed requirements and exemptions in UCS-66 to obtain the MDMT without impact testing. One of the more common exemptions is by calculating the "coincident ratio" permitted by UCS-66(b) and defined in Fig. UCS-66.1 and related footnotes, as follows:

$$\text{Coincident Ratio} = \frac{t_r \times E^*}{t_n - c}$$

where:

t_r = required thickness of the component under consideration in the corroded condition for all applicable loadings, based on the applicable joint efficiency E, in.

E^* = as defined in General Note (c) of Fig. UCS-66.2

t_n = nominal thickness of the component under consideration before corrosion allowance is deducted, in.

c = corrosion allowance, in.

Fig. UCS-66.1 can then be used to obtain a reduction to the MDMT without impact testing that can be applied to Fig. UCS-66 or Table UCS-66.

For P–Number 1 materials, two further means of lowering the exemption requirement can be realized. From Fig. UCS-66 or Table UCS-66, a temperature reduction of 30°F (17°C) may be realized by postweld heat treating the vessel—provided that other articles of the Code do not require it as indicated in UCS-68(c). UG-20(f) provides impact test exemption for P-Number 1, Groups 1 and 2 materials, which also must meet all of the other five requirements listed in this code paragraph.

UCS-66(b)(2) requires all carbon and low alloy steel materials be impact tested when the minimum design temperature is less than -55°F (-48°C) with the exception that the material is exempt down to -155°F (-104°C) if the coincident ratio is 0.35 or less.

Steps for Determining the Lowest Minimum Design Metal Temperature (MDMT) Without Impact Testing

Step 1. Determine appropriate Curve for the material, including the Notes in Fig. UCS-66.

Step 2. Determine the governing thickness (t_g) from UCS-66(a)(1).

Step 3. Using the Curve and t_g, determine the MDMT from Tabular Values in Table UCS-66.

Step 4. Determine additional exemption values for the MDMT by checking:

- a) UG-20(f);
- b) Fig. UCS-66.1 (coincident ratio); and
- c) UCS-68(c) provided the weld does not have to be PWHT to UCS-56—if yes, take 30°F reduction.

Step 5. Subtract the exemptions from the MDMT to obtain the lowest MDMT without impact testing for the governing thickness under consideration.

Example Q75: Minimum Design Metal Temperature (MDMT) Without Impact Testing

At what temperature is impact testing required for the following conditions in a new pressure vessel? A vertical vessel made from SA-516 grade 70, as-rolled, nominal wall thickness of 1.500 in., at 600°F with a MAWP of 350 psi, with seamless hemispherical heads (top and bottom).

Procedure:

Step 1: From the notes in Fig. UCS-66, SA-516 Gr. 70, if not normalized (i.e., as-rolled) is listed under Curve B.

FIG. UCS-66 IMPACT TEST EXEMPTION CURVES (CONT'D)

NOTES:

(2) Curve B applies to:

(a) SA-216 Grade WCA if normalized and tempered or water-quenched and tempered

SA-216 Grades WCB and WCC for thicknesses not exceeding 2 in. (50 mm), if produced to fine grain practice and water-quenched and tempered

SA-217 Grade WC9 if normalized and tempered

SA-285 Grades A and B

SA-414 Grade A

SA-515 Grade 60

SA-516 Grades 65 and 70 if not normalized

SA-612 if not normalized

SA-662 Grade B if not normalized

SA/EN 10028-2 Grades P295GH and P355GH as-rolled;

(b) except for cast steels, all materials of Curve A if produced to fine grain practice and normalized which are not listed in Curves C and D below;

(c) all pipe, fittings, forgings and tubing not listed for Curves C and D below;

(d) parts permitted under UG-11 shall be included in Curve B even when fabricated from plate that otherwise would be assigned to a different curve.

Step 2: t_g = 1.500 in. (see UCS-66(a)(1)(a))

Step 3: From Table UCS-66, under Curve B and thickness of 1.500 in., the MDMT = 51°F.

TABLE UCS-66
TABULAR VALUES FOR FIG. UCS-66 AND FIG. UCS-66M

Customary Units					SI Units				
Thickness, in.	Curve A, °F	Curve B, °F	Curve C, °F	Curve D, °F	Thickness, mm	Curve A, °C	Curve B, °C	Curve C, °C	Curve D, °C
1.5	88	51	14	-14	38.1	31	11	-10	-26
1.5625	90	53	16	-13	39.7	32	12	-9	-25
1.625	92	55	17	-11	41.3	33	13	-8	-24
1.6875	93	57	19	-10	42.9	34	14	-7	-23
1.75	94	58	20	-8	44.5	34	14	-7	-22

Step 4: a) From UG-20(f)(1)(b), since the vessel thickness is greater than 1 in. and is listed in Curve B, then this exemption cannot be taken.

b) There is no coincident ratio exemption.

c) From Table UCS-56 Note 2(b), since preheat was not applied and the thickness is greater than 1-1/4 in., then PWHT is required and the UCS-68(c) exemption cannot be taken.

Therefore, the MDMT (without impact testing) = 51°F.

Practice Problem Q76: Minimum Design Metal Temperature (MDMT) Without Impact Testing

At what temperature is impact testing required for the following conditions in a new pressure vessel? A vertical vessel made from SA-516 grade 70, normalized, nominal wall thickness of 1.500 in., has a design temperature of 600°F with a MAWP of 350 psi., and a WPS that included a 250°F preheat and PWHT.

a) 14°F
b) –14°F
c) –44°F
d) impact testing is not required

Example Q77: MDMT With Coincident Ratio

A pressure vessel is made from SA-516 grade 70, quenched and tempered, nominal wall thickness of 0.500 in., a MSTS of 70 ksi with a coincident ratio temperature reduction of 20°F, with a MAWP of 150 psi at 675°F. What is the MDMT without impact testing, including all exemptions?

Procedure:

Step 1: From the notes in Fig. UCS-66: SA-516 grade 70, quenched and tempered is listed under Curve D.

FIG. UCS-66 IMPACT TEST EXEMPTION CURVES (CONT'D)

NOTES:
(4) Curve D applies to:
SA-203
SA-508 Grade 1
SA-516 if normalized or quenched and tempered
SA-524 Classes 1 and 2
SA-537 Classes 1, 2, and 3
SA-612 if normalized
SA-662 if normalized
SA-738 Grade A
SA-738 Grade A with Cb and V deliberately added in accordance with the provisions of the material specification, not colder than −20°F (−29°C)
SA-738 Grade B not colder than −20°F (−29°C)
SA/AS 1548 Grades 7-430, 7-460, and 7-490 if normalized
SA/EN 10028-2 Grades P295GH and P355GH if normalized
SA/EN 10028-3 Grade P275NH

Step 2: t_g = 0.500 in. (see UCS-66(a)(1)(a))

Step 3: From Table UCS-66 under Curve D and thickness of 0.500 in., the MDMT = –55°F.

TABLE UCS-66
TABULAR VALUES FOR FIG. UCS-66 AND FIG. UCS-66M

Customary Units					SI Units				
Thickness, in.	Curve A, °F	Curve B, °F	Curve C, °F	Curve D, °F	Thickness, mm	Curve A, °C	Curve B, °C	Curve C, °C	Curve D, °C
0.25	18	-20	-55	-55	6.4	-8	-29	-48	-48
0.3125	18	-20	-55	-55	7.9	-8	-29	-48	-48
0.375	18	-20	-55	-55	9.5	-8	-29	-48	-48
0.4375	25	-13	-40	-55	11.1	-4	-25	-40	-48
0.5	32	-7	-34	-55	12.7	0	-22	-37	-48

Step 4:
a) From UG-20(f), although the material is P-No. 1, Group 2 and under 1 in. in thickness, it is not exempt from impact testing since UG-20(f)(3) limits the maximum design temperature to 650°F (i.e., the operating temperature is 675°F).
b) From the question, take the coincident ratio reduction of 20°F below the value in Table UCS-66.
c) There was no mention of PWHT in the question, so the UCS-68(c) exemption cannot be taken.

Therefore, with the coincident ratio exemption:

The final MDMT (without impact testing) = –55°F – (20°F) = –75°F

Practice Problem Q78: MDMT With Coincident Ratio

A pressure vessel is made from SA 516 grade 60, with a nominal wall thickness of 0.750 in., a MSTS of 60 ksi with a coincident ratio temperature reduction of 20°F, and a MAWP of 150 psi at 675°F. What is the MDMT without impact testing, including all exemptions?

a) –22°F
b) –4°F
c) –35°F
d) –62°F

UHT-6 Test Requirements

Quenched and Tempered Steel Products

The approved quenched and tempered steel products listed in Table UHT-23 are either in plate, pipe, casting, or forged component form.

When welding a quenched and tempered steel, the heat input of welding will develop temperatures higher than the final tempering temperature of the base metal [in the range of 1200°F (650°C)] and results in a destruction of strength, and, in many cases, a loss of toughness. UHT-5 requires these materials be toughness tested at the minimum service temperature and that tests be done to ensure welding, warm forming, or PWHTs have not destroyed the strength and toughness of the material. The toughness test criteria are given in UHT-6.

The minimum test requirement of UHT-6 is a Charpy impact test with a lateral expansion acceptance criterion. Figure 28 shows lateral expansion being measured. Some of the materials also require a drop weight test to demonstrate that the material can withstand a prescribed blow without cracking or fracture at the minimum service temperature of the vessel. The criteria for lateral expansion are shown graphically in Fig. UHT-6.1.

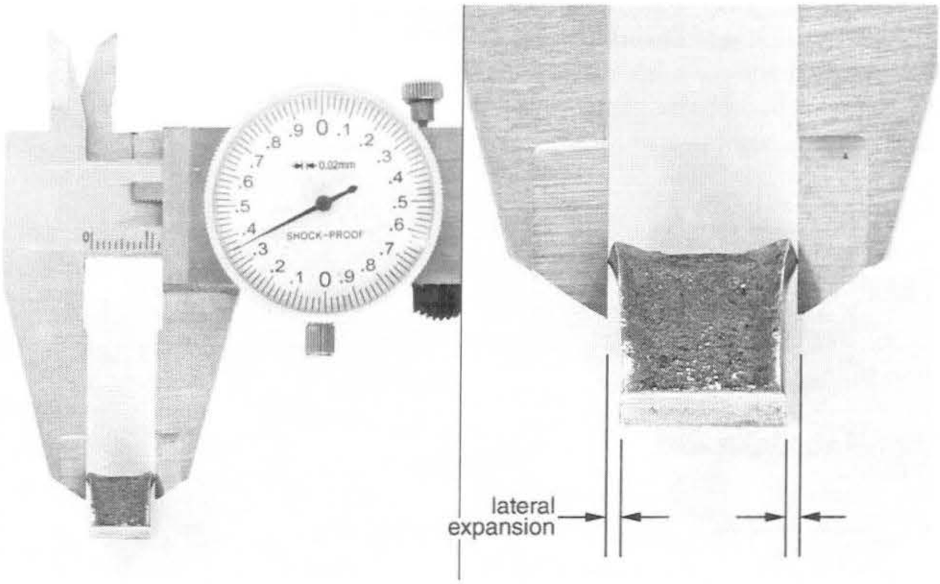


Figure 28 Vernier calipers being used to measure lateral expansion
on a 10 mm (full size) Charpy impact specimen.

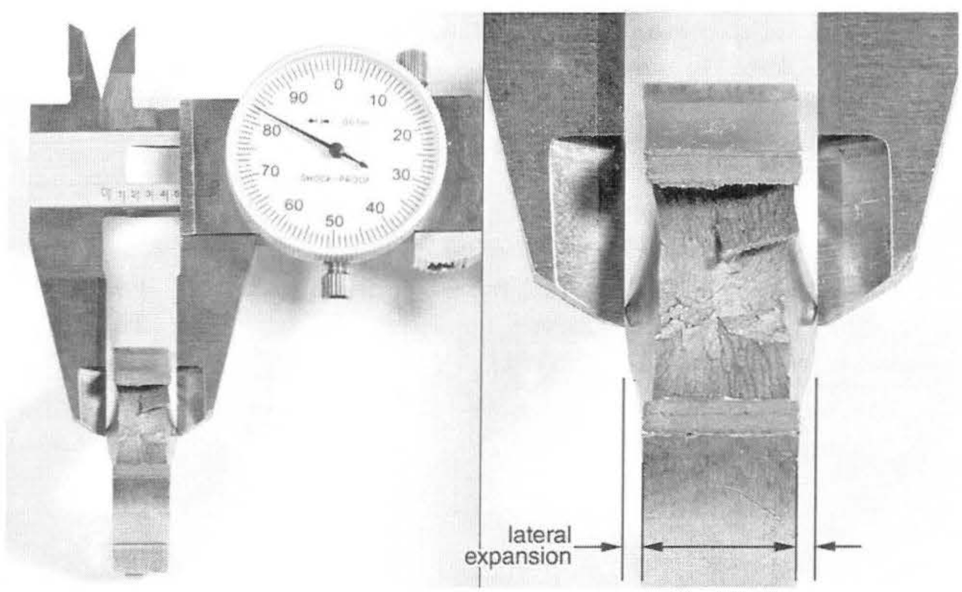


Figure 29 Vernier calipers being used to measure lateral expansion
on an unbroken 10 mm (full size) Charpy impact specimen.

If the value of lateral expansion for one specimen is less than that required in Fig. UHT-6.1, then the retest requirements in UHT-6(a)(4) are as follows:

- If the value of lateral expansion for one specimen is less than that required in Fig. UHT-6.1 but not less than 2/3 of the required value, a retest of three additional specimens may be made, each of which must be equal to or greater than the required value in Fig. UHT-6.1.

Note: UHT-6(b) requires that materials conforming to SA-353 and SA-553 for use at MDMTs colder than –320°F (–196°C), shall have, in addition to the Charpy tests required under UHT-6(a), drop-weight tests as defined by ASTM E 208; see UHT-6(b) for more details.

Practice Problem Q79: Alloy Steels

What is the impact testing basis for pressure vessel materials with a specified minimum tensile strength greater than 95 ksi and a known thickness?

a) lateral expansion (mils)
b) absorbed energy (ft-lb)
c) Charpy impact strength
d) absorbed energy (J)

Practice Problem Q80: Alloy Steels

For plate materials conforming to SA-353 for use at MDMTs colder than -320°F (-196°C), in addition to the Charpy tests, what other impact testing is required?

a) dropweight test
b) izod test
c) sudden load test
d) sub-size test

Solutions

For ASME Section VIII, Division 1, Practice Problems

Answer Key – ASME Section VIII, Division 1, Practice Problems

Practice Problem	Answer	Reference Paragraph
Q1:	b	U-1(c)(2)(f)
Q2:	a	U-2(b)(1)
Q3:	a	UG-4(a)
Q4:	d	UG-9
Q5:	a	UG-16(c)
Q6:	a	UG-16(e)
Q7:	b	UG-20(b)
Q8:	b	UG-20(f)(1)(b)
Q9:	c	UG-22(a)
Q10:	b	UG-24(a)
Q11:	d	UW-2(a)
Q12:	b	UW-2(d)(2)
Q13:	d	UW-3(d)
Q14:	c	UW-5(b)
Q15:	c	UW-9(c)
Q16:	a	UW-3(a)
Q18:	c	Table UW-12
Q19:	c	UW-11(a)(2)
Q20:	d	UW-11(a)(5), UG-116(e)(1)
Q21:	c	UG-116(b)(1)
Q22:	a	UG-116(c)
Q23:	b	UG-116(e)(4)
Q24:	b	UG-116(f)(2)
Q26:	b	UW-51(a)(2)
Q27:	b	Appendix 4, Table 4-1
Q25:	d	UG-119(b)
Q28:	a	UG-120(a)(3)(c)
Q29:	c	UG-27(b)
Q30:	d	UG-27(b)
Q31:	d	UG-27(b)
Q33:	c	UG-27(c)(1)
Q34:	d	UG-81(a)
Q36:	d	UG-37 and Fig. UG-37.1
Q37:	d	UG-99(h)
Q38:	a	UG-99(h)
Q40:	c	UG-99(b)

Practice Problem	Answer	Reference Paragraph
Q42:	d	UG-100(a)
Q43:	d	UG-100(d)
Q45:	c	UG-100(b)
Q46:	c	UG-102(a)
Q47:	b	UG-102(b)
Q49:	d	Fig. UW-16.1(d), BoK
Q50:	d	UW-30
Q51:	c	UW-33(a), UW-3, Fig. UW-3
Q52:	a	UW-35(a)
Q53:	d	UW-35(d)
Q54:	a	UW-37(a)
Q56:	a	Appendix R
Q57:	d	UW-40(a)
Q58:	d	UW-40(a)(1)
Q59:	c	UCS-56(d)(1)
Q60:	c	UCS-56(d)(2)
Q61:	d	UCS-56(d)(4)
Q62:	c	UCS-56(f)(2)
Q63:	a	UCS-56(f)(4)(a)
Q64:	d	UCS-56(f)(4)(c)
Q67:	d	Section IX QW-422, Table UCS-56, P-No. 4
Q69:	c	UG-84(c)(2) and Fig. UG-84
Q70:	a	Fig. UG-84
Q72:	d	Fig. UG-84.1 General Note (b)
Q74:	b	Table UG-84.2
Q76:	c	UCS-66, see notebook for step-by-step solution
Q78:	c	UCS-66, see notebook for step-by-step solution
Q79:	a	Fig. UHT-6.1, General Note
Q80:	a	UHT-6(b)

Practice Problem Q18 Solution

What is the maximum allowable joint efficiency for a Category D Type No. (2) joint with spot radiographic examination?

From Table UW-12:

TABLE UW-12
MAXIMUM ALLOWABLE JOINT EFFICIENCIES FOR ARC AND GAS WELDED JOINTS

Type No.	Joint Description	Limitations	Joint Category	Degree of Radiographic Examination (a) Full [Note(1)]	(b) Spot [Note(2)]	(c) None
(1)	Butt joints as attained by double-welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside weld surfaces to agree with the requirements of UW-35. Welds using metal backing strips which remain in place are excluded.	None	A, B, C & D	1.00	0.85	0.70
(2)	Single-welded butt joint with backing strip other than those included under (1)	*(a)* None except as in (b) below	A, B, C & D	0.90	0.80	0.65
		(b) Circumferential butt joints with one plate offset; see UW-13(b)(4) and Fig. UW-13.1, sketch (i)	A, B & C	0.90	0.80	0.65
(3)	Single-welded butt joint without use of backing strip	Circumferential butt joints only, not over 5/8 in. (16 mm) thick and not over 24 in. (600 mm) outside diameter	A, B & C	NA	NA	0.60
(4)	Double full fillet lap joint	*(a)* Longitudinal joints not over 3/8 in. (10 mm) thick	A	NA	NA	0.55
		(b) Circumferential joints not over 5/8 in. (16 mm) thick	B & C [Note (3)]	NA	NA	0.55
(5)	Single full fillet lap joints with plug welds conforming to UW-17	*(a)* Circumferential joints [Note (4)] for attachment of heads not over 24 in. (600 mm) outside diameter to shells not over 1/2 in. (13 mm) thick	B	NA	NA	0.50
		(b) Circumferential joints for the attachment to shells ofj ackets not over 5/8 in. (16 mm) in nominal thickness where the distance from the center of the plug weld to the edge of the plate is not less than 1 1/2 times the diameter of the hole for the plug.	C	NA	NA	0.50

The maximum allowable joint efficiency is 0.80.

Practice Problem Q33 Solution

A 150 foot vertical vessel is designed to have a cylindrical shell with an inside radius of 8 ft., an internal design pressure of 1,100 psi, made of SA-516 Gr. 70, normalized, operating at 500°F, with an allowable stress value of 20,000 psi, that was constructed with Type (2) weld joints and spot radiography. The content has the same specific gravity as water. What is the minimum thickness required for this design?

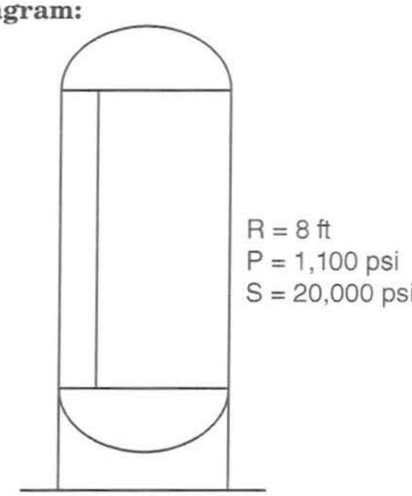
Formula:

from ASME Section VIII-1, ¶UG-27(c)(1) for cylindrical shells with circumferential stress:

$$t = \frac{PR}{SE - 0.6P}$$

from UG-22(b): P must include static head of contents.

Diagram:



Required Variables:

P = 1,100 psi + Static Head
R = 8 ft. = 96 in.
S = 20,000 psi
E = 0.8 from ASME Section VIII-1, Table UW-12 for Type (2) with spot radiography
Conversion factor = 0.433 psi/ft.

P = 1,100 psi + Static Head
P = 1,100 psi + (0.433 psi/ft. × 150 ft.)
P = 1,100 psi + 65 psi
P = 1,165 psi

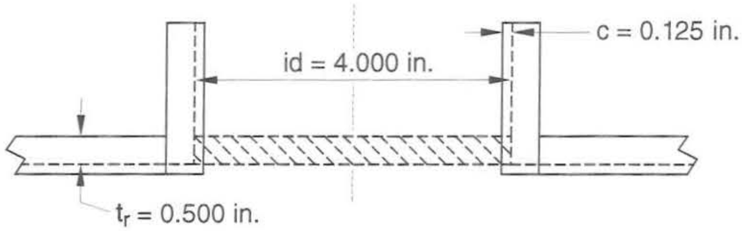
$$t = \frac{PR}{SE - 0.6P}$$
$$= \frac{(1{,}165 \text{ psi})(96 \text{ in.})}{(20{,}000 \text{ psi} \times 0.8) - (0.6 \times 1{,}165 \text{ psi})}$$
$$= \frac{111{,}840 \text{ psi} \cdot \text{in.}}{(16{,}000 \text{ psi} - 699 \text{ psi})}$$
$$= \frac{111{,}840 \text{ psi} \cdot \text{in.}}{15{,}301 \text{ psi}}$$
$$= 7.309 \text{ in.}$$

Correct answer is c).

Practice Problem Q36 Solution

A vertical vessel has a 36 in. diameter seamless shell with a required wall thickness of 0.500 in., made from SA-516 grade 70, as-rolled, with an allowable stress of 20,000 psi at 400°F with an internal design pressure of 350 psi. The inlet nozzle has an inside diameter of 4.000 inches in the uncorroded condition and required thickness of 0.375 in. The entire vessel, including all heads and nozzles, has a corrosion allowance of 0.125 in. What is the total cross-sectional area of reinforcement required for the corroded condition?

Diagram:



Formula:
From Fig. UG-37.1:

$A = d\ t_r$ since F = 1.0 and f_r = 1.0 (from Body of Knowledge)

To satisfy UG-16(e), the corroded condition must be achieved by removing the corrosion allowance from the nozzle thickness, then:

$d_{corroded} = id + 2\ c$ (in the corroded condition)

Required Variables:

id = 4.000 in.
c = 0.125 in.
t_r = 0.500 in.

$$\begin{aligned} A &= d\ t_r \\ &= (id + 2 \times c)\ t_r \\ &= (4.000 \text{ in.} + 2 \times 0.125 \text{ in.}) \times 0.500 \text{ in.} \\ &= 4.250 \text{ in.} \times 0.500 \text{ in.} \\ &= 2.125 \text{ in.}^2 \end{aligned}$$

Correct answer is d).

Practice Problem Q40 Solution

For design pressure and temperature limits of 1,100 psig and 700°F using SA-106 grade B as the shell material, what is the minimum hydrostatic test pressure required with a test fluid of water at 75°F? S at design temperature is 15.6 ksi and S at test temperature is 17.1 ksi. Round to the nearest whole number.

Formula:

from ASME Section VIII-1, ¶UG-99(b):

$$P_T = 1.3 \times MAWP \times \left(\frac{S_T}{S_D}\right)$$

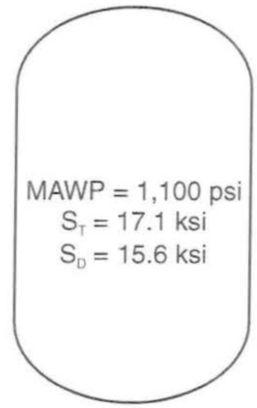
Required Variables:

MAWP = 1,100 psi
S_T = 17.1 ksi
S_D = 15.6 ksi

$$P_T = 1.3 \times MAWP \times \left(\frac{S_T}{S_D}\right)$$
$$= 1.3 \times 1{,}100\text{ psi} \times \left(\frac{17.1\text{ ksi}}{15.6\text{ ksi}}\right)$$
$$= 1.3 \times 1{,}100\text{ psi} \times 1.096$$
$$= 1{,}568\text{ psi}$$

Correct answer is c).

Diagram:



ASME SA-106 Grade B

Practice Problem Q45 Solution

For design pressure and temperature limits of 1,100 psi and 700°F using SA-106 grade B as the shell material, what is the minimum pneumatic test pressure required with a test temperature at 75°F? S at design temperature is 15.6 ksi and S at test temperature is 17.1 ksi. Round to the nearest whole number.

Formula:

From ASME Section VIII-1, ¶UG-100(b):

$$P_T = 1.1 \times MAWP \times \left(\frac{S_T}{S_D}\right)$$

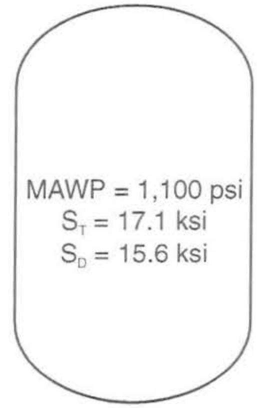
Required Variables:

MAWP = 1,100 psi
S_T = 17.1 ksi
S_D = 15.6 ksi

$$\begin{aligned} P_T &= 1.1 \times MAWP \times \left(\frac{S_T}{S_D}\right) \\ &= 1.1 \times 1{,}100 \text{ psi} \times \left(\frac{17.1 \text{ ksi}}{15.6 \text{ ksi}}\right) \\ &= 1.1 \times 1{,}100 \text{ psi} \times 1.096 \\ &= 1{,}326 \text{ psi} \end{aligned}$$

Correct answer is c).

Diagram:



ASME SA-106 Grade B

Practice Problem Q2 Solution:

What is the socket-welded flange-to-pipe leg size, where nominal wall thickness of pipe is 0.500 in. with a hub thickness of 0.600 in., and made from A381 Grade Y48?

Formula:

From Fig. UW-21:

X_{min} = the lesser of $1.4t_n$ or
the thickness of the hub

t_n = 0.500 in.
hub thickness = 0.600 in.

Diagram:

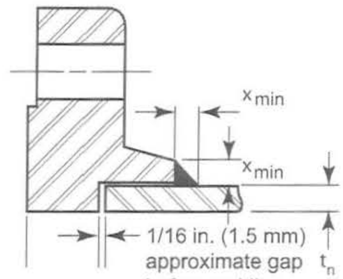


Fig. UW-21(4)

leg size = X_{min} = the lesser of $1.4t_n$ or the thickness of the hub.
= lesser of 1.4 × 0.500 in. or 0.600 in.
= lesser of 0.700 in. or 0.600 in.
= 0.600 in.

Practice Problem Q49 Solution

What is the outer fillet weld leg size in a nozzle designed to Fig. UW-16.1 (d), where t_c is 0.500 in., the nozzle thickness is 0.375 in., and made from SA-333 grade 6?

Formula:

t_c = 0.707 × leg size   from Body of Knowledge: 8(a) weld size throat to leg conversion

Required Variables:

t_c = 0.500 in.

t_c = 0.707 × leg size

$$\text{leg size} = \frac{t_c}{0.707} = \frac{0.500 \text{ in.}}{0.707} = 0.707 \text{ in.}$$

Correct answer is d).

Practice Problem Q56 Solution:

What is the Section VIII, Division 1, suggested preheat requirement for NPS 10, Sch 80, 0.594 inch, ASME SA-335/SA -335M Grade P1 seamless piping material with an ambient temperature of 0°F?

The P-No. for this material can be read from ASME Section IX, Table QW/QB-422

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	Nominal Composition	Product Form
SA-335	P1	K11522	55 (380)	3	1	101	C–0.5Mo	Smls. pipe
SA-335	P2	K11547	55 (380)	3	1	101	0.5Cr–0.5Mo	Smls. pipe
SA-335	P12	K11562	60 (415)	4	1	102	1Cr–0.5Mo	Smls. pipe
SA-335	P15	K11578	60 (415)	3	1	101	1.5Si–0.5Mo	Smls. pipe
SA-335	P11	K11597	60 (415)	4	1	102	1.25Cr–0.5Mo–Si	Smls. pipe
SA-335	P22	K21590	60 (415)	5A	1	102	2.25Cr–1Mo	Smls. pipe
SA-335	P21	K31545	60 (415)	5A	1	102	3Cr–1Mo	Smls. pipe
SA-335	P5c	K41245	60 (415)	5B	1	102	5Cr–0.5Mo–Ti	Smls. pipe
SA-335	P5	K41545	60 (415)	5B	1	102	5Cr–0.5Mo	Smls. pipe
SA-335	P5b	K51545	60 (415)	5B	1	102	5Cr–0.5Mo–Si	Smls. pipe

Using the P-No., the required minimum preheat temperature can be read from Appendix R.

P-No. 3 Group Nos. 1, 2, and 3

(a) 175°F (79°C) for material which has either a specified minimum tensile strength in excess of 70,000 psi (480 MPa) or a thickness at the joint in excess of 5/8 in. (16 mm);
(b) 50°F (10°C) for all other materials in this P-Number.

The suggested preheat is 50°F (10°C).

Correct answer is a).

Practice Problem Q67 Solution:

What is the minimum PWHT temperature and minimum holding time for SA-335 grade P11 with a nominal wall thickness of 2.50 in.?

Table UCS-56 lists heat treatment requirements that are organized by P-No. The P-No. for all B&PV materials are found in ASME Section IX, QW-422, as follows.

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-335	P1	K11522	55 (380)	3	1	101	1.1	C-0.5Mo	Smls. pipe
SA-335	P2	K11547	55 (380)	3	1	101	4.2	0.5Cr-0.5Mo	Smls. pipe
SA-335	P12	K11562	60 (415)	4	1	102	5.1	1Cr-0.5Mo	Smls. pipe
SA-335	P15	K11578	60 (415)	3	1	101	...	1.5Si-0.5Mo	Smls. pipe
SA-335	P11	K11597	60 (415)	4	1	102	5.1	1.25Cr-0.5Mo-Si	Smls. pipe

Since SA-335 Grade P11 has an ASME P-No. 4, then find the required PWHT values in Table UCS-56 for P-No. 5A, with a thickness of 2.50 in, as follows:

TABLE UCS-56
POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS (CONT'D)

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)] Up to 2 in. (50 mm)	Over 2 in. to 5 in. (50 mm to 125 mm)	Over 5 in. (125 mm)
P-No. 4 Gr. Nos. 1, 2	1,200 (650)	1 hr/in. (25 mm), 15 min minimum	1 hr/in. (25 mm)	5 hr plus 15 min for each additional inch (25 mm) over 5 in. (125 mm)

Minimum PWHT:

temperature = 1200°F

holding time for 2.50 inches = 2.50 in. × 1 hr/in.

= 2.50 hours

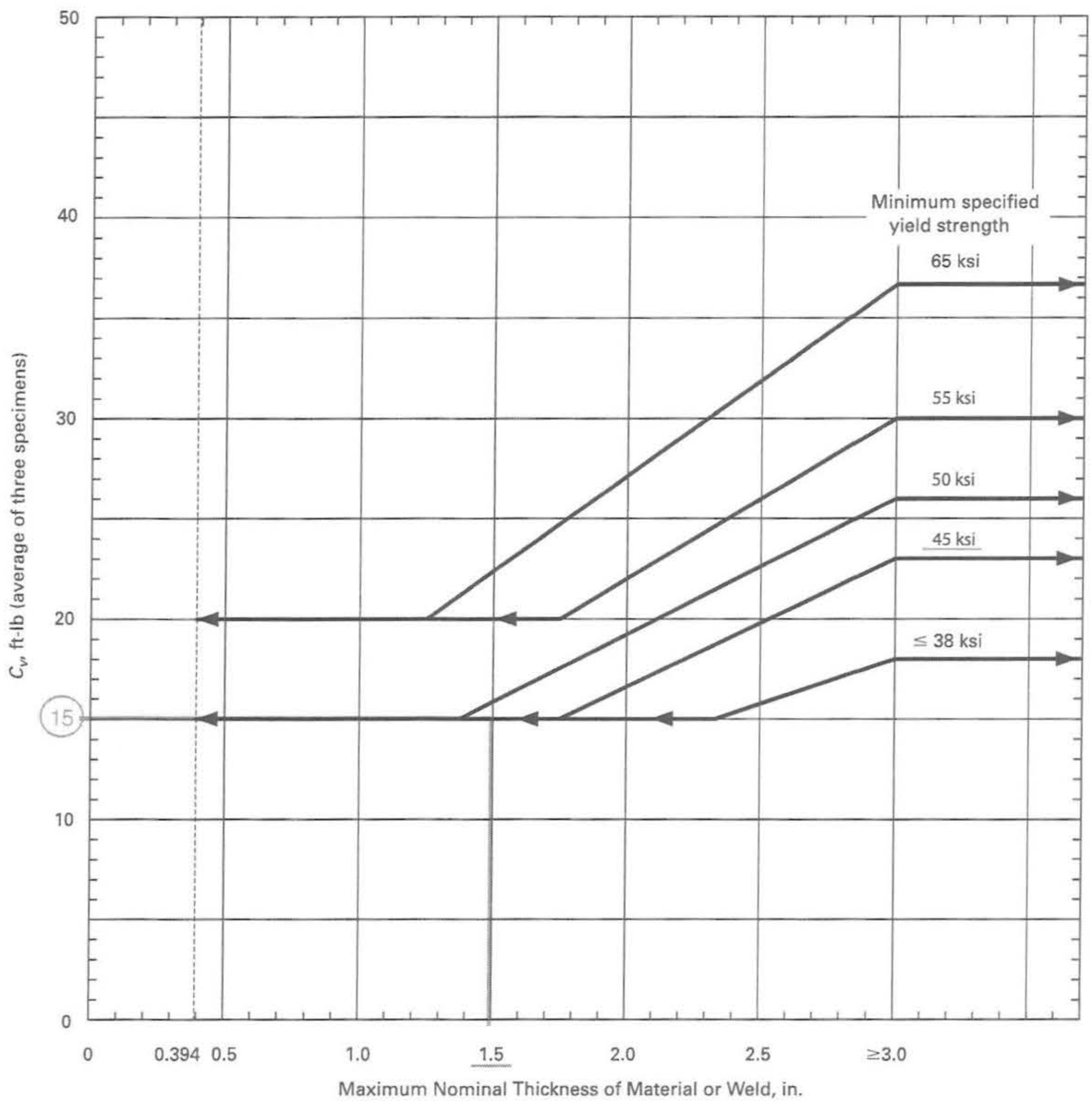
Correct answer is d).

Practice Problem Q72 Solution:

Which of the following Charpy impact test specimens would not be acceptable for a pressure vessel design using 1-1/2 in. thick carbon steel with a minimum specified yield strength of 45 ksi?

From Fig. UG-84.1, the minimum average impact value for three specimens for a material with MSYS of 45 ksi is 15 ft-lb.

FIG. UG-84.1 CHARPY V-NOTCH IMPACT TEST REQUIREMENTS FOR FULL SIZE SPECIMENS FOR CARBON AND LOW ALLOY STEELS, HAVING A SPECIFIED MINIMUM TENSILE STRENGTH OF LESS THAN 95 ksi, LISTED IN TABLE UCS-23



GENERAL NOTES:

(a) Interpolation between yield strengths shown is permitted.

(b) The minimum impact energy for one specimen shall not be less than ⅔ of the average energy required for three specimens. The average impact energy value of the three specimens may be rounded to the nearest ft-lb.

(c) Material produced and impact tested in accordance with SA-320, SA-333, SA-334, SA-350, SA-352, SA-420, impact tested SA/AS 1548 (*L* impact designations), SA-437, SA-540 (except for materials produced under Table 2, Note 4 in SA-540), and SA-765 do not have to satisfy these energy values. See UCS-66(g).

(d) For materials having a specified minimum tensile strength of 95 ksi or more, see UG-84(c)(4)(b).

Practice Problem Q72 Solution (continued):

From general note (b), the impact energy for one specimen shall not be less than 2/3 of the average energy.

Minimum impact energy for one specimen = 15 ft-lb × 2/3 = 10 ft-lb

9 ft-lb is less than 10 ft-lb, so the correct answer is d).

Practice Problem Q74 Solution:

An ASTM A671 Gr CC70 pipe has an actual thickness of 6.32 mm from which a 5 mm Charpy impact test specimen was machined. If the design minimum temperature is -46°C, what is the required Charpy impact test temperature?

Formula:

Since the width along the notch is less than 80% of a full-size specimen (i.e., < 8 mm):

$$\text{test temperature} = \text{design minimum temperature} + TR_{amt} - TR_s$$

Required Variables:

design minimum temperature = -46°C

The temperature reduction for a given material thickness and impact specimen width can be obtained from Table UG-84.2.

TABLE UG-84.2
CHARPY IMPACT TEST TEMPERATURE REDUCTION BELOW MINIMUM DESIGN METAL TEMPERATURE
For Table UCS-23 Materials Having a Specified Minimum Tensile Strength of Less Than 95,000 psi (655 MPa) When the Subsize Charpy Impact Width Is Less Than 80% of the Material Thickness

Actual Material Thickness [See UG-84(c)(5)(b)] of Charpy Impact Specimen Width Along the Notch[1]	
Thickness, in. (mm)	Temperature Reduction, °F (°C)
0.394 (Full-size standard bar) (10)	0 (0)
0.354 (9)	0 (0)
0.315 (8.00)	0 (0)
0.295 (3/4 size bar) (7.5)	5 (3)
0.276 (7)	8 (4)
0.262 (2/3 size bar) (6.7)	10 (6)
0.236 (6)	15 (8)
0.197 (1/2 size bar) (5.00)	20 (11)
0.158 (4)	30 (17)
0.131 (1/3 size bar) (3.3)	35 (19)
0.118 (3.00)	40 (22)
0.099 (1/4 size bar) (2.5)	50 (28)

NOTE:
(1) Straight line interpolation for intermediate values is permitted.

Step 1: Since the actual thickness is not listed in Table UG-84.2, it must be linearly interpolated:

$$\text{temperature reduction interpolation for 6.32 mm} = \frac{6.67\text{ mm} - 6.32\text{ mm}}{6.67\text{ mm} - 6\text{ mm}} \times (8-6)°C + 6°C$$

$$= \frac{0.35\text{ mm}}{0.67\text{ mm}} \times (2)°C + 6°C$$

$$= 0.522 \times 2°C + 6°C$$

$$= 1.04°C + 6°C$$

$$= 7.0°C$$

Practice Problem Q74 Solution (continued):

Step 2: temperature reduction for 5 mm impact specimen = 11°C

Step 3: test temperature = design minimum temperature + $TR_{amt} - TR_s$

= -46°C + 7.0°C – 11°C

= -50°C

Practice Problem Q76 Solution

At what temperature is impact testing required for the following conditions in a new pressure vessel? A vertical vessel made from SA-516 grade 70, normalized, nominal wall thickness of 1.500 in., has a design temperature of 600°F with a MAWP of 350 psi., and a WPS that included a 250°F preheat and PWHT.

Procedure:

Step 1: From the notes in Fig. UCS-66, SA-516 Gr. 70, normalized is listed under Curve D.

FIG. UCS-66 IMPACT TEST EXEMPTION CURVES (CONT'D)

NOTES:
(4) Curve D applies to:
SA-203
SA-508 Grade 1
SA-516 if normalized or quenched and tempered
SA-524 Classes 1 and 2
SA-537 Classes 1, 2, and 3
SA-612 if normalized
SA-662 if normalized
SA-738 Grade A
SA-738 Grade A with Cb and V deliberately added in accordance with the provisions of the material specification, not colder than −20°F (−29°C)
SA-738 Grade B not colder than −20°F (−29°C)
SA/AS 1548 Grades 7-430, 7-460, and 7-490 if normalized
SA/EN 10028-2 Grades P295GH and P355GH if normalized
SA/EN 10028-3 Grade P275NH

Step 2: t_g = 1.500 in. (see UCS-66(a)(1)(a))

Step 3: From Table UCS-66 under Curve D and thickness of 1.500 in. the MDMT = –14°F.

Step 4: a) From UG-20(f)(1)(b), since the vessel thickness is greater than 1 in. and is listed in Curve D, then this exemption cannot be taken.

b) There is no coincident ratio exemption.

c) From UCS-56 Note 2(b), since a preheat higher than 200°F was applied and the thickness is greater than 1-1/4 in., then PWHT is not required; however, since PWHT was performed on a P-No. 1 material when PWHT was not required, then the UCS-68(c) exemption of a 30°F (17°C) reduction in impact testing temperature can be taken.

Therefore, the final MDMT with the UCS-68(c) exemption = –14°F – (30°F) = –44°F

Correct answer is c).

Practice Problem Q78 Solution

A pressure vessel is made from SA 516 grade 60, with a nominal wall thickness of 0.750 in., a MSTS of 60 ksi with a coincident ratio temperature reduction of 20°F, and a MAWP of 150 psi at 675°F. What is the MDMT without impact testing, including all exemptions?

Procedure:

Step 1: From the notes in Fig. UCS-66, SA-516 Gr. 60, as-rolled is listed under Curve C.

FIG. UCS-66 IMPACT TEST EXEMPTION CURVES (CONT'D)

NOTES:
(3) Curve C applies to:
(a) SA-182 Grades F21 and F22 if normalized and tempered
SA-302 Grades C and D
SA-336 F21 and F22 if normalized and tempered, or liquid quenched and tempered
SA-387 Grades 21 and 22 if normalized and tempered, or liquid quenched and tempered
SA-516 Grades 55 and 60 if not normalized
SA-533 Grades B and C
SA-662 Grade A;
(b) all materials listed in 2(a) and 2(c) for Curve B if produced to fine grain practice and normalized, normalized and tempered, or liquid quenched and tempered as permitted in the material specification, and not listed for Curve D below.

Step 2: t_g = 0.750 in.

Step 3: From Table UCS-66 under Curve C and thickness of 0.750 in. the MDMT = 15°F

Step 4: a) From UG-20(f), although SA-516 Gr. 60 is listed as P-No. 1, Group 1 in ASME Section IX QW-422, and is under 1 in. in thickness, it is not exempt from impact testing since UG-20(f)(3) limits the maximum design temperature to 650°F (i.e., the operating temperature is 675°F).

b) From the question, take the coincident ratio reduction of 20°F below the value in Table UCS-66.

c) There was no mention of PWHT in the question, so the UCS-68(c) exemption cannot be taken.

Therefore, the final MDMT with the Table UG-84.2 exemption = –15°F – (20°F) = –35°F

Correct answer is c).

MANDATORY APPENDIX 2
RULES FOR BOLTED FLANGE CONNECTIONS WITH RING TYPE GASKETS

GENERAL

2-1 SCOPE

(a) The rules in Mandatory Appendix 2 apply specifically to the design of bolted flange connections with gaskets that are entirely within the circle enclosed by the bolt holes and with no contact outside this circle, and are to be used in conjunction with the applicable requirements in Subsections A, B, and C of this Division. The hub thickness of weld neck flanges designed to this Appendix shall also comply with the minimum thickness requirements in Subsection A of this Division. These rules are not to be used for the determination of the thickness of supported or unsupported tubesheets integral with a bolting flange as illustrated in Figure UW-13.2 sketches (h) through (l) or Figure UW-13.3 sketch (c). Nonmandatory Appendix S provides discussion on Design Considerations for Bolted Flanged Connections.

These rules provide only for hydrostatic end loads and gasket seating. The flange design methods outlined in 2-4 through 2-8 are applicable to circular flanges under internal pressure. Modifications of these methods are outlined in 2-9 and 2-10 for the design of split and noncircular flanges. see 2-11 for flanges with ring type gaskets subject to external pressure, 2-12 for flanges with nut-stops, and 2-13 for reverse flanges. Rules for calculating rigidity factors for flanges are provided in 2-14. Recommendations for qualification of assembly procedures and assemblers are in 2-15. Proper allowance shall be made if connections are subject to external loads other than external pressure.

(b) The design of a flange involves the selection of the gasket (material, type, and dimensions), flange facing, bolting, hub proportions, flange width, and flange thickness. See Note in 2-5(c)(1). Flange dimensions shall be such that the stresses in the flange, calculated in accordance with 2-7, do not exceed the allowable flange stresses specified in 2-8. Except as provided for in 2-14(a), flanges designed to the rules of this Appendix shall also meet the rigidity requirements of 2-14. All calculations shall be made on dimensions in the corroded condition.

(c) It is recommended that bolted flange connections conforming to the standards listed in UG-44 be used for connections to external piping. These standards may be used for other bolted flange connections and dished covers within the limits of size in the standards and the pressure–temperature ratings permitted in UG-44. The ratings in these standards are based on the hub dimensions given or on the minimum specified thickness of flanged fittings of integral construction. Flanges fabricated from rings may be used in place of the hub flanges in these standards provided that their strength, calculated by the rules in this Appendix, is not less than that calculated for the corresponding size of hub flange.

(d) Except as otherwise provided in (c) above, bolted flange connections for unfired pressure vessels shall satisfy the requirements in this Appendix.

(e) The rules of this Appendix should not be construed to prohibit the use of other types of flanged connections provided they are designed in accordance with good engineering practice and method of design is acceptable to the Inspector. Some examples of flanged connections which might fall in this category are as follows:

(1) flanged covers as shown in Figure 1-6;

(2) bolted flanges using full-face gaskets;

(3) flanges using means other than bolting to restrain the flange assembly against pressure and other applied loads.

2-2 MATERIALS

(a) Materials used in the construction of bolted flange connections shall comply with the requirements given in UG-4 through UG-14.

(b) Flanges made from ferritic steel and designed in accordance with this Appendix shall be full-annealed, normalized, normalized and tempered, or quenched and tempered when the thickness of the flange section exceeds 3 in. (75 mm).

(c) Material on which welding is to be performed shall be proved of good weldable quality. Satisfactory qualification of the welding procedure under Section IX is considered as proof. Welding shall not be performed on steel that has a carbon content greater than 0.35%. All welding on flange connections shall comply with the requirements for postweld heat treatment given in this Division.

(d) Fabricated hubbed flanges shall be in accordance with the following:

(1) Hubbed flanges may be machined from a hot rolled or forged billet or forged bar. The axis of the finished flange shall be parallel to the long axis of the original billet or bar. (This is not intended to imply that the axis of the finished flange and the original billet must be concentric.)

(2) Hubbed flanges [except as permitted in (1) above] shall not be machined from plate or bar stock material unless the material has been formed into a ring, and further provided that:

(-a) in a ring formed from plate, the original plate surfaces are parallel to the axis of the finished flange. (This is not intended to imply that the original plate surface be present in the finished flange.)

(-b) the joints in the ring are welded butt joints that conform to the requirements of this Division. Thickness to be used to determine postweld heat treatment and radiography requirements shall be the lesser of

$$t \text{ or } \frac{(A-B)}{2}$$

where these symbols are as defined in 2-3.

(-c) the back of the flange and the outer surface of the hub are examined by either the magnetic particle method as per Mandatory Appendix 6 or the liquid penetrant method as per Mandatory Appendix 8.

(e) Bolts, studs, nuts, and washers shall comply with the requirements in this Division. It is recommended that bolts and studs have a nominal diameter of not less than $^1/_2$ in. (13 mm). If bolts or studs smaller than $^1/_2$ in. (13 mm) are used, ferrous bolting material shall be of alloy steel. Precautions shall be taken to avoid over-stressing small-diameter bolts.

2-3 NOTATION

The symbols described below are used in the equations for the design of flanges (see also Figure 2-4):

A = outside diameter of flange or, where slotted holes extend to the outside of the flange, the diameter to the bottom of the slots

A_b = cross-sectional area of the bolts using the root diameter of the thread or least diameter of unthreaded position, if less

A_m = total required cross-sectional area of bolts, taken as the greater of A_{m1} and A_{m2}

A_{m1} = total cross-sectional area of bolts at root of thread or section of least diameter under stress, required for the operating conditions

= W_{m1} / S_b

A_{m2} = total cross-sectional area of bolts at root of thread or section of least diameter under stress, required for gasket seating

= W_{m2} / S_a

a = nominal bolt diameter

B = inside diameter of flange. When B is less than $20g_1$, it will be optional for the designer to substitute B_1 for B in the formula for longitudinal stress S_H.

B_s = bolt spacing. The bolt spacing may be taken as the bolt circle circumference divided by the number of bolts or as the chord length between adjacent bolt locations.

B_{sc} = bolt spacing factor

B_{smax} = maximum bolt spacing

B_1 = $B + g_1$ for loose type flanges and for integral type flanges that have calculated values h / h_o and g_1 / g_o which would indicate an f value of less than 1.0, although the minimum value of f permitted is 1.0.

= $B + g_o$ for integral type flanges when f is equal to or greater than one

b = effective gasket or joint-contact-surface seating width [see Note in 2-5(c)(1)]

b_o = basic gasket seating width (from Table 2-5.2)

C = bolt-circle diameter

C_b = conversion factor

= 0.5 for U.S. Customary calculations; 2.5 for SI calculations

c = basic dimension used for the minimum sizing of welds equal to t_n or t_x, whichever is less

d = factor

$$d = \frac{U}{V} h_o g_o^2 \text{ for integral type flanges}$$

$$d = \frac{U}{V_L} h_o g_o^2 \text{ for loose type flanges}$$

e = factor

$$e = \frac{F}{h_o} \text{ for integral type flanges}$$

$$e = \frac{F_L}{h_o} \text{ for loose type flanges}$$

F = factor for integral type flanges (from Figure 2-7.2)

F_L = factor for loose type flanges (from Figure 2-7.4)

f = hub stress correction factor for integral flanges from Figure 2-7.6 (When greater than one, this is the ratio of the stress in the small end of hub to the stress in the large end.) (For values below limit of figure, use $f = 1$.)

G = diameter at location of gasket load reaction. Except as noted in sketch (1) of Figure 2-4, G is defined as follows (see Table 2-5.2):
When $b_o \leq {}^1/_4$ in. (6 mm), G = mean diameter of gasket contact face
When $b_o > {}^1/_4$ in. (6 mm), G = outside diameter of gasket contact face less $2b$,

g_o = thickness of hub at small end

(a) for optional type flanges calculated as integral and for integral type flanges per Figure 2-4, illustration (7), $g_o = t_n$

(b) for other integral type flanges, g_o = the smaller of t_n or the thickness of the hub at the small end

g_1 = thickness of hub at back of flange

H = total hydrostatic end force

= $0.785G^2 P$

H_D = hydrostatic end force on area inside of flange
= $0.785B^2 P$

H_G = gasket load (difference between flange design bolt load and total hydrostatic end force)
= $W-H$

H_p = total joint-contact surface compression load
= $2b \times 3.14\ GmP$

H_T = difference between total hydrostatic end force and the hydrostatic end force on area inside of flange
= $H-H_D$

h = hub length

h_D = radial distance from the bolt circle, to the circle on which H_D acts, as prescribed in Table 2-6

h_G = radial distance from gasket load reaction to the bolt circle
= $(C-G)/2$

h_o = factor
= $\sqrt{Bg_0}$

h_T = radial distance from the bolt circle to the circle on which H_T acts as prescribed in Table 2-6

K = ratio of outside diameter of flange to inside diameter of flange
= A/B

L = factor

$$= \frac{te+1}{T} + \frac{t^3}{d}$$

M_D = component of moment due to H_D,
= $H_D h_D$

M_G = component of moment due to H_G,
= $H_G h_G$

M_o = total moment acting upon the flange, for the operating conditions or gasket seating as may apply (see 2-6)

M_T = component of moment due to H_T
= $H_T h_T$

m = gasket factor, obtain from Table 2-5.1 [see Note 1, 2-5(c)(1)]

N = width used to determine the basic gasket seating with b_o, based upon the possible contact width of the gasket (see Table 2-5.2)

P = internal design pressure (see UG-21). For flanges subject to external design pressure, see 2-11.

R = radial distance from bolt circle to point of intersection of hub and back of flange. For integral and hub flanges,

$$R = \frac{C-B}{2} - g_1$$

S_a = allowable bolt stress at atmospheric temperature (see UG-23)

S_b = allowable bolt stress at design temperature (see UG-23)

S_f = allowable design stress for material of flange at design temperature (operating condition) or atmospheric temperature (gasket seating), as may apply (see UG-23)

S_H = calculated longitudinal stress in hub

S_n = allowable design stress for material of nozzle neck, vessel or pipe wall, at design temperature (operating condition) or atmospheric temperature (gasket seating), as may apply (see UG-23)

S_R = calculated radial stress in flange

S_T = calculated tangential stress in flange

T = factor involving K (from Figure 2-7.1)

t = flange thickness

t_n = nominal thickness of shell or nozzle wall to which flange or lap is attached

t_x = two times the thickness g_0, when the design is calculated as an integral flange or two times the thickness of shell nozzle wall required for internal pressure, when the design is calculated as a loose flange, but not less than $^1/_4$ in. (6 mm)

U = factor involving K (from Figure 2-7.1)

V = factor for integral type flanges (from Figure 2-7.3)

V_L = factor for loose type flanges (from Figure 2-7.5)

W = flange design bolt load, for the operating conditions or gasket seating, as may apply [see 2-5(e)]

W_{m1} = minimum required bolt load for the operating conditions [see 2-5(c)]. For flange pairs used to contain a tubesheet for a floating head or a U-tube type of heat exchangers, or for any other similar design, W_{m1} shall be the larger of the values as individually calculated for each flange, and that value shall be used for both flanges.

W_{m2} = minimum required bolt load for gasket seating [see 2-5(c)]. For flange pairs used to contain a tubesheet for a floating head or U-tube type of heat exchanger, or for any other similar design where the flanges or gaskets are not the same, W_{m2} shall be the larger of the values calculated for each flange and that value shall be used for both flanges.

w = width used to determine the basic gasket seating width b_0, based upon the contact width between the flange facing and the gasket (see Table 2-5.2)

Y = factor involving K (from Figure 2-7.1)

y = gasket or joint-contact-surface unit seating load, [see Note 1, 2-5(c)]

Z = factor involving K (from Figure 2-7.1)

2-4 CIRCULAR FLANGE TYPES

(a) For purposes of computation, there are three types:

(1) Loose Type Flanges. This type covers those designs in which the flange has no direct connection to the nozzle neck, vessel, or pipe wall, and designs where the method of attachment is not considered to give the

mechanical strength equivalent of integral attachment. see Figure 2-4 sketches (1), (1a), (2), (2a), (3), (3a), (4), (4a), (4b), and (4c) for typical loose type flanges and the location of the loads and moments. Welds and other details of construction shall satisfy the dimensional requirements given in Figure 2-4 sketches (1), (1a), (2), (2a), (3), (3a), (4), (4a), (4b), and (4c).

(2) Integral Type Flanges. This type covers designs where the flange is cast or forged integrally with the nozzle neck, vessel or pipe wall, butt welded thereto, or attached by other forms of arc or gas welding of such a nature that the flange and nozzle neck, vessel or pipe wall is considered to be the equivalent of an integral structure. In welded construction, the nozzle neck, vessel, or pipe wall is considered to act as a hub. see Figure 2-4 sketches (5), (6), (6a), (6b), and (7) for typical integral type flanges and the location of the loads and moments. Welds and other details of construction shall satisfy the dimensional requirements given in Figure 2-4 sketches (5), (6), (6a), (6b), and (7).

(3) Optional Type Flanges. This type covers designs where the attachment of the flange to the nozzle neck, vessel or pipe wall is such that the assembly is considered to act as a unit, which shall be calculated as an integral flange, except that for simplicity the designer may calculate the construction as a loose type flange provided none of the following values is exceeded:

$$g_o = \tfrac{5}{8}\text{ in. } (16\text{ mm})$$
$$B/g_o = 300$$
$$P = 300\text{ psi } (2\text{ MPa})$$
$$\text{operating temperature} = 700°\text{F } (370°\text{C})$$

See Figure 2-4 sketches (8), (8a), (9), (9a), (10), (10a), and (11) for typical optional type flanges. Welds and other details of construction shall satisfy the dimensional requirements given in Figure 2-4 sketches (8), (8a), (9), (9a), (10), (10a), and (11).

2-5 BOLT LOADS

(a) General Requirements

(1) In the design of a bolted flange connection, calculations shall be made for each of the two design conditions of operating and gasket seating, and the more severe shall control.

(2) In the design of flange pairs used to contain a tubesheet of a heat exchanger or any similar design where the flanges and/or gaskets may not be the same, loads must be determined for the most severe condition of operating and/or gasket seating loads applied to each side at the same time. This most severe condition may be gasket seating on one flange with operating on the other, gasket seating on each flange at the same time, or operating on each flange at the same time. Although no specific rules are given for the design of the flange pairs, after the loads for the most severe conditions are determined, calculations shall be made for each flange following the rules of Mandatory Appendix 2.

(3) Recommended minimum gasket contact widths for sheet and composite gaskets are provided in Table 2-4.

(b) Design Conditions

(1) Operating Conditions. The conditions required to resist the hydrostatic end force of the design pressure tending to part the joint, and to maintain on the gasket or joint-contact surface sufficient compression to assure a tight joint, all at the design temperature. The minimum load is a function of the design pressure, the gasket material, and the effective gasket or contact area to be kept tight under pressure, per eq. (c)(1)(1) below, and determines one of the two requirements for the amount of the bolting A_{m1}. This load is also used for the design of the flange, per eq. (d)(3) below.

(2) Gasket Seating. The conditions existing when the gasket or joint-contact surface is seated by applying an initial load with the bolts when assembling the joint, at atmospheric temperature and pressure. The minimum initial load considered to be adequate for proper seating is a function of the gasket material, and the effective gasket or contact area to be seated, per eq. (c)(2)(2) below, and determines the other of the two requirements for the amount of bolting A_{m2}. For the design of the flange, this load is modified per eq. (e)(4) below to take account of the operating conditions, when these govern the amount of bolting required A_m, as well as the amount of bolting actually provided A_b.

(c) Required Bolt Loads. The flange bolt loads used in calculating the required cross-sectional area of bolts shall be determined as follows.

(1) The required bolt load for the operating conditions W_{m1} shall be sufficient to resist the hydrostatic end force H exerted by the maximum allowable working pressure on the area bounded by the diameter of gasket reaction, and, in addition, to maintain on the gasket or joint-contact surface a compression load H_p, which experience has shown to be sufficient to assure a tight joint. (This compression load is expressed as a multiple m of the internal pressure. Its value is a function of the gasket material and construction.)

NOTE: Tables 2-5.1 and 2-5.2 give a list of many commonly used gasket materials and contact facings, with suggested values of m, b, and y that have proved satisfactory in actual service. These values are suggested only and are not mandatory.

The required bolt load for the operating conditions W_{m1} is determined in accordance with eq. (1).

$$W_{m1} = H + H_p = 0.785G^2P + (2b \times 3.14GmP) \qquad (1)$$

(2) Before a tight joint can be obtained, it is necessary to seat the gasket or joint-contact surface properly by applying a minimum initial load (under atmospheric temperature conditions without the presence of internal

(13)

Figure 2-4
Types of Flanges

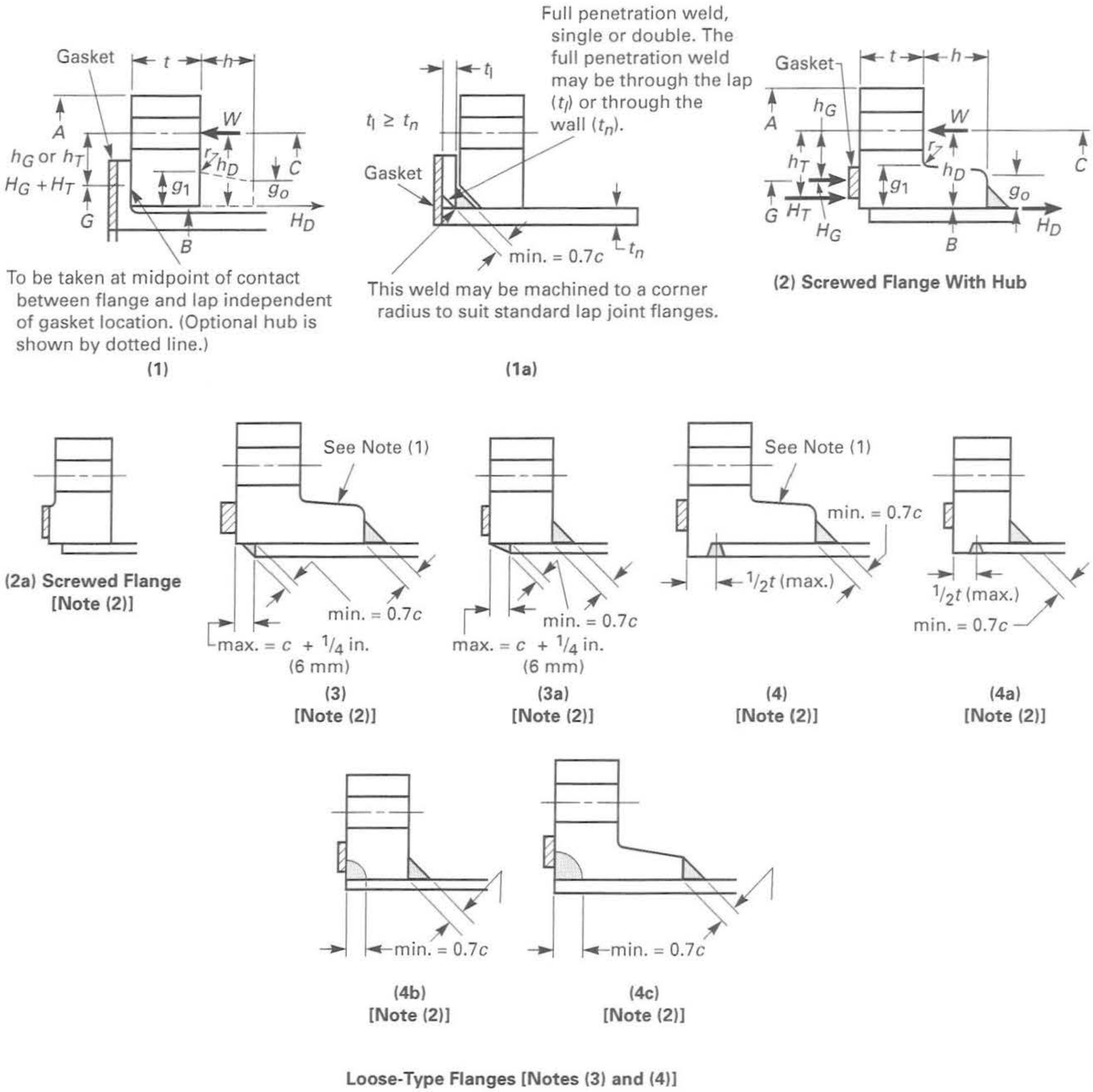
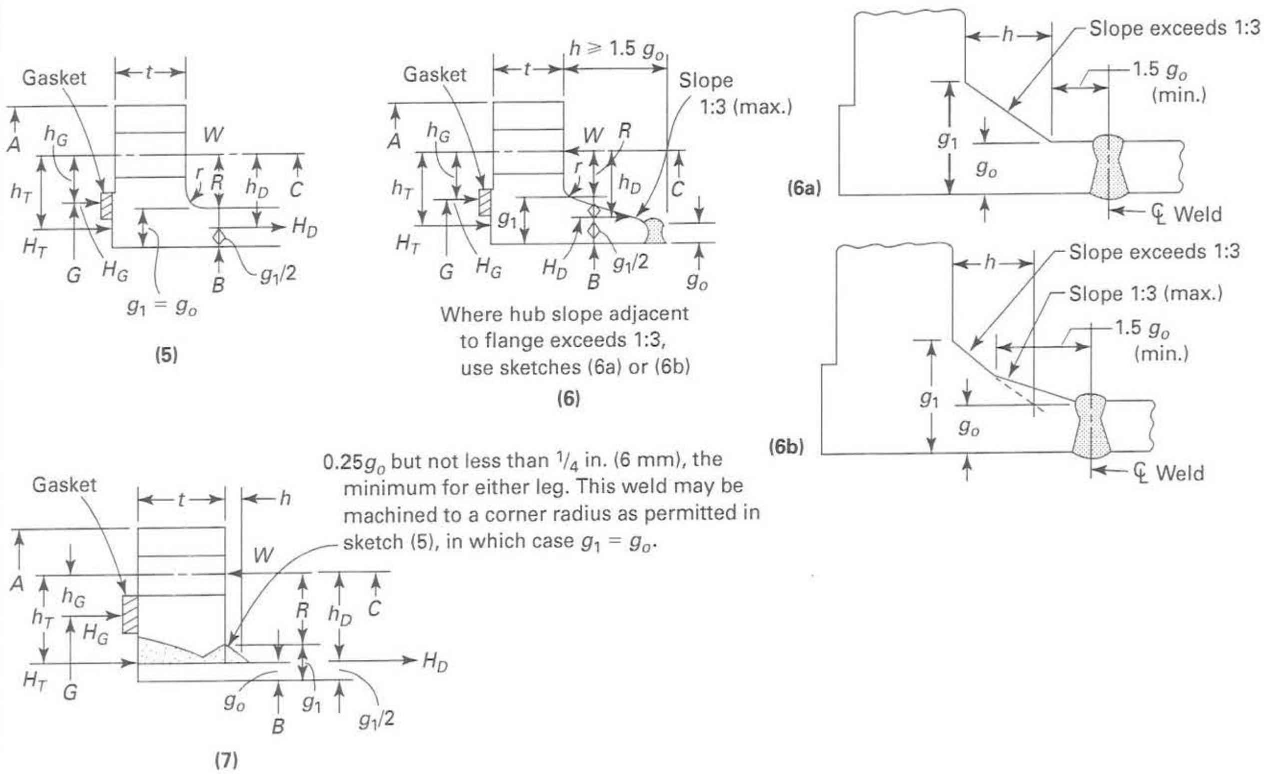
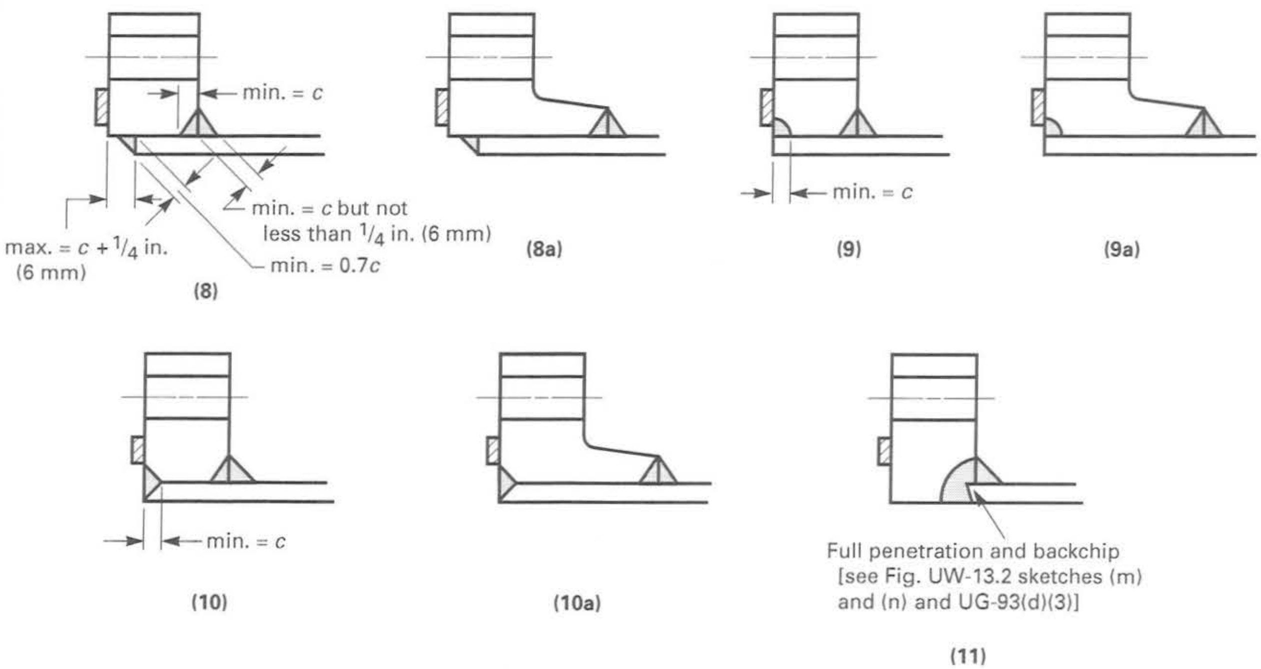


Figure 2-4
Types of Flanges (Cont'd)

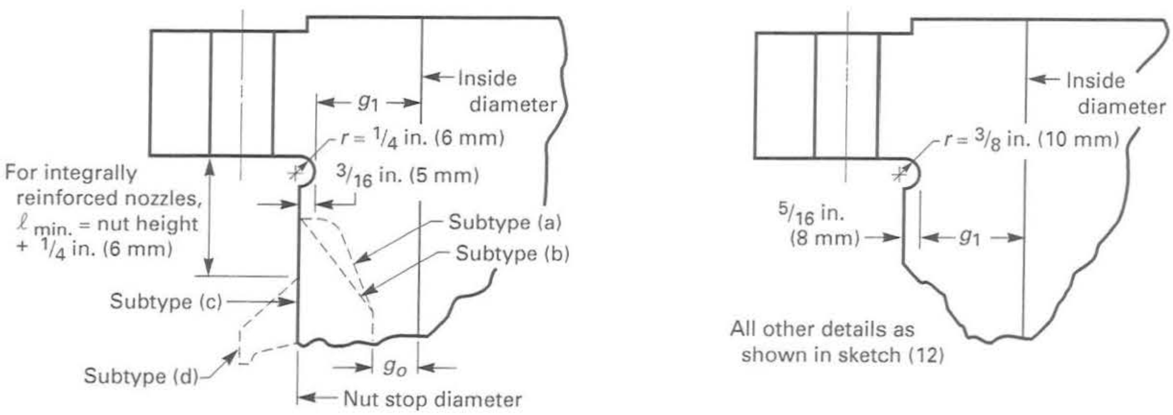


Integral-Type Flanges [Notes (3) and (4)]

Figure 2-4
Types of Flanges (Cont'd)



Optional-Type Flanges [Notes (5), (6), and (7)]



(12) For Flanged Nozzles 18 in. (460 mm) and Smaller Nominal Size

(12a) For Flanged Nozzles Over 18 in. (460 mm) Nominal Size

Flanges With Nut Stops [Note (8)]

NOTES:
(1) For hub tapers 6 deg or less, use $g_o = g_1$.
(2) Loading and dimensions for sketches (2a), (3), (3a), (4), (4a), (4b), and (4c) not shown are the same as for sketch (2).
(3) Fillet radius r to be at least 0.25 g_1 but not less than $^3/_{16}$ in. (5 mm).

Figure 2-4
Types of Flanges (Cont'd)

NOTES (CONT'D):
(4) Facing thicknesses or groove depths greater than $^1/_{16}$ in. (1.5 mm) shall be in excess of the required minimum flange thickness, t; those equal to or less than $^1/_{16}$ in. (1.5 mm) may be included in the overall flange thickness.
(5) Optional-type flanges may be calculated as either loose or integral type. See 2-4.
(6) Loadings and dimensions not shown in sketches (8), (8a), (9), (9a), (10), and (10a) are the same as shown in sketch (2) when the flange is calculated as a loose-type flange, and as shown in sketch (7) when the flange is calculated as an integral-type flange.
(7) The groove and fillet welds between the flange back face and the shell given in sketch (8) also apply to sketches (8a), (9), (9a), (10), and (10a).
(8) For subtypes (a) and (b), g_o is the thickness of the hub at the small end. For subtypes (c) and (d), $g_o = g_1$.

pressure), which is a function of the gasket material and the effective gasket area to be seated. The minimum initial bolt load required for this purpose W_{m2} shall be determined in accordance with eq. (2).

$$W_{m2} = 3.14bGy \tag{2}$$

The need for providing sufficient bolt load to seat the gasket or joint-contact surfaces in accordance with eq. (2) will prevail on many low-pressure designs and with facings and materials that require a high seating load, and where the bolt load computed by eq. (1)(1) for the operating conditions is insufficient to seat the joint. Accordingly, it is necessary to furnish bolting and to pretighten the bolts to provide a bolt load sufficient to satisfy both of these requirements, each one being individually investigated. When eq. (2) governs, flange proportions will be a function of the bolting instead of internal pressure.

(3) Bolt loads for flanges using gaskets of the self-energizing type differ from those shown above.

(-a) The required bolt load for the operating conditions W_{m1} shall be sufficient to resist the hydrostatic end force H exerted by the maximum allowable working pressure on the area bounded by the outside diameter of the gasket. H_p is to be considered as 0 for all self-energizing gaskets except certain seal configurations which generate axial loads which must be considered.

(-b) $W_{m2} = 0$.

Table 2-4
Recommended Minimum Gasket Contact Widths for Sheet and Composite Gaskets

Flange ID	Gasket Contact Width
24 in. (600 mm) < ID ≤ 36 in. (900 mm)	1 in. (25 mm)
36 in. (900 mm) < ID < 60 in. (1500 mm)	$1^1/_4$ in. (32 mm)
ID ≥ 60 in. (1500 mm)	$1^1/_2$ (38 mm)

Self-energizing gaskets may be considered to require an inconsequential amount of bolting force to produce a seal. Bolting, however, must be pretightened to provide a bolt load sufficient to withstand the hydrostatic end force H.

(d) Total Required and Actual Bolt Areas, A_m and A_b. The total cross-sectional area of bolts A_m required for both the operating conditions and gasket seating is the greater of the values for A_{m1} and A_{m2}, where $A_{m1} = W_{m1}/S_b$ and $A_{m2} = W_{m2}/S_a$. A selection of bolts to be used shall be made such that the actual total cross-sectional area of bolts A_b will not be less than A_m. For vessels in lethal service or when specified by the user or his designated agent, the maximum bolt spacing shall not exceed the value calculated in accordance with eq. (3).

$$B_{s\,\max} = 2a + \frac{6t}{m + 0.5} \tag{3}$$

(e) Flange Design Bolt Load W. The bolt loads used in the design of the flange shall be the values obtained from eqs. (4) and (5). For operating conditions,

$$W = W_{m1} \tag{4}$$

For gasket seating,

$$W = \frac{(A_m + A_b)S_a}{2} \tag{5}$$

S_a used in eq. (5)shall be not less than that tabulated in the stress tables (see UG-23). In addition to the minimum requirements for safety, eq. (5) provides a margin against abuse of the flange from overbolting. Since the margin against such abuse is needed primarily for the initial, bolting-up operation which is done at atmospheric temperature and before application of internal pressure, the flange design is required to satisfy this loading only under such conditions.

NOTE: Where additional safety against abuse is desired, or where it is necessary that the flange be suitable to withstand the full available bolt load A_bS_a, the flange may be designed on the basis of this latter quantity.

Table 2-5.1
Gasket Materials and Contact Facings
Gasket Factors *m* for Operating Conditions and Minimum Design Seating Stress *y*

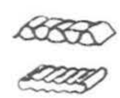
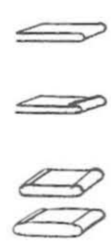
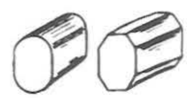
Gasket Material	Gasket Factor *m*	Min. Design Seating Stress *y*, psi (MPa)	Sketches	Facing Sketch and Column in Table 2-5.2
Self-energizing types (O rings, metallic, elastomer, other gasket types considered as self-sealing)	0	0 (0)	...	...
Elastomers without fabric or high percent of mineral fiber:				(1a), (1b), (1c), (1d), (4), (5); Column II
Below 75A Shore Durometer	0.50	0 (0)		
75A or higher Shore Durometer	1.00	200 (1.4)		
Mineral fiber with suitable binder for operating conditions:				(1a), (1b), (1c), (1d), (4), (5); Column II
$\frac{1}{8}$ in. (3.2 mm) thick	2.00	1,600 (11)		
$\frac{1}{16}$ in. (1.6 mm) thick	2.75	3,700 (26)		
$\frac{1}{32}$ in. (0.8 mm) thick	3.50	6,500 (45)		
Elastomers with cotton fabric insertion	1.25	400 (2.8)		(1a), (1b), (1c), (1d), (4), (5); Column II
Elastomers with mineral fiber fabric insertion (with or without wire reinforcement):				
3-ply	2.25	2,200 (15)		(1a), (1b), (1c), (1d), (4), (5); Column II
2-ply	2.50	2,900 (20)		
1-ply	2.75	3,700 (26)		
Vegetable fiber	1.75	1,100 (7.6)		(1a), (1b), (1c), (1d), (4), (5); Column II
Spiral-wound metal, mineral fiber filled:				(1a), (1b); Column II
Carbon	2.50	10,000 (69)		
Stainless, Monel, and nickel-base alloys	3.00	10,000 (69)		
Corrugated metal, mineral fiber inserted, or corrugated metal, jacketed mineral fiber filled:				(1a), (1b); Column II
Soft aluminum	2.50	2,900 (20)		
Soft copper or brass	2.75	3,700 (26)		
Iron or soft steel	3.00	4,500 (31)		
Monel or 4–6% chrome	3.25	5,500 (38)		
Stainless steels and nickel-base alloys	3.50	6,500 (45)		
Corrugated metal:				(1a), (1b), (1c), (1d); Column II
Soft aluminum	2.75	3,700 (26)		
Soft copper or brass	3.00	4,500 (31)		
Iron or soft steel	3.25	5,500 (38)		
Monel or 4–6% chrome	3.50	6,500 (45)		
Stainless steels and nickel-base alloys	3.75	7,600 (52)		
Flat metal, jacketed mineral fiber filled:				(1a), (1b), (1c), [Note (1)] (1d) [Note (1)]; (2) [Note (1)]; Column II
Soft aluminum	3.25	5,500 (38)		
Soft copper or brass	3.50	6,500 (45)		
Iron or soft steel	3.75	7,600 (52)		
Monel	3.50	8,000 (55)		
4–6% chrome	3.75	9,000 (62)		
Stainless steels and nickel-base alloys	3.75	9,000 (62)		

Table 2-5.1
Gasket Materials and Contact Facings
Gasket Factors *m* for Operating Conditions and Minimum Design Seating Stress *y* (Cont'd)

Gasket Material	Gasket Factor *m*	Min. Design Seating Stress *y*, psi (MPa)	Sketches	Facing Sketch and Column in Table 2-5.2
Grooved metal:				
Soft aluminum	3.25	5,500 (38)		(1a), (1b), (1c), (1d), (2), (3); Column II
Soft copper or brass	3.50	6,500 (45)		
Iron or soft metal	3.75	7,600 (52)		
Monel or 4–6% chrome	3.75	9,000 (62)		
Stainless steels and nickel-base alloys	4.25	10,100 (70)		
Solid flat metal:				
Soft aluminum	4.00	8,800 (61)		(1a), (1b), (1c), (1d), (2), (3), (4), (5); Column I
Soft copper or brass	4.75	13,000 (90)		
Iron or soft steel	5.50	18,000 (124)		
Monel or 4–6% chrome	6.00	21,800 (150)		
Stainless steels and nickel-base alloys	6.50	26,000 (180)		
Ring joint:				
Iron or soft steel	5.50	18,000 (124)		(6); Column I
Monel or 4–6% chrome	6.00	21,800 (150)		
Stainless steels and nickel-base alloys	6.50	26,000 (180)		

GENERAL NOTE: This Table gives a list of many commonly used gasket materials and contact facings with suggested design values of m and y that have generally proved satisfactory in actual service when using effective gasket seating width b given in Table 2-5.2. The design values and other details given in this Table are suggested only and are not mandatory.

NOTE:
(1) The surface of a gasket having a lap should not be against the nubbin.

2-6 FLANGE MOMENTS

In the calculation of flange stress, the moment of a load acting on the flange is the product of the load and its moment arm. The moment arm is determined by the relative position of the bolt circle with respect to that of the load producing the moment (see Figure 2-4). No consideration shall be given to any possible reduction in moment arm due to cupping of the flanges or due to inward shifting of the line of action of the bolts as a result thereof. It is recommended that the value of h_G $[(C-G)/2]$ be kept to a minimum to reduce flange rotation at the sealing surface.

For the operating conditions, the total flange moment M_o is the sum of the three individual moments M_D, M_T, and M_G, as defined in 2-3 and based on the flange design load of eq. 2-5(e)(4) with moment arms as given in Table 2-6.

For gasket seating, the total flange moment M_o is based on the flange design bolt load of eq. 2-5(e)(5), which is opposed only by the gasket load, in which case

$$M_o = W\frac{(C-G)}{2} \tag{6}$$

For vessels in lethal service or when specified by the user or his designated agent, the bolt spacing correction shall be applied in calculating the flange stress in 2-7, 2-13(c), and 2-13(d). The flange moment M_o without correction for bolt spacing is used for the calculation of the rigidity index in 2-14.

When the bolt spacing exceeds $2a + t$, multiply M_O by the bolt spacing correction factor B_{SC} for calculating flange stress

where

$$B_{SC} = \sqrt{\frac{B_S}{2a + t}} \tag{7}$$

ASME

→ PCC-2 : New eddition is about bolting

→ Bolts Allowable Stress is $\frac{UTS}{5}$

Pressure Test

1 - To pried design (UG101)
2 - To leak check: standard ASME Test P = Tfactor × MAP × $\frac{S \text{ at design Tem}}{S \text{ at Test Temprature}}$
3 - To strength check or structral

In section VIII no any time for leak Test but B31.3 said 10 minute Minimum.
Just we have to check the connections for leak. If there is changing in pressure does not matter. may be it related to temperature changing.

Material Specifications

(13)

MANDATORY APPENDIX III GUIDELINES ON MULTIPLE MARKING OF MATERIALS

III-100 BACKGROUND

A common inquiry topic is the permissibility of using material that is identified with two or more specifications (or grades, classes, or types), even if they have different strengths, or even if one of them is not permitted for use in the construction code of application. The Committee has addressed variants of these questions in several interpretations: I-89-11, IIA-92-08, VIII-1-89-269, and VIII-1-89-197.

III-200 GUIDELINES

The construction codes individually define what materials may be used in boilers, vessels, and components constructed in compliance to their rules. If a material meets all of the requirements for a specification for which it is marked, including documentation, if any, and if it meets all requirements for use imposed by the construction code, it may be used. The construction codes, in general, do not address the case of materials marked with more than one specification, grade, class, or type, so these guidelines are offered for clarification.

III-210 ACCEPTABILITY OF MULTIPLE MARKING

Dual or multiple marking is acceptable, as long as the material so marked meets all of the requirements of all the specifications, grades, classes, and types with which it is marked.

All of the measured and controlled attributes of the multiply marked grades or specifications must overlap (e.g., chemistry, mechanical properties, dimensions, and tolerances) and the material so marked must exhibit values that fall within the overlaps. Further, the controlled but unmeasured attributes of the specifications or grades must overlap (e.g., melting practices, heat treatments, and inspection).

Many specifications or grades have significant overlap of chemistry ranges or properties. It is common for material manufacturers to produce materials that satisfy more than one specification, grade, class, or type. Examples are SA-53 and SA-106 (some grades and classes), SA-213 TP304L and TP304, SA-213 TP304 and TP304H, and SA-106 B and C.

III-220 PROHIBITION ON MULTIPLE MARKING

Dual or multiple marking is not acceptable if two or more specifications to which the material is marked have mutually exclusive requirements.

This prohibition includes more than just chemistry and property requirements. One example is SA-515 and SA-516; the former requires melting to coarse grain practice while the latter requires melting to fine grain practice. Another example is SA-213 TP304L and TP304H; the carbon content ranges of these grades have no overlap.

III-230 GRADE SUBSTITUTION

Grade substitution is not permitted. Grade substitution occurs when

(a) the material contains an element (other than nitrogen) that is unspecified for one of the grades marked

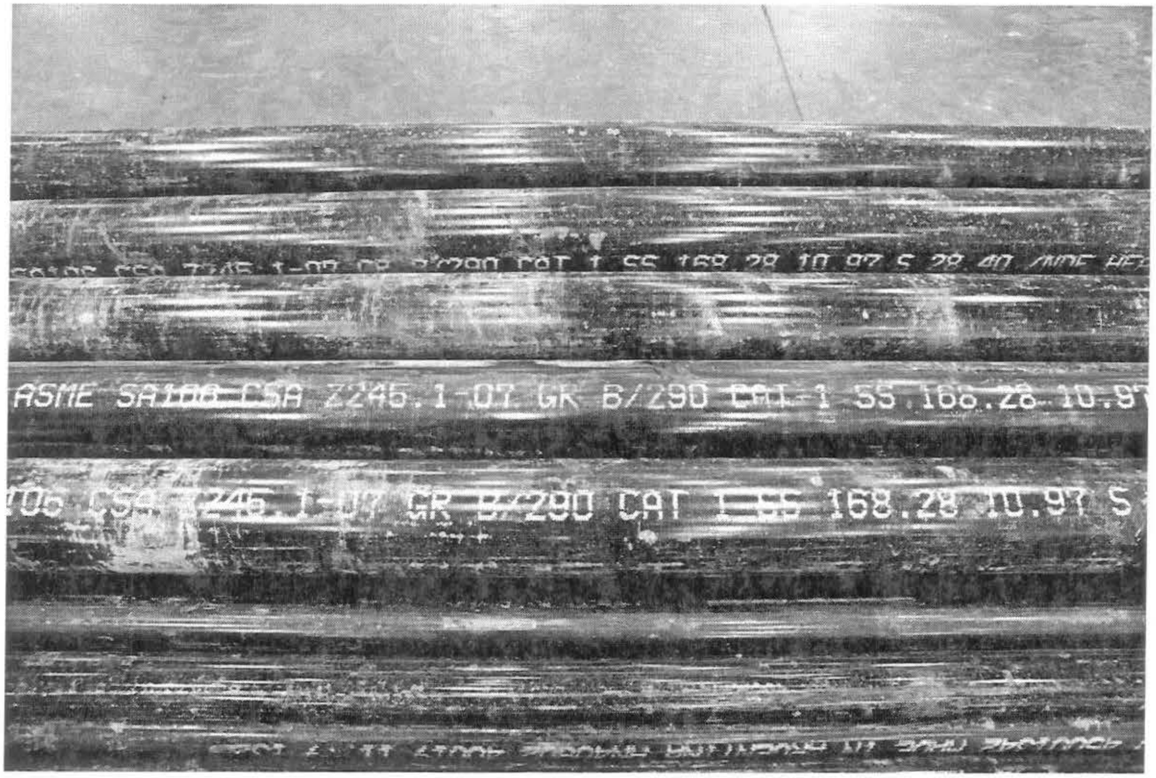
(b) the amount of that element present in the material meets the minimum and maximum composition limits for that element in another grade of a specification contained in Section II, Part A or Part B, whether or not it is also so marked

For example, a material meets all of the composition limits for SA-240 304, contains 0.06C and 0.02N, but also contains 0.45% Ti. This material cannot be marked or provided as meeting SA-240 304 because the Ti content meets the requirements of SA-240 321 [which is Ti greater than 5× (C + N) but less than 0.70].

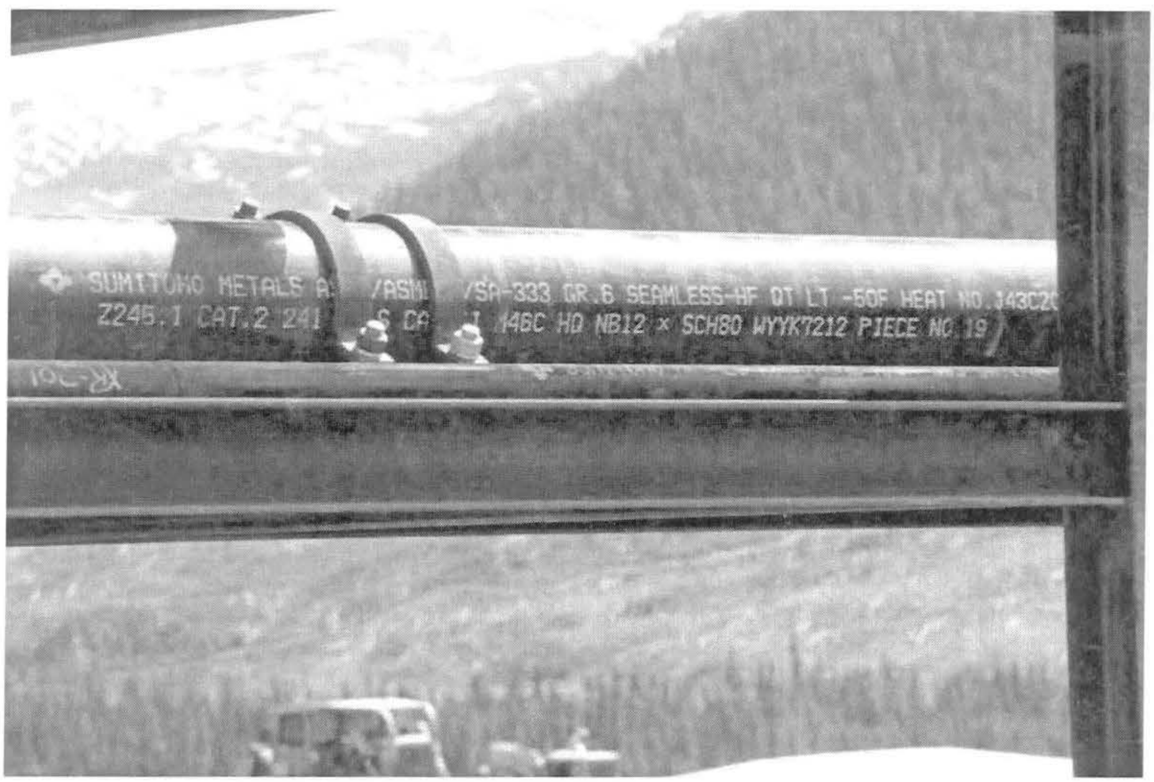
Another material, with identical composition, except 0.35% Ti, may be marked SA-240 304 because the Ti content does not meet the minimum requirement for 321. The Ti content is just a residual.

III-240 MARKING SELECTION

If a material is marked with specifications, grades, classes, or types, it may be used with the allowable stresses, design stress intensities, or ratings appropriate for any of the markings on the material, as long as the material specification, grade, class, and type is permitted by the code of construction governing the boiler, vessel, or component in which the material is to be used. However, once the designer has selected which marking applies (specification, grade, class, type, etc.), the designer must use all the design values appropriate for that selection and may not mix and match values from any other specifications, grades, classes, types, etc., with which the material may be marked.



Multiple marking of ASME SA-106 Grade B and CSA Z245.1 Grade 290 Cat. 1.



Multiple marking of ASME SA-333 Grade 6, and CSA Z245.1 Grade 241 Cat. 2.

SPECIFICATION FOR SEAMLESS CARBON STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

Pipe has -12.5% tolerance for thickness.

SA-106/SA-106M

(Identical with ASTM Specification A 106/A 106M-08)

1. Scope

1.1 This specification covers seamless carbon steel pipe for high-temperature service (Note 1) in NPS $\frac{1}{8}$ to NPS 48 [DN 6 to DN 1200] (Note 2) inclusive, with nominal (average) wall thickness as given in ASME B36.10M. It shall be permissible to furnish pipe having other dimensions provided such pipe complies with all other requirements of this specification. Pipe ordered under this specification shall be suitable for bending, flanging, and similar forming operations, and for welding. When the steel is to be welded, it is presupposed that a welding procedure suitable to the grade of steel and intended use or service will be utilized.

NOTE 1 — It is suggested, consideration be given to possible graphitization.

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

1.2 Supplementary requirements of an optional nature are provided for seamless pipe intended for use in applications where a superior grade of pipe is required. These supplementary requirements call for additional tests to be made and when desired shall be so stated in the order.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. 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 nonconformance with the standard.

1.4 The following precautionary caveat pertains only to the test method portion, Sections 11, 12, and 13 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ASME Standard:*

ASME B36.10M Welded and Seamless Wrought Steel Pipe

2.3 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.5 *Other Standards:*

SSPC-SP 6 Surface Preparation Specification No. 6

3. Ordering Information

3.1 The inclusion of the following, as required will describe the desired material adequately, when ordered under this specification:

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

3.1.2 Name of material (seamless carbon steel pipe),

3.1.3 Grade (Table 1),

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

3.1.5 Size (NPS [DN] and weight class or schedule number, or both; outside diameter and nominal wall thickness; or inside diameter and nominal wall thickness),

3.1.6 Special outside diameter tolerance pipe (16.2.2),

3.1.7 Inside diameter tolerance pipe, over 10 in. [250 mm] ID (16.2.3),

3.1.8 Length (specific or random, Section 17),

3.1.9 Optional requirements (Section 9 and S1 to S8),

3.1.10 Test report required (Section on Certification of Specification A 530/A 530M),

3.1.11 Specification designation (A 106 or A 106M, including year-date),

3.1.12 End use of material,

3.1.13 Hydrostatic test in accordance with Specification A 530/A 530M or 13.3 of this specification, or NDE in accordance with Section 14 of this specification.

3.1.14 Special requirements.

4. Process

4.1 The steel shall be killed steel, with the primary melting process being open-hearth, basic-oxygen, or electric-furnace, possibly combined with separate degassing or refining. If secondary melting, using electroslag remelting or vacuum-arc remelting is subsequently employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.2 Steel cast in ingots or strand cast is permissible. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 For pipe NPS 1½ [DN 40] and under, it shall be permissible to furnish hot finished or cold drawn.

4.4 Unless otherwise specified, pipe NPS 2 [DN 50] and over shall be furnished hot finished. When agreed upon between the manufacturer and the purchaser, it is permissible to furnish cold-drawn pipe.

5. Heat Treatment

5.1 Hot-finished pipe need not be heat treated. Cold-drawn pipe shall be heat treated after the final cold draw pass at a temperature of 1200°F (650°C) or higher.

6. General Requirements

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

7. Chemical Composition

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

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified in Section 7. If the secondary melting processes of 5.1 are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7.

9. Product Analysis

9.1 At the request of the purchaser, analyses of two pipes from each lot (see 20.1) shall be made by the manufacturer from the finished pipe. The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 7.

9.2 If the analysis of one of the tests specified in 9.1 does not conform to the requirements specified in Section 7, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to requirements specified.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties given in Table 2.

11. Bending Requirements

11.1 For pipe NPS 2 [DN 50] and under, a sufficient length of pipe shall stand being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the outside diameter (as shown in ASME B36.10M) of the pipe, without developing cracks. When ordered for close coiling, the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the outside diameter (as shown in ASME B36.10M) of the pipe, without failure.

11.2 For pipe whose diameter exceeds 25 in. [635 mm] and whose diameter to wall thickness ratio, where the shall transfer complete identifying information, including the name or brand of the manufacturer to each unmarked cut length, or to metal tags securely attached to bundles of unmarked small diameter pipe. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

25.3 *Bar Coding* — In addition to the requirements in 25.1 and 25.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used.

26. Government Procurement

26.1 When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for the shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Fed. Std. No. 183 if continuous marking is required for military agencies.

26.2 *Inspection* — Unless otherwise specified in the contract, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the producer shall use his own, or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that the material conforms to the prescribed requirements.

27. Keywords

27.1 carbon steel pipe; seamless steel pipe; steel pipe

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max[A]	0.25	0.30	0.35
Manganese	0.27–0.93	0.29–1.06	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	0.10	0.10	0.10
Chrome, max[B]	0.40	0.40	0.40
Copper, max[B]	0.40	0.40	0.40
Molybdenum, max[B]	0.15	0.15	0.15
Nickel, max[B]	0.40	0.40	0.40
Vanadium, max[B]	0.08	0.08	0.08

[A] For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to a maximum of 1.35%.

[B] These five elements combined shall not exceed 1%.

TABLE 2
TENSILE REQUIREMENTS

	Grade A		Grade B		Grade C	
Tensile strength, min, psi (MPa)	48 000 [330]		60 000 [415]		70 000 [485]	
Yield strength, min, psi (MPa)	30 000 [205]		35 000 [240]		40 000 [275]	
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. [50 mm], min, %:						
Basic minimum elongation transverse strip tests, and for all small sizes tested in full section	35	25	30	16.5	30	16.5
When standard round 2 in. [50 mm] gage length test specimen is used	28	20	22	12	20	12
For longitudinal strip tests	A		A		A	
For transverse strip tests, a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [7.9 mm] from the basic minimum elongation of the following percentage shall be made		1.25		1.00		1.00

[A] The minimum elongation in 2 in. [50 mm] shall be determined by the following equation:

$$e = 625\,000 A^{0.2}/U^{0.9}$$

for inch-pound units, and

$$e = 1\,940 A^{0.2}/U^{0.9}$$

for SI units,

where:

e = minimum elongation in 2 in. [50 mm], %, rounded to the nearest 0.5%.

A = cross-sectional area of the tension test specimen, in.^{2} [mm^2], based upon specified outside diameter or nominal specimen width and specified wall thickness rounded to the nearest 0.01 in.^{2} [mm^2]. If the area thus calculated is greater than 0.75 in.^{2} [500 mm^2], then the value 0.75 in.^{2} [50 mm^2] shall be used, and

U = specified tensile strength, psi [MPa].

TABLE 3
VARIATIONS IN OUTSIDE DIAMETER

NPS [DN Designator]	Permissible Variations in Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
$^1/_8$ to $1^1/_2$ [6 to 40], incl	$^1/_{64}$ (0.015)	0.4	$^1/_{64}$ (0.015)	0.4
Over $1^1/_2$ to 4 [40 to 100], incl	$^1/_{32}$ (0.031)	0.8	$^1/_{32}$ (0.031)	0.8
Over 4 to 8 [100 to 200], incl	$^1/_{16}$ (0.062)	1.6	$^1/_{32}$ (0.031)	0.8
Over 8 to 18 [200 to 450], incl	$^3/_{32}$ (0.093)	2.4	$^1/_{32}$ (0.031)	0.8
Over 18 to 26 [450 to 650], incl	$^1/_8$ (0.125)	3.2	$^1/_{32}$ (0.031)	0.8
Over 26 to 34 [650 to 850], incl	$^5/_{32}$ (0.156)	4.0	$^1/_{32}$ (0.031)	0.8
Over 34 to 48 [850 to 1200], incl	$^3/_{16}$ (0.187)	4.8	$^1/_{32}$ (0.031)	0.8

TABLE 4
MARKING

Hydro	NDE	Marking
Yes	No	Test Pressure
No	Yes	NDE
No	No	NH
Yes	Yes	Test Pressure/NDE

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 Test

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 [DN 200] 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 A 530/A 530M and satisfactory retest.

S3. Flattening Test, Standard

S3.1 For pipe over NPS 2 [DN 50], a section of pipe not less than 2½ in. [63.5 mm] in length shall be flattened cold between parallel plates until the opposite walls of the pipe meet. Flattening tests shall be in accordance with Specification A 530/A 530M, except that in the formula used to calculate the "H" value, the following "e" constants shall be used:

0.08 for Grade A

0.07 for Grades B and C

S3.2 When low *D*-to-*t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than ten.

S3.3 The flattening test shall be made on one length of pipe from each lot of 400 lengths or fraction thereof of each size over NPS 2 [DN 50], up to but not including NPS 6 [DN 150], and from each lot of 200 lengths or fraction thereof, of each size NPS 6 [DN 150] and over.

S3.4 Should a crop end of a finished pipe fail in the flattening test, one retest is permitted to be made from the failed end. Pipe shall be normalized either before or after the first test, but pipe shall be subjected to only two normalizing treatments.

S4. Flattening Test, Enhanced

S4.1 The flattening test of Specification A 530/A 530M 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 A 530/A 530M 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.

S5. Metal Structure and Etching Test

S5.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate sections of Method E 381. 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.

S6. Carbon Equivalent

S6.1 The steel shall conform to a carbon equivalent (CE) of 0.50 maximum as determined by the following formula:

$$CE = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Ni + \%Cu}{15}$$

S6.2 A lower CE maximum may be agreed upon between the purchaser and the producer.

S6.3 The CE shall be reported on the test report.

S7. Heat Treated Test Specimens

S7.1 At the request of the purchaser, one tensile test shall be performed by the manufacturer on a test specimen

Safety Design Code   Focus on

14" PIPE

NOV 14 2001 13:24

DATE: 11/14/01
TIME: 14:08:51

TUBULAR PRODUCTS
CERTIFIED TEST REPORT

(TYPE B - IN ACCORDANCE WITH ISO 10474/EN10204/DIN50049)

MILL ORDER/ITEM NO.	SHIPPERS NO.	P.O. NUMBER	VEHICLE I.D.	
DR15942 01		1686		

SOLD TO ADDRESS	MAIL TO ADDRESS	VENDOR

SPECIFICATION AND GRADE

PIPE CARBON SMLS LINE PIPE ASTM A106-M99 GRADE B/C ASME SA106-M2001 EDITION GRADE B/C TO TSI/USS-003 REV 3 DTD 7/6/01 API 5L-M42ND EDITION DATED 1/00 PSL-1 GRADE X42 BLK REG MILL COAT PE SC MEETING ALL THE APPLICABLE REQUIREMENTS OF NACE STANDARD MR-01-75 M2000

A23405   mat'l used in Burst test

MATERIAL COND: AS ROLLED   O.D.: 14.000(355.600) in (mm)   WALL: 0.750 (19.050) in (mm)

PRODUCT IDENTIFICATION	TENSILE TEST TYPE/ ORIENTATION	TEST COND.	GAUGE WIDTH IN	YIELD PSI	EXT % .50	TENSILE PSI	Y/T	ELONG % (IN 2")	HARDNESS SCALE HRB	MIN HYDRO PSI	DWELL (SEC)
				MIN 52000		MIN 70000	MAX	MIN 22.5	MIN	3000	5
				MAX		MAX			MAX 90.7		
A23405	ROUND/T/B	AR	0.350	59000	.50	86000	0.68	29.0	B 85.0	3000	5
A23405	ROUND/T/B	AR	0.350	61500	.50	88000	0.70	27.0			
A23405	ROUND/L/B	AR	0.350	59500	.50	86000	0.69	29.0			
A23405	ROUND/L/B	AR	0.350	60000	.50	87000	0.69	27.0			

** END OF DATA THIS SHEET **

LEGEND: L - LONGITUDINAL, U - UPSET, T - TRANSVERSE, N - NORMALIZED, QT - QUENCHED & TEMPERED, SR - STRESS RELIEVED, AR - AS ROLLED, B - BODY, W - WELD

PRODUCT IDENTIFICATION	TYPE	C	MN	P	S	SI	CU	NI	CR	MO	AL	N	V	B	TI	CA	CO	CE* MAX .42
A23405	HEAT	14	124	007	006	28	03	02	05	06	029	006	060		016	024		.38
A23405	PROD	15	128	006	010	25	03	02	05	06	032	006	059		017	026		.40
A23405	PROD	14	126	008	008	26	03	02	05	06	032	006	057		017	027		.39

** END OF DATA THIS SHEET **

*C.E. IS BASED ON THE FOLLOWING EQUATION(S): CE=C+(MN/6)+(CR+MO+V)/5+ (NI+CU)/15

DECIMAL POSITIONS FOR ELEMENTS ARE INDICATED BY THE LEFT MARGIN, VERTICAL DOTTED LINE OR DECIMAL POINT.

SPECIFICATION FOR SEAMLESS AND WELDED STEEL PIPE FOR LOW-TEMPERATURE SERVICE

SA-333/SA-333M

(Identical with ASTM Specification A 333/A 333M-04a except for the deletion of 12.3 that conflicts with 15.)

1. Scope

1.1 This specification covers nominal (average) wall seamless and welded carbon and alloy steel pipe intended for use at low temperatures. Several grades of ferritic steel are included as listed in Table 1. Some product sizes may not be available under this specification because heavier wall thicknesses have an adverse effect on low-temperature impact properties.

1.2 Supplementary Requirement S1 of an optional nature is provided. This shall apply only when specified by the purchaser.

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

NOTE 1 — 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:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 671 Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures

A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials

3. Ordering Information

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

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

3.1.2 Name of material (seamless or welded pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (NPS or outside diameter and schedule number of average wall thickness),

3.1.5 Length (specific or random) (Section 9), (see the Permissible Variations in Length section of Specification A 999/A 999M),

3.1.6 End finish (see the Ends section of Specification A 999/A 999M),

3.1.7 Optional requirements (see the Heat Analysis requirement in the Chemical Composition section of A 999/A 999M, the Repair by Welding section, and the section on Nondestructive Test Requirements),

3.1.8 Test report required (see the Certification section of Specification A 999/A 999M),

3.1.9 Specification designation, and

3.1.10 Special requirements or exceptions to this specification.

4. Materials and Manufacture

4.1 *Manufacture* — The pipe shall be made by the seamless or welding process with the addition of no filler metal in the welding operation. Grade 4 shall be made by the seamless process.

NOTE 2 — For electric-fusion-welded pipe, with filler metal added, see Specification A 671.

4.2 *Heat Treatment:*

4.2.1 All seamless and welded pipe, other than Grades 8 and 11, shall be treated to control their microstructure in accordance with one of the following methods:

4.2.1.1 Normalize by heating to a uniform temperature of not less than 1500°F [815°C] and cool in air or in the cooling chamber of an atmosphere controlled furnace.

4.2.1.2 Normalize as in 4.2.1.1, and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

4.2.1.3 For the seamless process only, reheat and control hot working and the temperature of the hot-finishing operation to a finishing temperature range from 1550 to 1750°F [845 to 945°C] and cool in air or in a controlled atmosphere furnace from an initial temperature of not less than 1550°F [845°C].

4.2.1.4 Treat as in 4.2.1.3 and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

4.2.1.5 Seamless pipe of Grades 1, 6, and 10 may be heat treated by heating to a uniform temperature of not less than 1500°F [815°C], followed by quenching in liquid and reheating to a suitable tempering temperature, in place of any of the other heat treatments provided for in 4.2.1.

4.2.2 Grade 8 pipe shall be heat treated by the manufacturer by either of the following methods:

4.2.2.1 *Quenched and Tempered* — Heat to a uniform temperature of 1475 ± 25°F [800 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; quench by immersion in circulating water. Reheat until the pipe attains a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air or water quench at a rate no less than 300°F [165°C]/h.

4.2.2.2 *Double Normalized and Tempered* — Heat to a uniform temperature of 1650 ± 25°F [900 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat until the pipe attains a uniform temperature of 1450 ± 25°F [790 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. [2 min/mm] of thickness but in no case less than 15 min; cool in air or water quench at a rate not less than 300°F [165°C]/h.

4.2.3 Whether to anneal Grade 11 pipe is per agreement between purchaser and supplier. When Grade 11 pipe is annealed, it shall be normalized in the range of 1400 to 1600°F [760 to 870°C].

4.2.4 Material from which test specimens are obtained shall be in the same condition of heat treatment as the pipe furnished. Material from which specimens are to be taken shall be heat treated prior to preparation of the specimens.

4.2.5 When specified in the order the test specimens shall be taken from full thickness test pieces which have been stress relieved after having been removed from the heat-treated pipe. The test pieces shall be gradually and uniformly heated to the prescribed temperature, held at that temperature for a period of time in accordance with Table 2, and then furnace cooled at a temperature not exceeding 600°F [315°C]. Grade 8 shall be cooled at a minimum rate of 300°F [165°C]/ h in air or water to a temperature not exceeding 600°F [315°C].

5. Chemical Composition

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

5.2 When Grades 1, 6, or 10 are ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted. However, the addition of elements required for the deoxidation of the steel is permitted.

6. Product Analysis

6.1 At the request of the purchaser, an analysis of one billet or two samples of flat-rolled stock from each heat or of two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following:

NPS Designator	Length of Pipe in Lot
Under 2	400 or fraction thereof
2 to 6	200 or fraction thereof
Over 6	100 or fraction thereof

6.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified.

6.3 If the analysis of one of the tests specified in 6.1 does not conform to the requirements specified, 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.

7. Tensile Requirements

7.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

8. Impact Requirements

8.1 For Grades 1, 3, 4, 6, 7, 9, and 10, the notched-bar impact properties of each set of three impact specimens, including specimens for the welded joint in welded pipe with wall thicknesses of 0.120 in. [3 mm] and larger, when tested at temperatures in conformance with 14.1 shall be not less than the values prescribed in Table 4. The impact test is not required for Grade 11.

8.1.1 If the impact value of one specimen is below the minimum value, or the impact values of two specimens are less than the minimum average value but not below the minimum value permitted on a single specimen, a retest shall be allowed. The retest shall consist of breaking three additional specimens and each specimen must equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedures, a retest will be allowed.

8.2 For Grade 8 each of the notched bar impact specimens shall display a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

8.2.1 When the average lateral expansion value for the three impact specimens equals or exceeds 0.015 in. [0.38 mm] and the value for one specimen is below 0.015 in. [0.38 mm] but not below 0.010 in. [0.25 mm], a retest of three additional specimens may be made. The lateral expansion of each of the retest specimens must equal or exceed 0.015 in. [0.38 mm].

8.2.2 Lateral expansion values shall be determined by the procedure in Test Methods and Definitions A 370.

8.2.3 The values of absorbed energy in foot-pounds and the fracture appearance in percentage shear shall be recorded for information. A record of these values shall be retained for a period of at least 2 years.

9. Lengths

9.1 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft (Note 3) with 5% 12 to 16 ft (Note 3), or in double random lengths with a minimum average of 35 ft (Note 3) and a minimum length of 22 ft (Note 3) with 5% 16 to 22 ft (Note 3).

NOTE 3 — This value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

10. Workmanship, Finish, and Appearance

10.1 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 10.2.

10.2 Surface imperfections that penetrate more than $12\frac{1}{2}\%$ 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:

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

10.2.2 Repaired in accordance with the repair welding provisions of 10.5.

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

10.2.4 The defective pipe may be rejected.

10.3 To provide a workmanlike finish and basis for evaluating conformance with 10.2, the pipe manufacturer shall remove by grinding the following:

10.3.1 Mechanical marks, abrasions and pits, any of which imperfections are deeper than $\frac{1}{16}$ in. [1.6 mm], and

10.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 10.1 to be deeper than 5% of the nominal wall thickness.

10.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 10.2 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.

10.5 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.

10.5.1 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.

10.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 999/A 999M.

10.7 The finished pipe shall be reasonably straight.

11. General Requirements

11.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

12. Mechanical Testing

12.1 *Sampling* — For mechanical testing, the term *"lot"* applies to all pipe of the same nominal size and wall thickness (or schedule) that is produced from the the same heat of steel and subjected to the same finishing treatment in a continuous furnace. If the final heat treatment is in a batch-type furnace, the lot shall include only those pipes that are heat treated in the same furnace charge.

12.2 *Transverse or Longitudinal Tensile Test and Flattening Test* — For material heat treated in a batch-type furnace, tests shall be made on 5% of the pipe from each lot. If 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 pipes.

12.3 DELETED

12.4 *Impact Test* — One notched bar impact test, consisting of breaking three specimens, shall be made from each heat represented in a heat-treatment load on specimens taken from the finished pipe. This test shall represent only pipe from the same heat and the same heat-treatment load, the wall thicknesses of which do not exceed by more than $\frac{1}{4}$ in. [6.3 mm] the wall thicknesses of the pipe from which the test specimens are taken. If heat treatment is performed in continuous or batch-type furnaces controlled within a 50°F [30°C] range and equipped with recording pyrometers so that complete records of heat treatment are available, then one test from each heat in a continuous run only shall be required instead of one test from each heat in each heat-treatment load.

12.5 *Impact Tests (Welded Pipe)* — On welded pipe, additional impact tests of the same number as required in 12.3 or 12.4 shall be made to test the weld.

12.6 Specimens showing defects while being machined or prior to testing may be discarded and replacements shall be considered as original specimens.

12.7 Results obtained from these tests shall be reported to the purchaser or his representative.

13. Specimens for Impact Test

13.1 Notched bar impact specimens shall be of the simple beam, Charpy-type, in accordance with Test Methods E 23, Type A with a V notch. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable subsize specimens shall be used. Charpy specimens of width along the notch larger than 0.394 in. [10 mm] or smaller than 0.099 in. [2.5 mm] are not provided for in this specification.

13.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the pipe while the axis of the notch shall be perpendicular to the surface. On wall thicknesses of 1 in. [25 mm] or less, the specimens shall be obtained with their axial plane located at the midpoint; on wall thicknesses over 1 in. [25 mm], the specimens shall be obtained with their axial plane located $\frac{1}{2}$ in. [12.5 mm] from the outer surface.

13.3 When testing welds the specimen shall be, whenever diameter and thickness permit, transverse to the longitudinal axis of the pipe with the notch of the specimen in the welded joint and perpendicular to the surface. When diameter and thickness do not permit obtaining transverse specimens, longitudinal specimens in accordance with 13.2 shall be obtained; the bottom of the notch shall be located at the weld joint.

14. Impact Test

14.1 Except when the size of the finished pipe is insufficient to permit obtaining subsize impact specimens, all material furnished to this specification and marked in accordance with Section 16 shall be tested for impact resistance at the minimum temperature for the respective grades as shown in Table 5.

14.1.1 Special impact tests on individual lots of material may be made at other temperatures as agreed upon between the manufacturer and the purchaser.

14.1.2 When subsize Charpy impact specimens are used and the width along the notch is less than 80% of the actual wall thickness of the original material, the specified Charpy impact test temperature for Grades 1, 3, 4, 6, 7, 9, and 10 shall be lower than the minimum temperature shown in Table 5 for the respective grade. Under these circumstances the temperature reduction values shall be by an amount equal to the difference (as shown in Table 6) between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to the Charpy specimen width actually tested. Appendix X1 shows some examples of how the temperature reductions are determined.

14.2 The notched bar impact test shall be made in accordance with the procedure for the simple beam, Charpy-type test of Test Methods E 23.

14.3 Impact tests specified for temperatures lower than 70°F [20°C] should be made with the following precautions. The impact test specimens as well as the handling tongs shall be cooled a sufficient time in a suitable container so that both reach the desired temperature. The temperature shall be measured with thermocouples, thermometers, or any other suitable devices and shall be controlled within 3°F [2°C]. The specimens shall be quickly transferred from the cooling device to the anvil of the Charpy impact testing machine and broken with a time lapse of not more than 5 s.

15. Hydrostatic or Nondestructive Electric Test

15.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

15.2 The hydrostatic test shall be in accordance with Specification A 999/A 999M.

15.3 *Nondestructive Electric Test*— Nondestructive electric tests shall be in accordance with Specification A 999/A 999M, with the following addition.

15.3.1 If the test signals were produced by visual imperfections (listed in 15.3.2), the pipe may be accepted based on visual examination, provided the imperfection is less than 0.004 in. (0.1 mm) or 12½% of the specified wall thickness (whichever is greater).

15.3.2 *Visual Imperfections:*

15.3.2.1 Scratches,

15.3.2.2 Surface roughness,

15.3.2.3 Dings,

15.3.2.4 Straightener marks,

15.3.2.5 Cutting chips,

15.3.2.6 Steel die stamps,

15.3.2.7 Stop marks, or

15.3.2.8 Pipe reducer ripple.

16. Product Marking

16.1 Except as modified in 16.1.1, in addition to the marking prescribed in Specification A 999/A 999M, the marking shall include whether hot finished, cold drawn, seamless or welded, the schedule number and the letters "LT" followed by the temperature at which the impact tests were made, except when a lower test temperature is required because of reduced specimen size, in which case, the higher impact test temperature applicable to a full-size specimen should be marked.

16.1.1 When the size of the finished pipe is insufficient to obtain subsize impact specimens, the marking shall not include the letters "LT" followed by an indicated test temperature unless Supplementary Requirement S1 is specified.

16.1.2 When the pipe is furnished in the quenched and tempered condition, the marking shall include the letters "QT," and the heat treatment condition shall be reported to the purchaser or his representative.

17. Keywords

17.1 low; low temperature service; seamless steel pipe; stainless steel pipe; steel pipe; temperature service applications

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %								
	Grade 1[A]	Grade 3	Grade 4	Grade 6[A]	Grade 7	Grade 8	Grade 9	Grade 10	Grade 11
Carbon, max	0.30	0.19	0.12	0.30	0.19	0.13	0.20	0.20	0.10
Manganese	0.40–1.06	0.31–0.64	0.50–1.05	0.29–1.06	0.90 max	0.90 max	0.40–1.06	1.15–1.50	0.60 max
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.035	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.015	0.025
Silicon	...	0.18–0.37	0.08–0.37	0.10 min	0.13–0.32	0.13–0.32	...	0.10–0.35	0.35 max
Nickel	...	3.18–3.82	0.47–0.98	...	2.03–2.57	8.40–9.60	1.60–2.24	0.25 max	35.0–37.0
Chromium	...	...	0.44–1.01	...	...	...	...	0.15 max	0.50 max
Copper	...	...	0.40–0.75	...	...	...	0.75–1.25	0.15 max	...
Aluminum	...	...	0.04–0.30	...	...	...	...	0.06 max	...
Vanadium, max	...	...	...	...	...	...	...	0.12	...
Columbium, max	...	...	...	...	...	...	...	0.05	...
Molybdenum, max	...	...	...	...	...	...	...	0.05	0.50 max
Cobalt	...	...	...	...	...	...	...	...	0.50 max

[A] For each reduction of 0.01% carbon below 0.30%, an increase of 0.05% manganese above 1.06% would be permitted to a maximum of 1.35% manganese.

TABLE 2
STRESS RELIEVING OF TEST PIECES

Metal Temperature[A,B]				Minimum Holding Time, h/in. [min/mm] of Thickness
Grades 1, 3, 6, 7, and 10		Grade 4[C]		
°F	°C	°F	°C	
1100	600	1150	620	1 [2.4]
1050	565	1100	600	2 [4.7]
1000	540	1050	565	3 [7.1]

[A] For intermediate temperatures, the holding time shall be determined by straight-line interpolation.

[B] Grade 8 shall be stress relieved at 1025 to 1085°F [550 to 585°C], held for a minimum time of 2 h for thickness up to 1.0 in. [25.4 mm], plus a minimum of 1 h for each additional inch [25.4 mm] of thickness and cooled at a minimum rate of 300°F [165°C]/h in air or water to a temperature not exceeding 600°F [315°C].

[C] Unless otherwise specified, Grade 4 shall be stress relieved at 1150°F [620°C].

TABLE 3
TENSILE REQUIREMENTS

	Grade 1		Grade 3		Grade 4		Grade 6		Grade 7		Grade 8		Grade 9		Grade 10		Grade 11	
	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa
Tensile strength, min	55 000	380	65 000	450	60 000	415	60 000	415	65 000	450	100 000	690	63 000	435	80 000	550	65 000	450
Yield strength, min	30 000	205	35 000	240	35 000	240	35 000	240	35 000	240	75 000	515	46 000	315	65 000	450	35 000	240
	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	
Elongation in 2 in. or 50 mm (or 4D), min, %:																		
Basic minimum elongation for walls $^5/_{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	35	25	30	20	30	16.5	30	16.5	30	22	22	...	28	...	22	...	18[A]	
When standard round 2 in. or 50 mm gage length or proportionally smaller size test specimen with the gage length equal to 4D (4 times the diameter) is used	28	20	22	14	22	12	22	12	22	14	16	...	...	...	16	...	...	
For strip tests, a deduction for each $^1/_{32}$ in. [0.8 mm] decrease in wall thickness below $^5/_{16}$ in. [8 mm] from the basic minimum elongation of the following percentage	1.75[B]	1.25[B]	1.50[B]	1.00[B]	1.50[B]	1.00[B]	1.50[B]	1.00[B]	1.50[B]	1.00[B]	1.25[B]	...	1.50[B]	...	1.25[B]	...	...	

[A] Elongation of Grade 11 is for all walls and small sizes tested in full section.
[B] The following table gives the calculated minimum values.

TABLE 4
IMPACT REQUIREMENTS FOR GRADES 1, 3, 4, 6, 7, 9, AND 10

Size of Specimen, mm	Minimum Average Notched Bar Impact Value of Each Set of Three Specimens[A]		Minimum Notched Bar Impact Value of One Specimen Only of a Set[A]	
	ft-lbf	J	ft-lbf	J
10 by 10	13	18	10	14
10 by 7.5	10	14	8	11
10 by 6.67	9	12	7	9
10 by 5	7	9	5	7
10 by 3.33	5	7	3	4
10 by 2.5	4	5	3	4

[A] Straight line interpolation for intermediate values is permitted.

TABLE 5
IMPACT TEMPERATURE

Grade	Minimum Impact Test Temperature	
	°F	°C
1	−50	−45
3	−150	−100
4	−150	−100
6	−50	−45
7	−100	−75
8	−320	−195
9	−100	−75
10	−75	−60

TABLE 6
IMPACT TEMPERATURE REDUCTION

Specimen Width Along Notch or Actual Material Thickness		Temperature Reduction, Degrees Colder[A]	
in.	mm	°F	°C
0.394	10 (standard size)	0	0
0.354	9	0	0
0.315	8	0	0
0.295	7.5 (3/4 std. size)	5	3
0.276	7	8	4
0.262	6.67 (2/3 std. size)	10	5
0.236	6	15	8
0.197	5 (1/2 std. size)	20	11
0.158	4	30	17
0.131	3.33 (1/3 std. size)	35	19
0.118	3	40	22
0.099	2.5 (1/4 std. size)	50	28

[A] Straight line interpolation for intermediate values is permitted.

(A04) (A02)

MATERIAL TEST REPORT

INSPECTION CERTIFICATE EN 10204 3.1.B

ISO 9001

(A06)**Purchaser :**

(A07)**Order n° :**

(B01)SEAMLESS STEEL PIPE,HOT FINISHED (KILLED STEEL)

(B04) HOT FINISHED NORMALIZED CONDITION 920°C (1688 F) mini-air

ENDS BEVELLED 37,5° ANTI-RUST COATING DRY VARNISH

(B02)Specification :ASTM A 333 (01/03/05) +ASME SA 333 ADD 05(01/07/05) +GRADE 1 AND 6+CSA Z245-1 (01/03/98)+GRADE 290 CAT.II+NACE MR0175 ISO 1516 +CPCN-4 REV. DASME SA 530 (01/07/04)+ASME SECT. II PART.A PART.D(2004) ADD (2005)

(B06-B07)

Stencil marking: [illegible] A/SA333 Z245-1 1 + 6 + 290 CAT II 4 SCH 40 0.237 HFS LT 49 F HT HEAT NUMBER [illegible]

QUANTITY PER ITEM

Y/R	O/R	(B11-B12) Size	(B13) single length	(B10) Quantity	length ft	(B14) Weight lb	(B08) Heat
05	05	NPS 4 SCH 40 114.30 X 6.02 MM	12192 /13411MM 480.02 /528.01in	55	2363.16	25522	331406

(C71-C92)

LADLE ANALYSIS

CE = C + F {MN/6 + SI/24 + CU/15 + NI/20 + (CR + MO + V + NB) / 5 + 5 B } < 0.40% : HEAT 331406 = 0.32%

022: MN/C (C70) Process	(B08) Heat	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	Ti	Nb	V	B	022
MIN.			0.10	0.40											3
MAX.		0.24	0.50	1.35	0.025	0.025					0.11	0.11	0.11	0.001	
		%	%	%	%	%	%	%	%	%	%	%	%	%	%
L	331406	0.14	0.21	1.04	0.013	0.003	0.12	0.01	0.03	0.02	0.02	0.00	0.00	0.000	7

FOR EACH REDUCTION OF 0.01% CARBON BELOW 0.30% , AN INCREASE OF 0.05% MANGANESE ABOVE 1.06% WOULD BE PERMITTED TO A MAXIMUM OF 1.35% MANGANESE

(A04) (A02)

MATERIAL TEST REPORT

INSPECTION CERTIFICATE EN 10204 3.1.B

ISO 9001

(C10-C02-C03)
RECTANGULAR SPECIMEN LONGITUDINAL TENSILE TEST AT ROOM TEMPERATURE

(C00) Test	(B08) Heat	width	thick.	sect.	(C11) Y.S.	(C12) T.S.	(C13) Elong. 2"
MIN.					42000	60000	30
MAX.							
		mm	mm	mm2	psi	psi	%
01FE065	331406	19.7	5.8	114.89	44684	68622	35
02FE065	331406	19.4	6.0	117.33	43524	68187	37
05FE065	331406	19.8	6.0	119.47	45264	70653	36
06FE065	331406	19.7	5.9	116.88	42363	68622	36

ROCKWELL C HARDNESS < OR = 22 GUARANTEED
(C40-C02-C41)
CHARPY V LONGITUDINAL IMPACT TEST

(C00) Test	(B08) Heat	(C03) temp.	width	height	sect.	(C42) E1	(C42) E2	(C42) E3	(C43) mean	(C42) shear1	(C42) shear2	(C42) shear3	(C43) shear mean
MIN.						4	4	4	7				
MAX.													
		°F	mm	mm	cm2	ft.lbf	ft.lbf	ft.lbf	ft.lbf	%	%	%	%
01FE065	331406	-69	3.33	10.00	0.27	26	28	27	27	40	60	50	50

(C30)HB
BRINELL HARDNESS

(C00) Test	(B08) Heat	(C31) hardness 1
MIN.		
MAX.		200
		HB
01FE065	331406	137

(A04)

(A02)

MATERIAL TEST REPORT

INSPECTION CERTIFICATE EN 10204 3.1.B

ISO 9001

(D01-D99)
NON DESTRUCTIVE TESTS

test	test rate	specification	pressure psi	hold time sec	result
APPEARANCE & DIMENSIONS	100% LOT				OK
EDDY CURRENT TEST	100% LOT	CSA Z245-1			OK
HYDROSTATIC TEST	100% LOT		2654	5	OK

(C50-C69)
TECHNOLOGICAL TESTS

test	result
FLATTENING TEST	OK

(Z01)**31/01/2006**

(Z02) Original computer copy - authenticity is guaranteed by the logo.	(A05) The authorized expert in Quality Control Section
All the pipes/tubes conform to the requirements of the order and standard regarding the grade,quality and heat treatment throughout their whole length.	

QUALITY CONTROL DOCUMENT #36 (MILL TEST CERTIFICATE)

PRODUCT SIZE & GAUGE 168.3 x 6.4
HYDROSTATIC PRESSURE 25,900 kPa
HYDROSTATIC TIME 5 SEC % SMYS
CONFORMING TO: C.S.A. Z245.1 CAT.II S.S. G359

SHIPPED VIA
CUSTOMER P.O.
MILL ORDER

DATE 23/02/90
ITEM NO.

SEAM INDUCTION
NORMALIZING TEMP. 1058 °C
MILL SPEED 127 FT./MIN.
METERS SHIPPED
SECTIONS SHIPPED

HEAT NO.	COIL CODE	YIELD	TENSILE	% ELONG IN 50 mm	YIELD / TENSILE	CHEMICAL ANALYSIS	C	Mn	P	S	Si	Al	Cr	Mo	Ni	Cu	Cb	Ca	V	B	CARBON EQUIV.	HARDNESS TYPE	LOW	HIGH	AVERAGE
8077	58DY	449	541	31	.83	LADLE	.11	.85	.009	.0014	.24	.04	.03	.01	.01	.01	.01	.0038	0	0		HRB	87	90	88.7
						CHECK	.11	.77	.008	.001	.26	.039	.02	.011	.013	.010	.010	.003	0	0	.22	HV	183	214	195.5
8077	62DY	426	539	32	.79	LADLE	.11	.85	.009	.0014	.24	.04	.03	.01	.01	.01	.01	.0038	0	0		HRB	84	90	87.2
						CHECK	.11	.77	.008	.001	.25	.038	.02	.011	.013	.010	.010	.003	0	0	.22	HV	183	214	195.5
8078	66DY	450	542	31	.83	LADLE	.12	.85	.009	.0011	.24	.05	.04	.01	.01	.03	.01	.0039	0	0		HRB	87	91	89.3
						CHECK	.12	.87	.009	.001	.25	.04	.03	.011	.018	.021	.010	.003	0	0	.24	HV	189	218	200.1
8078	74DY	458	548	30	.84	LADLE	.12	.85	.009	.0011	.24	.05	.04	.01	.01	.03	.01	.0039	0	0		HRB	86	92	89.4
						CHECK	.13	.77	.009	.001	.26	.040	.04	.012	.019	.024	.008	.003	0	0	.24	HV	189	218	200.1
						LADLE																HRB			
						CHECK																HV			
						LADLE																HRB			
						CHECK																HV			
						LADLE			*DEOXIDATION PRACTICE – ALUMINUM SILICON FULLY KILLED													HRB			
						CHECK																HV			
						LADLE																HRB			
						CHECK																HV			
						LADLE																HRB			
						CHECK																HV			
						LADLE																HRB			
						CHECK																HV			

CHARPY V NOTCH IMPACT TESTS

ORIENTATION: TRANSVERSE LONGITUDINAL
POSITION CODE: SKELP PIPEBODY PIPEWELD
SPECIMEN SIZE: TEMPERATURE:
ENERGY: JOULES FOOT POUNDS

HEAT NO. SAMPLE POS.	ENERGY	% SHEAR	ENERGY	% SHEAR	ENERGY	% SHEAR	ENERGY	% SHEAR	ENERGY	% SHEAR
#1										
#2										
#3										

HEAT NO. SAMPLE POS.	ENERGY	% SHEAR	ENERGY	% SHEAR	ENERGY	% SHEAR	ENERGY	% SHEAR	ENERGY	% SHEAR
#1										
#2										
#3										

WE CERTIFY THAT THE PRODUCT DESCRIBED ABOVE PASSED ALL OF THE TESTS REQUIRED BY THE SPECIFICATION.

GENERAL COMMENTS

*FULL NORMALIZING WAS ACHIEVED ON ALL OF THE ABOVE HEATS.

*IMPACT RESULTS ON ATTACHED PAGES

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, FOR MODERATE- AND LOWER-TEMPERATURE SERVICE

SA-516/SA-516M

(Identical with ASTM Specification A 516/A 516M-06)

1. Scope

1.1 This specification covers carbon steel plates intended primarily for service in welded pressure vessels where improved notch toughness is important.

1.2 Plates under this specification are available in four grades having different strength levels as follows:

Grade U.S. [SI]	Tensile Strength, ksi [MPa]
55 [380]	55–75 [380–515]
60 [415]	60–80 [415–550]
65 [450]	65–85 [450–585]
70 [485]	70–90 [485–620]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

Grade U.S. [SI]	Maximum Thickness, in. [mm]
55 [380]	12 [305]
60 [415]	8 [205]
65 [450]	8 [205]
70 [485]	8 [205]

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results of Specification A 20/A 20M apply.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, and so forth.

3.2 Specification A 20/A 20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1: For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 Plates 1.50 in. [40 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 1.50 in. [40 mm] in thickness shall be normalized.

5.3 When notch-toughness tests are required on plates 1½ in. [40 mm] and under in thickness, the plates shall be normalized unless otherwise specified by the purchaser.

5.4 If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible for improvement of the toughness, provided the plates are subsequently tempered in the temperature range 1100 to 1300°F [595 to 705°C].

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Properties

7.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

8. Keywords

8.1 carbon steel; carbon steel plate; pressure containing parts; pressure vessel steels; steel plates for pressure vessels

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, % Grade 55 [Grade 380]	Grade 60 [Grade 415]	Grade 65 [Grade 450]	Grade 70 [Grade 485]
Carbon, max(A), (B):				
½ in. [12.5 mm] and under	0.18	0.21	0.24	0.27
Over ½ in. to 2 in. [12.5 to 50 mm], incl	0.20	0.23	0.26	0.28
Over 2 in. to 4 in. [50 to 100 mm], incl	0.22	0.25	0.28	0.30
Over 4 to 8 in. [100 to 200 mm], incl	0.24	0.27	0.29	0.31
Over 8 in. [200 mm]	0.26	0.27	0.29	0.31
Manganese(B):				
½ in. [12.5] and under:				
Heat analysis	0.60–0.90	0.60–0.90 (C)	0.85–1.20	0.85–1.20
Product analysis	0.55–0.98	0.55–0.98 (C)	0.79–1.30	0.79–1.30
Over ½ in. [12.5 mm]:				
Heat analysis	0.60–1.20	0.85–1.20	0.85–1.20	0.85–1.20
Product analysis	0.55–1.30	0.79–1.30	0.79–1.30	0.79–1.30
Phosphorus, max(A)	0.035	0.035	0.035	0.035
Sulfur, max(A)	0.035	0.035	0.035	0.035
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45

NOTES:

(A) Applies to both heat and product analyses.

(B) For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50% by heat analysis and 1.60% by product analysis.

(C) Grade 60 plates ½ in. [12.5 mm] and under in thickness may have 0.85–1.20% manganese on heat analysis, and 0.79–1.30% manganese on product analysis.

TABLE 2
TENSILE REQUIREMENTS

	Grade 55 [380]	60 [415]	65 [450]	70 [485]
Tensile strength, ksi [MPa]	55–75 [380–515]	60–80 [415–550]	65–85 [450–585]	70–90 [485–620]
Yield strength, min, ksi [MPa](A)	30 [205]	32 [220]	35 [240]	38 [260]
Elongation in 8 in. [200 mm], min, % (B)	23	21	19	17
Elongation in 2 in. [50 mm], min, % (B)	27	25	23	21

NOTES:

(A) Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

(B) See Specification A 20/A 20M for elongation adjustment.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in ASTM Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following supplementary requirement is suitable for this application.

S54. Requirements for Carbon Steel Plate for Hydrofluoric Acid Alkylation Service

S54.1 Plates shall be provided in the normalized heat-treated condition.

S54.2 The maximum carbon equivalent shall be as follows:

Plate thickness less than or equal to 1 in. [25 mm]: CE maximum = 0.43

Plate thickness greater than 1 in. [25 mm]: CE maximum = 0.45

S54.3 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S54.4 Vanadium and niobium maximum content based on heat analysis shall be:

Maximum vanadium = 0.02%

Maximum niobium = 0.02%

Maximum vanadium plus niobium = 0.03%

(Note: niobium = columbium)

S54.5 The maximum composition based on heat analysis of Ni + Cu shall be 0.15%.

S54.6 The minimum C content based on heat analysis shall be 0.18%. The maximum C content shall be as specified for the ordered grade.

S54.7 Welding consumables for repair welds shall be of the low-hydrogen type. E60XX electrodes shall not be used and the resulting weld chemistry shall meet the same chemistry requirements as the base metal.

S54.8 In addition to the requirements for product marking in the specification, an "HF-N" stamp or marking shall be provided on each plate to identify that the plate complies with this supplementary requirement.

Notebook Page 196

Certificate Of Test
Certificat D'Essai
Pruefbescheinigung

20> 01/ 9/ 67

95/193/ 2 | 2280 | 22/ 5/ 81

A.S.T.M A516-1988 GR.70 + IMPS

PLATES NORMALISED

XXXXXXXXXX
XXXXXXXXXX
XXXXXXXXXX

--C ALLOY465 AR/VANCOUVER DIMS IN INCHES/CAST NO ASTM A516-86 GR 70

Item	Dimensions	Cast Number	Plate Number	Yield (TRANSVERSE) P.S.I.	Tensile (TRANSVERSE)	Elong. % (TRANSVERSE)	CHARPY V 10X10X2MM FT.LBS @ -50 F (LONGITUDINAL)	C	SI	MN	P	S	CR	MO	NI	CEV
1	32" 0.000" 96.000" 0.7500"	83151	DJ700	54100	78612	27	28 21 22 24	.22	.34	1.13	.011	.015	.024	.005	.025	.42

AL.043 CU.033 N .008
NB.003 V .002

ATE(S) AND TESTS NORMALISED AT 890C - 930C FOR A MINIMUM 1.5 MINUTES PER MILLIMETRE OF THICKNESS

McQuaid EHN Grain Size
83151 = 7

XXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXX

Made by the BOS Process
These results are certified by British Steel Corporation, and comply with the requirements of the Product specification.

On behalf of the
Test House Manager
Essais et Controle
Chef der Abnahme

CUSTOMER PURCHASE ORDER NUMBER	ENTRY DATE	SHIP DATE	SHIPPERS NUMBER	CARRIER	PAGE NO	MILL ORDER
9965	DEC 11/87	88-02-29	02 5010		3 of 7	64213

CHARGE TO CUSTOMER NAME AND ADDRESS

SHIP TO CUSTOMER NAME AND ADDRESS

TEST REPORTS

WE HEREBY CERTIFY THAT THE MATERIAL HEREIN DESCRIBED WAS MADE AND TESTED IN ACCORDANCE WITH THE RULES OF THE SPECIFICATION SHOWN HEREIN AND AS CONTAINED IN THE CORPORATION RECORDS

MAR - 1 1988

CUSTOMER SPECIFICATION

HR PLATE - CARBON - ASME SA 516 70 (86 A86) - PVQ - SHEARED

SUPPLEMENTARY INSTRUCTIONS

RESALE

MILL SN/TR

RESALE

NN-NN-NN

SENIOR METALLURGIST

PLATE MILL

HEAT AND INGOT NUMBER	IDENTIFICATION OF PIECE TESTED	WEIGHT	NUMBER OF PIECES	THICKNESS OF TEST	CONDITION OF TEST	TENSILE PROPERTIES YIELD PSI	TENSILE PSI	% ELONGATION 2"	4"	8"	BEND	MC QUAID	TYPE DIRECT	IMPACT PROPERTIES 1 FTLB	2 FTLB	3 FTLB	TEMP °F
CUST ITEM 2 OUR ITEM 002 .375 X 120 X 384 "																	
4440M-03	15428	9801	2	.375		47840	74160	22									
4690M-03	19325	9801	2	.375		50670	74070	25									
4690M-54	19324	9801	2	.375		49700	73650	23									
CUST ITEM 3 OUR ITEM 003 .500 X 120 X 384 "																	
4345M-03	14277	13068	2	.500		51900	78740	23									
4345M-51	14278	13068	2	.500		51130	75420	20									

4345M-03 C .25.MN 1.10.S .016.P .020.SI .21.CR .10.NI .01.CU .01.MO .01.AL .060.CB <.01.V <.01
4345M-51 C .25.MN 1.10.S .016.P .020.SI .21.CR .10.NI .01.CU .01.MO .01.AL .060.CB <.01.V <.01

CONTINUED ON NEXT PAGE

SPECIFICATION FOR CARBON STEEL ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.1/SFA-5.1M

(Identical with AWS Specification A5.1/A5.1M:2004. In case of dispute, the original AWS text applies.)

1. Scope

1.1 This specification prescribes requirements for the classification of carbon steel electrodes for shielded metal arc welding.

1.2 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in the Nonmandatory Annex Sections A5 and A10. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*,[1] and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to material properties. The specification with the designation A5.1 uses U.S. Customary Units. The specification A5.1M uses SI Units. The latter are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for sizing of filler metal or packaging or both under A5.1 or A5.1M specifications.

PART A — GENERAL REQUIREMENTS

2. Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreement based on this AWS standard are encouraged to investigate the possibility of applying the most recent editions of the documents shown below. For undated references, the latest edition of the standard reference applies.

The following documents are referenced in the mandatory sections of this document:

(a) ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*[2]

(b) ASTM E 142, *Standard Method for Controlling Quality of Radiographic Testing*

(c) ASTM E 350, *Standard Method for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron*

(d) AWS A1.1, *Metric Practice Guide for the Welding Industry*[3]

(e) AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

(f) AWS A4.4, *Standard Procedure for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*

(g) AWS A5.01, *Filler Metal Procurement Guidelines*

(h) AWS B4.0 or B4.0M, *Standard Methods for Mechanical Testing of Welds*

(i) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

(j) ISO 544, *Welding consumables–Technical delivery conditions for welding filler materials–Type of product, dimensions, tolerances and markings*[4]

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[1] This ANSI standard can be obtained from Global Engineering Documents, an Information Handling Services (IHS) Group Company, 15 Inverness Way East, Englewood, CO 80112-5776.

[2] ASTM standards can be obtained from American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[3] AWS standards can be obtained from Global Engineering Documents, an Information Handling Services (IHS) Group Company, 15 Inverness Way East, Englewood, CO 80112-5776.

[4] ISO standards can be obtained from American National Standards Institute, 11 West 42nd Street, New York, NY 10036-8002.

TABLE 1
ELECTRODE CLASSIFICATION

AWS Classification				
A5.1	A5.1M	Type of Covering	Welding Position[1]	Type of Current[2]
E6010	E4310	High cellulose sodium	F, V, OH, H	dcep
E6011	E4311	High cellulose potassium	F, V, OH, H	ac or dcep
E6012	E4312	High titania sodium	F, V, OH, H	ac or dcen
E6013	E4313	High titania potassium	F, V, OH, H	ac, dcep or dcen
E6018[3]	E4318[3]	Low-hydrogen potassium, iron powder	F, V, OH, H	ac or dcep
E6019	E4319	Iron oxide titania potassium	F, V, OH, H	ac decp or dcen
E6020	E4320	High iron oxide	H-fillet F	ac or dcen ac, dcep or dcen
E6022[4]	E4322[4]	High iron oxide	F, H-fillet	ac or dcen
E6027	E4327	High iron oxide, iron powder	H-fillet F	ac or dcen ac, dcep or dcen
E7014	E4914	Iron powder, titania	F, V, OH, H	ac, dcep or dcen
E7015	E4915	Low-hydrogen sodium	F, V, OH, H	dcep
E7016[3]	E4916[3]	Low hydrogen potassium	F, V, OH, H	ac or dcep
E7018[3]	E4918[3]	Low-hydrogen potassium, iron powder	F, V, OH, H	ac or dcep
E7018M	E4918M	Low-hydrogen iron powder	F, V, OH, H	dcep
E7024[3]	E4924[3]	Iron powder, titania	H-fillet, F	ac, dcep or dcen
E7027	E4927	High iron oxide, iron powder	H-fillet F	ac or dcen ac, dcep or dcen
E7028[3]	E4928[3]	Low-hydrogen potassium, iron powder	H-fillet, F	ac or dcep
E7048	E4948	Low-hydrogen potassium, iron powder	F, OH, H, V-down	ac or dcep

NOTES:

(1) The abbreviations, F, H, H-fillet, V, V-down, and OH indicate the welding positions as follows: F = Flat, H = Horizontal, H-fillet = Horizontal fillet, V = Vertical, progression upwards (for electrodes 3/16 in. [5.0 mm] and under, except 5/32 in. [4.0 mm] and under for classifications E6018 [E4318], E7014 [E4914], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7048 [E4948]). V-down = Vertical, progression downwards (for electrodes 3/16 in. [5.0 mm] and under, except 5/32 in. [4.0 mm] and under for classifications E6018 [E4318], E7014 [E4914], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7048 [E4948]), OH = Overhead (for electrodes 3/16 in. [5.0 mm] and under, except 5/32 in. [4.0 mm] and under for classifications E6018 [E4318], E7014 [E4914], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7048 [E4948]).

(2) The term "dcep" refers to direct current electrode positive (dc, reverse polarity). The term "dcen" refers to direct current electrode negative (dc, straight polarity).

(3) Electrodes with supplemental elongation, notch toughness, absorbed moisture, and diffusible hydrogen requirements may be further identified as shown in Tables 2, 3, 10, and 11.

(4) Electrodes of the E6022 [E4322] classification are intended for single-pass welds only.

TABLE 3
CHARPY V-NOTCH IMPACT REQUIREMENTS

AWS Classification		Limits for 3 out of 5 Specimens[1]	
A5.1	A5.1M	Average, Min.	Single Value, Min.
E6010, E6011, E6018, E6027, E7015, E7016[2], E7018[2], E7027, E7048	E4310, E4311, E4318 E4327, E4915, E4916[2], E4918[2], E4927, E4948	20 ft-lbf at −20°F [27 J at −30°C]	15 ft-lbf at −20°F [20 J at −30°C]
E6019 E7028	E4319 E4928	20 ft-lbf at 0°F [27 J at −20°C]	15 ft-lbf at 0°F [20 J at −20°C]
E6012, E6013, E6020, E6022, E7014, E7024[2]	E4312, E4313 E4320, E4322 E4914, E4924[2]	Not specified	Not specified
AWS Classification		**Limits for 5 out of 5 Specimens[3]**	
A5.1	A5.1M	Average, Min.	Single Value, Min.
E7018M	E4918M	50 ft-lbf at −20°F [67 J at −30°C]	40 ft-lbf at −20°F [54 J at −30°C]

NOTES:

(1) Both the highest and lowest test values obtained shall be disregarded in computing the average. Two of these remaining three values shall equal or exceed 20 ft-lbf [27 J].

(2) Electrodes with the following optional supplemental designations shall meet the lower temperature impact requirements specified below.

AWS Classification		Electrode Designation		Charpy V-Notch Impact Requirements, Limits for 3 out of 5 specimens [Refer to Note (1) above]	
A5.1	A5.1M	A5.1	A5.1M	Average, Min.	Single Value, Min.
E7016 E7018	E4916 E4918	E7016-1 E7018-1	E4916-1 E4918-1	20 ft-lbf at −50°F [27 J at −45°C]	15 ft-lbf at −50°F [20 J at −45°C]
E7024	E4924	E7024-1	E4924-1	20 ft-lbf at 0°F [27 J at −20°C]	15 ft-lbf at 0°F [20 J at −20°C]

(3) All five values obtained shall be used in computing the average. Four of the five values shall equal, or exceed, 50 ft-lbf [67 J].

rounded to the nearest 1000 psi for tensile and yield strength for A5.1, or to the nearest 10 MPa for tensile and yield strength for A5.1M and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities in accordance with the rounding-off method given in ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications.*

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

7. Summary of Tests

The tests required for each classification are specified in Table 4. The purpose of these tests is to determine the chemical composition, mechanical properties, and soundness of the weld metal, moisture content of the low-hydrogen electrode covering, and the usability of the electrode. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Sections 9 through 18. The supplemental tests for absorbed moisture, in Section 17, and diffusible hydrogen, in Section 18, are not required for classification of the low-hydrogen electrodes except for E7018M [E4918M], where these are required [see Notes (9) and (13) of Table 4].

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for retest may be taken from the original test assembly or from a new test assembly. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retests fail to meet the

FIG. 10 ORDER OF MANDATORY AND OPTIONAL SUPPLEMENTAL DESIGNATORS

EXXYY
EXXYYM
EXXYY–1 HZ R

Mandatory Classification Designators [Note (1)]

- Designates an electrode. This designator may be deleted from the product imprint required for identification of the electrode.
- Designates the tensile strength (minimum), in ksi, or MPa ÷ 10 of the weld metal when produced in accordance with the test assembly preparation of this specification (see Table 2).
- Designates the welding position in which electrodes are usable, the type of covering, and the kind of welding current for which the electrodes are suitable (see Table 1).
- Designates an electrode (E7018M) [E4918M] intended to meet most military requirements (greater toughness, lower moisture content — both as-received and after exposure — and mandatory diffusible hydrogen limits for weld metal). (See Tables 3, 10, and 11.)

Optional Classification Designators

- Designates that the electrode meets the requirements of the absorbed moisture test [an optional supplemental test for all low hydrogen electrodes except the E7018M (E4918M) classification, for which the test is required]. (See Table 10.)
- Designates that the electrode meets the requirements of the diffusible hydrogen test (an optional supplemental test of the weld metal from low hydrogen electrodes — as-received or conditioned — with an average value not exceeding "Z" mL of H_2 per 100 g of deposited metal, where "Z" is 4, 8, or 16). (See Table 11.)
- Designates that the electrode (E7016, E7018, or E7024) [E4916, E4918, or E4924] meets the requirements for improved toughness — and ductility in the case of E7024 [E4924] (optional supplemental test requirements shown in Tables 2 and 3). (See Notes to Tables 2 and 3.)

NOTE:
(1) The combination of these designators constitutes the electrode classification.

SUBPART 1
STRESS TABLES

(13) STATEMENT OF POLICY ON INFORMATION PROVIDED IN THE STRESS TABLES

The purpose of this Statement of Policy is to clarify which information in the stress tables is mandatory and which is not. The information and restrictions provided in the Notes found throughout the various stress tables provided in Subpart 1 of Section II, Part D are mandatory. It is vital to recognize that lines of information in Tables 1A, 1B, 2A, 2B, 3, 4, 5A, and 5B frequently have essential information referenced in the Notes column. These Notes are organized as follows:

(a) EXX: defining onset of values based on successful experience in service

(b) GXX: general requirements

(c) HXX: heat treatment requirements

(d) SXX: size requirements

(e) TXX: defining onset of time-dependent behavior

(f) WXX: welding requirements

The specifications and grades or types, coupled with the assigned Notes for each line, provide the complete description of material in the context of the allowable stresses or design stress intensities. Additional requirements for particular types of construction must also be obtained from the rules governing the construction.

In Tables 1A, 2A, and 5A, the information in the Nominal Composition column is nonmandatory and is for information only. However, these nominal compositions are the primary sorting used in these three tables. See the Guideline on Locating Materials in Stress Tables, and in Tables of Mechanical and Physical Properties. The information in the Alloy Designation/UNS Number column is nonmandatory for specifications for which a grade or type is provided. This is primarily true for the non-stainless steel alloys in these tables. For specifications for which no type or grade is listed, the UNS number is mandatory. Particularly for the stainless steels, for which no type or grade is listed, the UNS number is the grade.

The only difference between Tables 1A, 2A, and 5A, and Tables 1B, 2B, and 5B, with regard to the mandatory/nonmandatory nature of the information, is that in Tables 1B, 2B, and 5B, the UNS number information is used as the basis of the sorting scheme for materials and is almost always mandatory.

Where provided, the information in the columns for Product Form, Specification Number, Type/Grade, Class/Condition/Temper, Size/Thickness, and External Pressure Chart Number is mandatory. The information in the P-Number and Group Number columns is also mandatory; however, the primary source for this information is Table QW/QB-422 in Section IX. When there is a conflict between the P-number and Group number information in these stress tables and that in Section IX, the numbers in Section IX shall govern.

The information in the Minimum Tensile Strength and Minimum Yield Strength columns is nonmandatory. These values are a primary basis for establishing the allowable stresses and design stress intensities. When there is a conflict between the tensile and yield strength values in the stress tables and those in the material specifications in Section II, Parts A and B, the values in Parts A and B shall govern.

The information in the Applicability and Maximum Temperature Limits columns is mandatory. Where a material is permitted for use in more than one Construction Code, and in the SI units version of these tables, the maximum use temperature limit in these columns is critical. The temperature to which allowable stress or design stress intensity values are listed is not necessarily the temperature to which use is permitted by a particular Construction Code. Different Construction Codes often have different use temperature limits for the same material and condition. Further, in the SI units version of the stress tables, values may be listed in the table at temperatures above the maximum use temperature limit. These stress values are provided to permit interpolation to be used to determine the allowable stress or design stress intensity at temperatures between the next lowest temperature for which stress values are listed and the maximum-use temperature limit listed in these columns.

GUIDELINE ON LOCATING MATERIALS IN STRESS TABLES, AND IN TABLES OF MECHANICAL AND PHYSICAL PROPERTIES

1 INTRODUCTION

The goal of this Guideline is to assist the users of Section II, Part D in locating materials in stress tables (Tables 1A, 1B, 2A, 2B, 3, 4, 5A, and 5B), tables of mechanical properties (Tables U, U-2, and Y-1), and tables of physical properties (Tables TE-1 through TE-5, TCD, TM-1 through TM-5, and PRD). This Guideline defines the logic used to place materials within these tables.

2 STRESS TABLES

Stress tables are all found within Subpart 1 of Section II, Part D. Tables 1A, 1B, 3, 5A, and 5B cover allowable stresses, while Tables 2A, 2B, and 4 cover design stress intensities. Although Subpart 1 also covers ultimate tensile strength and yield strength, the organization of those mechanical property tables will be discussed separately in para. 3. A table-by-table listing of the materials-organization logic used to place materials within the designated tables follows.

2.1 TABLE 1A

Table 1A provides allowable stresses for ferrous[1] materials used in Section I; Section III, Division 1, Classes 2 and 3; Section VIII, Division 1; and Section XII construction. Within Table 1A, the first step in ordering materials is to use their nominal compositions. These nominal compositions are nothing more than accepted compositional fingerprints or widely recognized designators for each alloy or alloy class. These nominal compositions are arranged in Table 1A as follows:

(a) carbon steels

(b) carbon steels with small additions of Cb, Ti, and V (microalloyed steels)

(c) C–$^1/_2$Mo steels

(d) chromium steels, including ferritic stainless steels, by increasing Cr content [$^1/_2$Cr, $^3/_4$Cr, 1Cr, 1$^1/_4$Cr, 2$^1/_4$Cr, 3Cr, 5Cr, 9Cr, 11Cr, 12Cr, 13Cr, 15Cr, 17Cr (including 17Cr–4Ni–4Cu and 17Cr–4Ni–6Mn), 18Cr, 26Cr, 27Cr, and 29Cr]

(e) manganese steels (Mn–$^1/_4$Mo, Mn–$^1/_2$Mo, Mn–$^1/_2$Ni, and Mn–V)

(f) silicon steel (1$^1/_2$Si–$^1/_2$Mo)

(g) nickel steels ($^1/_2$Ni, $^3/_4$Ni, 1Ni, 1$^1/_4$Ni, 2Ni, 2$^1/_2$Ni, 2$^3/_4$Ni, 3Ni, 3$^1/_2$Ni, 4Ni, 5Ni, 8Ni, and 9Ni)

(h) other high nickel steels [25Ni–15Cr–2Ti (Grade 660) and 29Ni–20Cr–3Cu–2Mo (CN7M)]

(i) high alloy steels, including the duplex stainless steels, in order of increasing chromium content [beginning with 16Cr–9Mn–2Ni–N, then 16Cr–12Ni–2Mo (316L), etc.], then by increasing nickel content within a given chromium or other alloy content [18Cr–8Ni, 18Cr–8Ni–N, 18Cr–8Ni–4Si–N, 18Cr–10Ni–Cb (first S34700, then S34709, S34800, and S34809), 18Cr–10Ni–Ti, 18Cr–11Ni, etc., ending with 25Cr–22Ni–2Mo–N].

Unfortunately, most specifications for materials do not give nominal compositions — and without that information, one may not know the nominal composition for a particular material in Table 1A. If the specification number and alloy grade or type designation are known, then one can go to Table QW/QB-422 of Section IX of the Code and find the corresponding nominal composition.

Now, for a given nominal composition, Table 1A is arranged by increasing tensile strength. For a given nominal composition and tensile strength, stress listings are provided in order of increasing specification number. Sometimes, for a given nominal composition, tensile strength, yield strength, and specification number/grade or type, there may be more than one line of stresses. At this point, the Notes referenced on the second page of each page set within Table 1A will define why there are two or more lines of stresses and when each applies.

2.2 TABLE 1B

Table 1B provides allowable stresses for nonferrous materials used in Section I; Section III, Division 1, Classes 2 and 3; Section VIII, Division 1; and Section XII construction. Aluminum alloys (UNS AXXXXX materials) are the first materials covered in Table 1B, followed by copper alloys (UNS CXXXXX), nickel alloys (UNS NXXXXX), and the reactive and refractory metals and alloys (UNS RXXXXX). Within this latter category there are the following:

(a) chromium alloys (R2XXXX)

(b) cobalt alloys (R3XXXX)

(c) titanium alloys (R5XXXX)

(d) zirconium alloys (R6XXXX)

Within each of these material class groupings, stress lines are first organized by increasing UNS (Unified Numbering System) number. The nonferrous specifications now show these numbers in association with grade designations. Then, for a given UNS number, stress lines are next ordered by strength — first tensile strength and then yield strength. Finally, for a given UNS number, tensile strength, and yield strength, stress lines are ordered by increasing specification number. Again, some materials may have two or more stress lines even if their UNS number, tensile strength, yield strength, and specification number are the same. The Notes provide direction for the applicability of each line.

For those material specifications that may not show UNS numbers associated with alloy grades, one again can refer to Section IX's Table QW/QB-422 for that information.

For Table 1B, nominal compositions are shown only for the NXXXXX and RXXXXX materials, but they have no influence on the location of alloys in the table. In this table, the nominal compositions are simply for information.

2.3 TABLE 2A

Table 2A provides design stress intensities for ferrous materials for Section III, Division 1, Classes 1, TC, and SC construction. This table is organized in the same manner as Table 1A. Refer back to para. 2.1 for that description.

2.4 TABLE 2B

Table 2B provides design stress intensities for nonferrous materials for Section III, Division 1, Classes 1, TC, and SC construction. Table 2B materials are ordered in the same manner as in Table 1B. Refer back to para. 2.2 for that description.

2.5 TABLE 3

Table 3 provides allowable stresses for bolting materials for use in Section III, Division 1, Classes 2 and 3; Section VIII, Division 1; Section VIII, Division 2 (using Part 4.16 of Section VIII, Division 2); and Section XII construction. The table first covers ferrous materials and then nonferrous materials. For the ferrous materials, the ordering logic parallels that used in Tables 1A and 2A — first by nominal composition, then by increasing ultimate tensile strength, then by increasing yield strength, and finally by increasing specification number. Again, refer back to para. 2.1 for a discussion on nominal composition.

Nonferrous materials are presented using the same logic as in Tables 1B and 2B; see para. 2.2 for that discussion.

2.6 TABLE 4

Table 4 provides design stress intensities for bolting materials used in Section III, Division 1, Classes 1, TC, and SC; and in Section VIII, Division 2 (using Part 5 and Annex 5.F of Section VIII, Division 2).

Table 4 is organized in the same manner as Table 3 — first covering ferrous materials and then nonferrous materials — except that Table 4 covers far fewer materials. For the ordering logic, again refer to paras. 2.1 and 2.2 for ferrous and nonferrous materials, respectively.

2.7 TABLE 5A

Table 5A provides allowable stresses for ferrous materials for Section VIII, Division 2 construction. This Table is organized in the same manner as Table 1A. Refer back to para. 2.1 for that description.

2.8 TABLE 5B

Table 5B provides allowable stresses for nonferrous materials for Section VIII, Division 2 construction. This Table is organized in the same manner as Table 1B. Refer back to para. 2.2 for that description.

3 MECHANICAL PROPERTY TABLES

Ultimate tensile strength values and yield strength values are to be used in design calculations according to the rules of the Construction Codes. However, they are not to be construed as minimum strength values at temperature. This is explained in the General Notes to these tables. Paragraphs 3.1 through 3.3 provide a table-by-table listing of the materials-organization logic.

3.1 TABLE U

Table U provides tensile strength values for ferrous and nonferrous materials, in that order. The ordering logic for ferrous materials is the same as used in Table 1A, except yield strength level is not shown. Using the logic described in para. 2.1, stress lines are organized by nominal composition, then by increasing tensile strength level, and then by increasing specification number.

Nonferrous materials coverage begins following the last of the high alloy steels (25Cr–22Ni–2Mo–N). Coverage of nonferrous alloys begins with the UNS CXXXXX alloys, followed by NXXXXX and RXXXXX alloys. No tensile strength values are available at this time for the aluminum alloys. The ordering of materials within these three groups has been previously described in para. 2.2.

3.2 TABLE U-2

Table U-2 provides ultimate tensile strengths for special ferrous materials used in Section VIII, Division 3 construction. The only material covered is wire produced to either SA-231 or SA-232, and lines are arranged in order of decreasing tensile strength, resulting from increasing wire diameter.

3.3 TABLE Y-1

Table Y-1 provides yield strength values for ferrous and nonferrous materials, in that order. Again, the ordering of yield strength lines parallels the logic described for ferrous and nonferrous materials in paras. 2.1 and 2.2, respectively. Unlike Table U, for ferrous materials, the tensile strength level does enter into the ordering process, again following nominal composition designation. And, unlike Table U, Table Y-1's nonferrous materials listings do begin with the aluminum-base alloys (UNS AXXXXX).

Table 1A (Cont'd)
Section I; Section III, Classes 2 and 3;* Section VIII, Division 1; and Section XII
Maximum Allowable Stress Values S for Ferrous Materials
(*See Maximum Temperature Limits for Restrictions on Class)

	Line No.	Nominal Composition	Product Form	Spec. No.	Type/Grade	Alloy Desig./ UNS No.	Class/Con-dition/ Temper	Size/Thickness, in.	P-No.	Group No.
	1	Carbon steel	Forgings	SA-541	1	K03506	...	...	1	2
	2	Carbon steel	Forgings	SA-541	1A	K03020	...	...	1	2
	3	Carbon steel	Cast pipe	SA-660	WCB	J03003	...	...	1	2
	4	Carbon steel	Forgings	SA-765	II	K03047	...	...	1	2
	5	Carbon steel	Plate	SA-515	70	K03101	...	...	1	2
	6	Carbon steel	Plate	SA-516	70	K02700	...	...	1	2
	7	Carbon steel	Wld. pipe	SA-671	CB70	K03101	...	...	1	2
	8	Carbon steel	Wld. pipe	SA-671	CC70	K02700	...	...	1	2
	9	Carbon steel	Wld. pipe	SA-672	B70	K03101	...	...	1	2
	10	Carbon steel	Wld. pipe	SA-672	C70	K02700	...	...	1	2
	11	Carbon steel	Plate	SA/JIS G3118	SGV480	...	...	...	1	2
	12	Carbon steel	Smls. pipe	SA-106	C	K03501	...	...	1	2
	13	Carbon steel	Wld. tube	SA-178	D	...	...	...	1	2
	14	Carbon steel	Wld. tube	SA-178	D	...	...	...	1	2
	15	Carbon steel	Wld. tube	SA-178	D	...	...	...	1	2
	16	Carbon steel	Smls. tube	SA-210	C	K03501	...	...	1	2
	17	Carbon steel	Castings	SA-216	WCC	J02503	...	...	1	2
	18	Carbon steel	Smls. & wld. fittings	SA-234	WPC	K03501	...	...	1	2
	19	Carbon steel	Castings	SA-352	LCC	J02505	...	...	1	2
	20	Carbon steel	Castings	SA-487	16	...	A	...	1	2
	21	Carbon steel	Plate	SA-537	...	K12437	3	$4 < t \leq 6$	1	3
	22	Carbon steel	Smls. tube	SA-556	C2	K03006	...	...	1	2
	23	Carbon steel	Wld. tube	SA-557	C2	K03505	...	...	1	2
	24	Carbon steel	Cast pipe	SA-660	WCC	J02505	...	...	1	2
(13)	25	...	...	...	...	...	...	...	...	...
	26	Carbon steel	Bar	SA-696	C	K03200	...	...	1	2
	27	Carbon steel	Sheet	SA-414	F	K03102	...	...	1	2
	28	Carbon steel	Plate	SA-662	C	K02007	...	...	1	2
	29	Carbon steel	Plate	SA-537	...	K12437	2	$4 < t \leq 6$	1	3
	30	Carbon steel	Plate	SA-738	C	K02008	...	$4 < t \leq 6$	1	3
	31	Carbon steel	Plate	SA-537	...	K12437	1	$\leq 2^1/_2$	1	2
	32	Carbon steel	Wld. pipe	SA-671	CD70	K12437	...	$\leq 2^1/_2$	1	2
	33	Carbon steel	Wld. pipe	SA-672	D70	K12437	...	$\leq 2^1/_2$	1	2
	34	Carbon steel	Wld. pipe	SA-691	CMSH-70	K12437	...	$\leq 2^1/_2$	1	2
	35	Carbon steel	Plate	SA-841	A	...	1	$\leq 2^1/_2$	1	2
(13)	36	Carbon steel	Plate	SA/GB 713	Q345R	...	...	$2^1/_4 < t \leq 4$	1	2
(13)	37	Carbon steel	Plate	SA/EN 10028-2	P355GH	...	...	$2.5 < t \leq 4$	1	2
(13)	38	Carbon steel	Plate	SA/GB 713	Q345R	...	...	$1.5 < t \leq 2^1/_4$	1	2
(13)	39	...	...	...	...	...	...	...	...	...

Table 1A (Cont'd)
Section I; Section III, Classes 2 and 3;* Section VIII, Division 1; and Section XII Maximum Allowable Stress Values *S* for Ferrous Materials (*See Maximum Temperature Limits for Restrictions on Class)

Line No.	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Applicability and Max. Temperature Limits (NP = Not Permitted) (SPT = Supports Only): I	III	VIII-1	XII	External Pressure Chart No.	Notes
1	70	36	NP	700	1000	650	CS-2	G10, T2
2	70	36	NP	700	1000	650	CS-2	G10, T2
3	70	36	1000	700	NP	NP	CS-2	G1, G10, G17, S1, T2
4	70	36	NP	NP	1000	650	CS-2	G10, T2
5	70	38	1000	700	1000	650	CS-2	G10, S1, T2
6	70	38	850	700	1000	650	CS-2	G10, S1, T2
7	70	38	NP	700	NP	NP	CS-2	S5, W10, W12
8	70	38	NP	700	NP	NP	CS-2	S6, W10, W12
9	70	38	NP	700	NP	NP	CS-2	S5, W10, W12
10	70	38	NP	700	NP	NP	CS-2	S6, W10, W12
11	70	38	850	NP	NP	NP	CS-2	G10, S1, T2
12	70	40	1000	700	1000	650	CS-2	G10, S1, T1
13	70	40	1000	NP	NP	NP	CS-2	G10, S1, T1, W13
14	70	40	1000	NP	NP	NP	CS-2	G4, G10, S1, T4
15	70	40	1000	NP	NP	NP	CS-2	G3, G10, S1, T2
16	70	40	1000	NP	1000	650	CS-2	G10, S1, T1
17	70	40	1000	700	1000	650	CS-2	G1, G10, G17, S1, T1
18	70	40	800	700	800	650	CS-2	G10, T1, W14
19	70	40	NP	700	NP	NP	CS-2	G17, T1
20	70	40	NP	700	NP	NP	CS-2	...
21	70	40	NP	NP	700	650	CS-2	G23, W11
22	70	40	NP	NP	800	650	CS-2	G10, T1
23	70	40	NP	NP	1000	650	CS-2	G24, T2, W6
24	70	40	1000	700	NP	NP	CS-2	G1, G10, G17, S1, T1
25	...	...	...	...	...	...	...	...
26	70	40	NP	700	NP	NP	CS-2	T1
27	70	42	NP	NP	900	650	CS-2	G10, T1
28	70	43	NP	NP	700	650	CS-3	T1
29	70	46	NP	700	700	650	CS-3	G23, T1, W11
30	70	46	NP	650	650	650	CS-3	G23, W11
31	70	50	NP	700	650	650	CS-3	G23, T1
32	70	50	NP	700	NP	NP	CS-3	S6, T1, W10, W12
33	70	50	NP	700	NP	NP	CS-3	S6, T1, W10, W12
34	70	50	NP	700	NP	NP	CS-3	S6, T1, W10, W12
35	70	50	NP	NP	650	NP	CS-3	...
36	71	44	800	NP	800	NP	CS-2	T1
37	71	45.5	850	NP	1000	NP	CS-2	G10, S1, T1
38	71	45.5	800	NP	800	NP	CS-2	T1
39	...	...	...	...	...	...	...	...

Table 1A (Cont'd)
Section I; Section III, Classes 2 and 3;* Section VIII, Division 1; and Section XII
Maximum Allowable Stress Values *S* for Ferrous Materials
(*See Maximum Temperature Limits for Restrictions on Class)

Line No.	Maximum Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding													
	−20 to 100	150	200	250	300	400	500	600	650	700	750	800	850	900
1	20.0	20.0	20.0	...	20.0	20.0	19.6	18.4	17.8	17.2	14.8	12.0	9.3	6.7
2	20.0	20.0	20.0	...	20.0	20.0	19.6	18.4	17.8	17.2	14.8	12.0	9.3	6.7
3	20.0	...	20.0	...	20.0	20.0	19.6	18.4	17.8	17.2	14.8	12.0	9.3	6.7
4	20.0	20.0	20.0	...	20.0	20.0	19.6	18.4	17.8	17.2	14.8	12.0	9.3	6.7
5	20.0	20.0	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	14.8	12.0	9.3	6.7
6	20.0	20.0	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	14.8	12.0	9.3	6.7
7	20.0	...	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	...	...	...	...
8	20.0	...	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	...	...	...	...
9	20.0	...	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	...	...	...	...
10	20.0	...	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	...	...	...	...
11	20.0	20.0	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	14.8	12.0	9.3	...
12	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	18.3	14.8	12.0	9.3	6.7
13	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	18.3	14.8	12.0	9.3	6.7
14	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	18.3	14.8	12.0	9.3	5.7
15	17.0	...	17.0	...	17.0	17.0	17.0	17.0	16.8	15.5	12.6	10.2	7.9	5.7
16	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	18.3	14.8	12.0	9.3	6.7
17	20.0	20.0	20.0	...	20.0	20.0	20.0	20.0	19.8	18.3	14.8	12.0	9.3	6.7
18	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	18.3	14.8	12.0	...	...
19	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	18.3	...	...	...	...
20	20.0	...	19.9	...	18.8	18.1	17.9	17.9	17.9	17.9	...	...	...	...
21	20.0	20.0	20.0	...	19.7	19.5	18.9	18.0	17.6	17.2	...	...	...	...
22	20.0	20.0	20.0	...	20.0	20.0	20.0	20.0	19.8	18.3	14.8	12.0	...	...
23	17.0	17.0	17.0	...	17.0	17.0	17.0	17.0	16.8	15.5	12.6	10.2	7.9	5.7
24	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	18.3	14.8	12.0	9.3	6.7
25	...	...	...	...	...	...	...	...	...	...	...	...	...	...
26	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	18.3	...	...	...	...
27	20.0	20.0	20.0	...	20.0	20.0	20.0	20.0	20.0	18.3	14.8	12.0	9.3	6.7
28	20.0	20.0	20.0	...	20.0	20.0	20.0	20.0	20.0	18.3	...	...	...	...
29	20.0	...	20.0	...	19.7	19.5	19.5	19.5	19.5	18.3	...	...	...	...
30	20.0	...	20.0	...	19.7	19.5	19.5	19.5	19.5	...	...	...	...	...
31	20.0	...	20.0	...	19.7	19.5	19.5	19.5	19.5	18.3	...	...	...	...
32	20.0	...	20.0	...	19.7	19.5	19.5	19.5	19.5	18.3	...	...	...	...
33	20.0	...	20.0	...	19.7	19.5	19.5	19.5	19.5	18.3	...	...	...	...
34	20.0	...	20.0	...	19.7	19.5	19.5	19.5	19.5	18.3	...	...	...	...
35	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	...	...	...	...	...
36	20.3	...	20.3	...	20.3	20.3	20.3	20.3	20.3	18.3	14.8	12.0	...	...
37	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	18.3	14.8	12.0	9.3	6.7
38	20.3	...	20.3	...	20.3	20.3	20.3	20.3	20.3	18.3	14.8	12.0	...	...
39	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Table 1A (Cont'd)
Section I; Section III, Classes 2 and 3;* Section VIII, Division 1; and Section XII Maximum Allowable Stress Values *S* for Ferrous Materials (*See Maximum Temperature Limits for Restrictions on Class)

Line No.	Maximum Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding															
	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	
1	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
2	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
3	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
4	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
5	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
6	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
12	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
13	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
14	*3.4*	*2.1*	...	...	...	...	...	...	...	...	...	...	...	...	...	
15	*3.4*	*2.1*	...	...	...	...	...	...	...	...	...	...	...	...	...	
16	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
17	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
18	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
19	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
20	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
21	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
23	*3.4*	*2.1*	...	...	...	...	...	...	...	...	...	...	...	...	...	
24	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	(**13**)
26	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
27	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
28	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
29	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
30	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
31	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
32	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
33	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
34	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
35	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
36	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	(**13**)
37	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	(**13**)
38	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	(**13**)
39	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	(**13**)

NOTES TO TABLE 1A

GENERAL NOTES

(a) The following abbreviations are used: Norm. rld., Normalized rolled; Smls., Seamless; Sol. ann., Solution annealed; and Wld., Welded.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures. The values at intermediate temperatures shall be rounded to the same number of decimal places as the value at the higher temperature between which values are being interpolated. The rounding rule is: when the next digit beyond the last place to be retained is less than 5, retain unchanged the digit in the last place retained; when the digit next beyond the last place to be retained is 5 or greater, increase by 1 the digit in the last place retained.

(c) For Section VIII and XII applications, stress values in restricted shear such as dowel bolts or similar construction in which the shearing member is so restricted that the section under consideration would fail without reduction of area shall be 0.80 times the values in the above Table.

(d) For Section VIII and XII applications, stress values in bearing shall be 1.60 times the values in the above Table.

(e) Stress values for −20°F to 100°F are applicable for colder temperatures when the toughness requirements of Section III, VIII, or XII are met.

(f) An alternative typeface is used for stress values obtained from time-dependent properties (see Notes T1 through T11).

(g) Where specifications, grades, classes, and types are listed in this Table, and where the material specification in Section II, Part A or Part B is a dual-unit specification (e.g., SA-516/SA-516M), the values listed in this Table shall be applicable to either the customary U.S. version of the material specification or the SI units version of the material specification. For example, the values listed for SA-516 Grade 70 shall be used when SA-516M Grade 485 is used in construction.

(h) The properties of steels are influenced by the processing history, heat treatment, melting practice, and level of residual elements. See Nonmandatory Appendix A for more information.

(13) (i) Where a size limit appears in the Size/Thickness column, the limit applies to the dimension appropriate to the product form: wall thickness of tubing, pipe, pipe fittings, and hollow forgings; thickness of plate, flat bar and forgings, and polygonal bar; diameter of solid bar and bolting; and thickest cross-section of other pressure parts, e.g., castings and forgings.

NOTES – GENERAL REQUIREMENTS

G1 To these stress values a casting quality factor as specified in PG-25 of Section I; UG-24 of Section VIII, Division 1; or TM-190 of Section XII shall be applied.

G2 These stress values include a joint efficiency factor of 0.60.

G3 These stress values include a joint efficiency factor of 0.85.

G4 For Section I applications, these stresses apply when used for boiler, water wall, superheater, and economizer tubes that are enclosed within a setting. A joint efficiency factor of 0.85 is included in values above 850°F.

G5 Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short-time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The stress values in this range exceed 66⅔% but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction. For Section III applications, Table Y-2 lists multiplying factors that, when applied to the yield strength values shown in Table Y-1, will give allowable stress values that will result in lower levels of permanent strain.

G6 Creep-fatigue, thermal ratcheting, and environmental effects are increasingly significant failure modes at temperatures in excess of 1500°F and shall be considered in the design.

(13) G7 For Section VIII applications, these stress values are based on expected minimum values of 45,000 psi tensile strength and yield strength of 20,000 psi resulting from loss of strength due to thermal treatment required for the glass coating operation. UG-85 does not apply.

(13) G8 These stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the flexibility of the flange and bolts and corresponding relaxation properties.

G9 For Section III applications, the use of these materials shall be limited to materials for tanks covered in Subsections NC and ND, component supports, and for nonpressure-retaining attachments (NC/ND-2190).

G10 Upon prolonged exposure to temperatures above 800°F, the carbide phase of carbon steel may be converted to graphite. See Nonmandatory Appendix A, A-201 and A-202.

G11 Upon prolonged exposure to temperatures above 875°F, the carbide phase of carbon-molybdenum steel may be converted to graphite. See Nonmandatory Appendix A, A-201 and A-202.

G12 At temperatures above 1000°F, these stress values apply only when the carbon is 0.04% or higher on heat analysis.

G13 These stress values at 1050°F and above shall be used only when the grain size is ASTM No. 6 or coarser.

G14 These stress values shall be used when the grain size is not determined or is determined to be finer than ASTM No. 6.

G15 For Section I applications, use is limited to stays as defined in PG-13 except as permitted by PG-11.

G16 For Section III Class 3 applications, these *S* values do not include a casting quality factor. Statically and centrifugally cast products meeting the requirements of NC-2570 shall receive a casting quality factor of 1.00.

G17 For Section III Class 3 applications, statically and centrifugally cast products meeting the requirements of NC-2571(a) and (b), and cast pipe fittings, pumps, and valves with inlet piping connections of 2 in. nominal pipe size and less, shall receive a casting quality factor of 1.00. Other casting quality factors shall be in accordance with the following:

(a) for visual examination, 0.80;
(b) for magnetic particle examination, 0.85;
(c) for liquid penetrant examination, 0.85;
(d) for radiography, 1.00;
(e) for ultrasonic examination, 1.00;
(f) for magnetic particle or liquid penetrant plus ultrasonic examination or radiography, 1.00.

G18 See Table Y-1 for yield strength values as a function of thickness over this range. Allowable stresses are independent of yield strength in this thickness range.

NOTES TO TABLE 1A (CONT'D)

NOTES – GENERAL REQUIREMENTS (CONT'D)

(**13**) G19 This steel may be expected to develop embrittlement after service at moderately elevated temperature; see Nonmandatory Appendix A, A-207 and A-208.

(**13**) G20 These stresses are based on weld metal properties.

(**13**) G21 For Section I, use is limited to PEB-5.3. See PG-5.5 for cautionary note.

G22 For Section I applications, use of external pressure charts for material in the form of bar stock is permitted for stiffening rings only.

G23 For temperatures above the maximum temperature shown on the external pressure chart for this material, Fig. CS-2 may be used for the design using this material.

G24 A factor of 0.85 has been applied in arriving at the maximum allowable stress values in tension for this material. Divide tabulated values by 0.85 for maximum allowable longitudinal tensile stress.

G25 For Section III applications, for both Class 2 and Class 3, the completed vessel after final heat treatment shall be examined by the ultrasonic method in accordance with NB-2542 except that angle beam examination in both the circumferential and the axial directions may be performed in lieu of the straight beam examination in the axial direction. The tensile strength shall not exceed 125,000 psi.

G26 Material that conforms to Class 10, 11, or 12 is not permitted.

G27 Material that conforms to Class 11 or 12 is not permitted.

G28 Supplementary Requirement S15 of SA-781, Alternate Mechanical Test Coupons and Specimen Locations for Castings, is mandatory.

G29 For Section III applications, impact testing in accordance with the requirements of NC-2300 is required for Class 2 components and in accordance with ND-2300 for Class 3 components.

NOTES – HEAT TREATMENT REQUIREMENTS

H1 For temperatures above 1000°F, these stress values may be used only if the material is heat treated by heating to the minimum temperature specified in the material specification, but not lower than 1900°F, and quenching in water or rapidly cooling by other means.

H2 For temperatures above 1000°F, these stress values may be used only if the material is heat treated by heating to a minimum temperature of 2000°F, and quenching in water or rapidly cooling by other means.

(**13**) H3 Normalized and tempered.

(**13**) H4 Solution treated and quenched.

H5 For Section III applications, if heat treatment is performed after forming or fabrication, it shall be performed at 1500°F to 1850°F for a period of time not to exceed 10 min at temperature, followed by rapid cooling.

H6 Material shall be solution annealed at 2010°F to 2140°F, followed by a rapid cooling in water or air.

NOTES – SIZE REQUIREMENTS

S1 For Section I applications, stress values at temperatures of 850°F and above are permissible but, except for tubular products 3 in. O.D. or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.

S2 For Section I applications, stress values at temperatures of 900°F and above are permissible but, except for tubular products 3 in. O.D. or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.

S3 For Section I applications, stress values at temperatures of 1000°F and above are permissible but, except for tubular products 3 in. O.D. or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.

S4 For Section I applications, stress values at temperatures of 1150°F and above are permissible but, except for tubular products 3 in. O.D. or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.

S5 Material that conforms to Class 10, 11, or 12 is not permitted when the nominal thickness of the material exceeds ¾ in.

S6 Material that conforms to Class 10, 11, or 12 is not permitted when the nominal thickness of the material exceeds 1¼ in.

S7 The maximum thickness of unheat-treated forgings shall not exceed 3¾ in. The maximum thickness as-heat-treated may be 4 in.

S8 The maximum section thickness shall not exceed 3 in. for double-normalized-and-tempered forgings, or 5 in. for quenched-and-tempered forgings.

S9 Both NPS 8 and larger, and schedule 140 and heavier.

S10 The maximum pipe size shall be NPS 4 (DN 100) and the maximum thickness in any pipe size shall be Schedule 80.

(**13**) S11 Either NPS 8 and larger and less than schedule 140 wall, or less than NPS 8 and all wall thicknesses.

NOTES – TIME-DEPENDENT PROPERTIES [See General Note (f)]

T1 Allowable stresses for temperatures of 700°F and above are values obtained from time-dependent properties.

T2 Allowable stresses for temperatures of 750°F and above are values obtained from time-dependent properties.

T3 Allowable stresses for temperatures of 850°F and above are values obtained from time-dependent properties.

T4 Allowable stresses for temperatures of 900°F and above are values obtained from time-dependent properties.

T5 Allowable stresses for temperatures of 950°F and above are values obtained from time-dependent properties.

T6 Allowable stresses for temperatures of 1000°F and above are values obtained from time-dependent properties.

T7 Allowable stresses for temperatures of 1050°F and above are values obtained from time-dependent properties.

T8 Allowable stresses for temperatures of 1100°F and above are values obtained from time-dependent properties.

T9 Allowable stresses for temperatures of 1150°F and above are values obtained from time-dependent properties.

T10 Allowable stresses for temperatures of 800°F and above are values obtained from time-dependent properties.

(**13**) T11 Allowable stresses for temperatures of 650°F and above are values obtained from time-dependent properties.

NOTES – WELDING REQUIREMENTS

W1 Not for welded construction.

W2 Not for welded construction in Section III.

W3 Welded.

W4 Nonwelded, or welded if the tensile strength of the Section IX reduced section tension test is not less than 100 ksi.

NOTES TO TABLE 1A (CONT'D)

NOTES – WELDING REQUIREMENTS (CONT'D)

W5 Welded, with the tensile strength of the Section IX reduced tension test less than 100 ksi but not less than 95 ksi.

W6 This material may be welded by the resistance technique.

W7 In welded construction for temperatures above 850°F, the weld metal shall have a carbon content of greater than 0.05%.

W8 Welding and oxygen or other thermal cutting processes are not permitted when carbon content exceeds 0.35% by heat analysis.

W9 For Section I applications, for pressure retaining welds in 2¼Cr–1Mo materials, other than circumferential butt welds less than or equal to 3½ in. in outside diameter, when the design metal temperatures exceed 850°F, the weld metal shall have a carbon content greater than 0.05%.

W10 For Section III applications, material that conforms to Class 10, 13, 20, 23, 30, 33, 40, 43, 50, or 53 is not permitted for Class 2 and Class 3 construction when a weld efficiency factor of 1.00 is used in accordance with Note W12.

W11 For Section VIII applications, Section IX, QW–250 Variables QW–404.12, QW–406.3, QW–407.2, and QW–409.1 shall also apply to this material. These variables shall be applied in accordance with the rules for welding of Part UF.

W12 These *S* values do not include a longitudinal weld efficiency factor. For Section III applications, for materials welded without filler metal, ultrasonic examination, radiographic examination, or eddy current examination, in accordance with NC–2550, shall provide a longitudinal weld efficiency factor of 1.00. Materials welded with filler metal meeting the requirements of NC–2560 shall receive a longitudinal weld efficiency factor of 1.00. Other longitudinal weld efficiency factors shall be in accordance with the following:

(a) for single butt weld, with filler metal, 0.80;

(b) for single or double butt weld, without filler metal, 0.85;

(c) for double butt weld, with filler metal, 0.90;

(d) for single or double butt weld, with radiography, 1.00.

W13 For Section I applications, electric resistance and autogenous welded tubing may be used with these stresses, provided the following additional restrictions and requirements are met:

(a) The tubing shall be used for boiler, waterwall, superheater, and economizer tubes that are enclosed within the setting.

(b) The maximum outside diameter shall be 3½ in.

(c) The weld seam of each tube shall be subjected to an angle beam ultrasonic inspection per SA–450.

(d) A complete volumetric inspection of the entire length of each tube shall be performed in accordance with SA–450.

(e) Material test reports shall be supplied.

W14 These *S* values do not include a weld factor. For Section VIII, Division 1 and Section XII applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW–12 for Section VIII, Division 1, or TW–130.4 for Section XII, as applicable.

W15 The Nondestructive Electric Test requirements of SA–53 Type E pipe are required for all sizes. The pipe shall be additionally marked "NDE" and so noted on the material certification.

Part UW of ASME. Requirements to fabricate pressure vessels by welding methods.

→ UW-2: service requirements. If the pressure vessels contain Lethal (مرگ آور) materials, All welds needs to be inspected %100 Radiography. ERW weld type is not Permitted.

→ UW-3: weld Joint Category. Category "A" has highest stress due to pressure. (Figure UW-3 on Page 111 of Version 2013) Page 64 of this note book

→ ASME Section VIII did not accept ultrasonic test for cracks, but B31.3 accept that one.

→ UW-18: Fillet welds. weld effeciency strength factor is only 0.55

UW-20: Tube-to tubesheet welds.

→ Tack welds mean welds with length less than 3/4" : begining and ending of the Tack welds shall be grind out to mitigate stress concentration.

→ For Peening: use a spherical hammer. 10 mm diameter ball is recommended. 4kg hammer. let the hammer do the work. preheat to 200°F befor hammering. do both weld deposit and diffuse line. do not peen on roote or toe of the welds.

→ UHX: Unfired Heat Exchanger. This part is new and published in 2013.

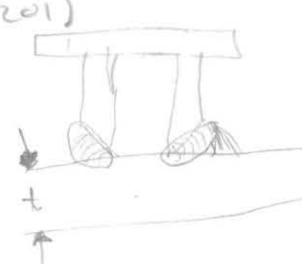
Hot Tap steps API 2201 has a very good check list.

1- we need a minimum Required thickness (1/2" As per API 2201)

2- PT befor hot tap

3- volumetry UT for internal flaws.

4- Check ID surface Geometry using UTSW inspection



5- operation & Safety peoples shall be on site for helping

6- Area Preaparation, All drains needs to be plugged.

7- Talk to welder to practice this weld. use low He electrod and oven in site.

8- Drag Test for welder is recommended

9- Delay cracking check after 48 hours. by WFMT method.

E-PCC-2

ASME BOILER AND PRESSURE VESSEL CODE, SECTION IX – WELDING QUALIFICATION

"This standard was not exist befor 1968"

Scope

The scope of Section IX specifies the requirements for the qualification of welders, brazers, and the welding and brazing procedure specifications employed when welding or brazing in accordance with the ASME Boiler and Pressure Code, and the ASME B31 Code for Pressure Piping.

A Code user may be directed to use Section IX by any of the construction codes of ASME, such as Sections I, III, IV, VIII, XI, and by the ASME B31 Pressure Piping codes, such as B31.1 or B31.3. Section IX may also be referenced by the API Petrochemical and Refinery codes such as API 510, API 570, and API 653. Or it may simply be required by purchase order.

Qualification of welders and the welding procedure specifications they use in code construction involves many factors that are difficult to outline in a code or standard. The CASTI Guidebook to ASME Section IX - *Welding Qualifications,* is a guide to the requirements of the ASME Boiler and Pressure Vessel Code Section IX - Welding and Brazing Qualifications.

Organization of Section IX

Section IX is divided into two parts: welding and brazing. The welding part is divided into five articles, as outlined in Table 1.1 and explained further in the pages that follow. The brazing part is divided into four articles, also explained further in the pages that follow.

Table 1 Organization of Section IX

Foreword	Brief history, Code operations, committee activities, Code user responsibility, Code cases, revisions, jurisdiction precautions, the National Board of Boiler and Pressure Vessel Inspectors, inquiries and materials.
Introduction	Brief guide and explanation of Code rules and parts.
Article I QW-100 General	General rules which apply to the qualification of welding procedure specifications (WPS) and to the qualification of the performance of the welders who will use the WPSs.
Article II QW-200 Welding Procedure Qualifications	Rules for responsibility, variables and tests for the preparation of a WPS, the qualification of the WPS and recording the qualification on PQR forms.
Article III QW-300 Performance	Rules for responsibility, variables and tests for the preparation of a WPQ, rules for the expiration, renewal and continuity records for welders.
Article IV QW-400 Data	Specific data for variables, P-Nos., S-Nos., F-Nos. & A-Nos., thickness ranges, diameters, positions, types of specimens, removal of specimens, test equipment, etching and definitions.
Article V QW-500 SWPS	Rules for the use of standard welding procedure specifications (SWPS).
Appendices	Technical Inquiries, Forms, Materials by P-No. and Group No.
QB-Brazing	QB has the first four articles as in QW, except related to brazing and labeled as QB-100, QB-200, QB-300 and QB-400.

Summary of Articles

Article I – Welding General Requirements QW-100

Article I covers the scope of Section IX; the purpose and use of the WPS, PQR and WPQ; responsibility; test positions; types and purposes of tests and examinations; test procedures; acceptance criteria; visual examination; radiographic examination; and stud, laser, and resistance welding tests.

Article II – Welding Procedure Qualifications QW-200

Article II covers the rules for the preparation of welding procedure specifications (WPS) and of procedure qualification records (PQR).

Each process is listed separately in QW-250 with the essential, nonessential, and supplementary essential variables as they apply to that process. The WPS must specify a value or range for each essential, nonessential and, when required, each supplementary essential variable listed for each welding process.

The PQR records the value for each essential and, when required, each supplementary essential variable used for each welding process.

If a change is made in a nonessential variable, the WPS must be revised, or amended, but does not need to be requalified.

When a change is made in an essential variable, the WPS must be revised, and the revised WPS must be qualified with a new PQR, or the revision must be supported by an existing, valid PQR.

Article III – Welding Performance Qualifications QW-300

Article III covers the preparation of welder performance qualification (WPQ) records. Each process is listed separately in QW-350 with the essential variables as they apply to that process. The WPQ form must record a value for each essential variable used and must list a qualified range for each of these essential variables.

Items addressed are; Code users' responsibility, simultaneous qualifications of welders and welding operators, types of tests, records, welder identification requirements, welding positions, diameter limitations, qualifications expiration, and renewal of qualifications.

The rules for welders versus welding operators qualifications are clearly separated. Welders and Welding Operators may be qualified by visual and mechanical tests, or by radiography of a test coupon. Radiography of the initial production weld, depending upon the welding process used, is also allowed.

Article IV – Welding Data QW-400

Article IV covers welding data that must be applied to the preparation and qualification of the WPS, PQR, and the WPQ depending on the process. The welding data groups the variables into the categories of: joints, base materials, filler materials, positions, preheat, postweld heat treatment, gas, electrical characteristics, and technique.

Article IV also includes assignments of P-Numbers (ASME base materials), S-Numbers (other materials), F-Numbers (grouping of filler metals) and A-Numbers (weld metal chemical analysis).

Tables for welding procedure specification qualification thickness limits, and welder performance qualification thickness and diameter limits are provided.

Welding positions also are specified in QW-400. Qualification ranges for welder positions are defined

Article IV also gives guidance for test coupons, the removal of test specimens, and requirements for the test jig dimensions.

Article V – Standard Welding Procedure Specifications (SWPS) QW-500

Article V covers rules for the adoption, demonstration, and application of the Standard Welding Procedure Specifications, (SWPSs), listed in Appendix E. See details in Chapter 15. Welder qualifications for using SWPSs are the same as when using Section IX qualified procedures.

Table 2 Scopes of the WPS, PQR, and WPQ

Welding Application	**WPS** Specify: Variable ranges Essential variables Nonessential variables Other directions	**PQR** Record: Actual values Essential variables Tests and results Other data	**WPQ** Record: value tested / Specify: range qualified Record tests and test results
Example 1.2.1			
What do each of these documents provide?	A WPS provides direction for making welds, specifies what material is to be welded and how it is to be welded.	A PQR provides support (proof) of the mechanical and other weldability properties of the WPS.	A WPQ provides proof of the welder's ability to make sound welds.
How are these documents prepared and/or qualified?	A WPS is prepared by specifying what is to be welded and how it is to be welded by specifying values or ranges for each variable on the WPS.	A WPS is qualified by welding a test coupon, preparing test specimens, recording the tests and test results on a PQR.	A welder is qualified by welding a test coupon, preparing test specimens, recording the tests performed, the results and ranges qualified on a WPQ.
What must be documented, specified or recorded?	A WPS must specify, for each process, the ranges of all essential and nonessential variables that must be followed.	A PQR must record, for each process, all essential variables used to weld the test coupon, the tests performed and the test results.	A WPQ must record the essential variables used to weld the test coupon, the tests performed, the test results, and the ranges qualified.
What happens when changes are made?	The WPS must be revised or rewritten for any change in an essential or nonessential variable.	A PQR must be prepared to support any change made to an essential variable in a WPS.	A WPQ must be prepared to support each performance variable change in a welder's WPQ.

Welding Procedure Specification Hierarchy

There are three steps and documents involved in qualifying welding procedure specifications and welders/welding operators for Code construction.

- The first step requires the Code user to prepare the first document, a **welding procedure specification (WPS)**. The WPS must contain the minimum requirements that are specified by the construction or repair code. The WPS is intended to provide guidance for welding by specifying ranges for each variable. The WPS must be supported by a procedure qualification record (PQR).

- The second step requires the Code user to qualify the WPS by welding procedure qualification test coupon. The Code user must record the variables and tests used, and must certify the tests and test results on the second document, the **procedure qualification record (PQR)**.

- The third step requires the Code user to qualify the performance of the welders by welding performance qualification test coupons. The Code user must record the variables and tests used, specify the variable ranges qualified, and must certify the tests and tests results on the third document, a **welders performance qualification (WPQ)** record.

The majority of the rules in Section IX involve one of these three documents, the WPS, PQR or WPQ. One of the biggest sources of confusion with Section IX is mixing the rules between these three documents. So be careful when reading exam questions and answers to be sure which document is being referenced.

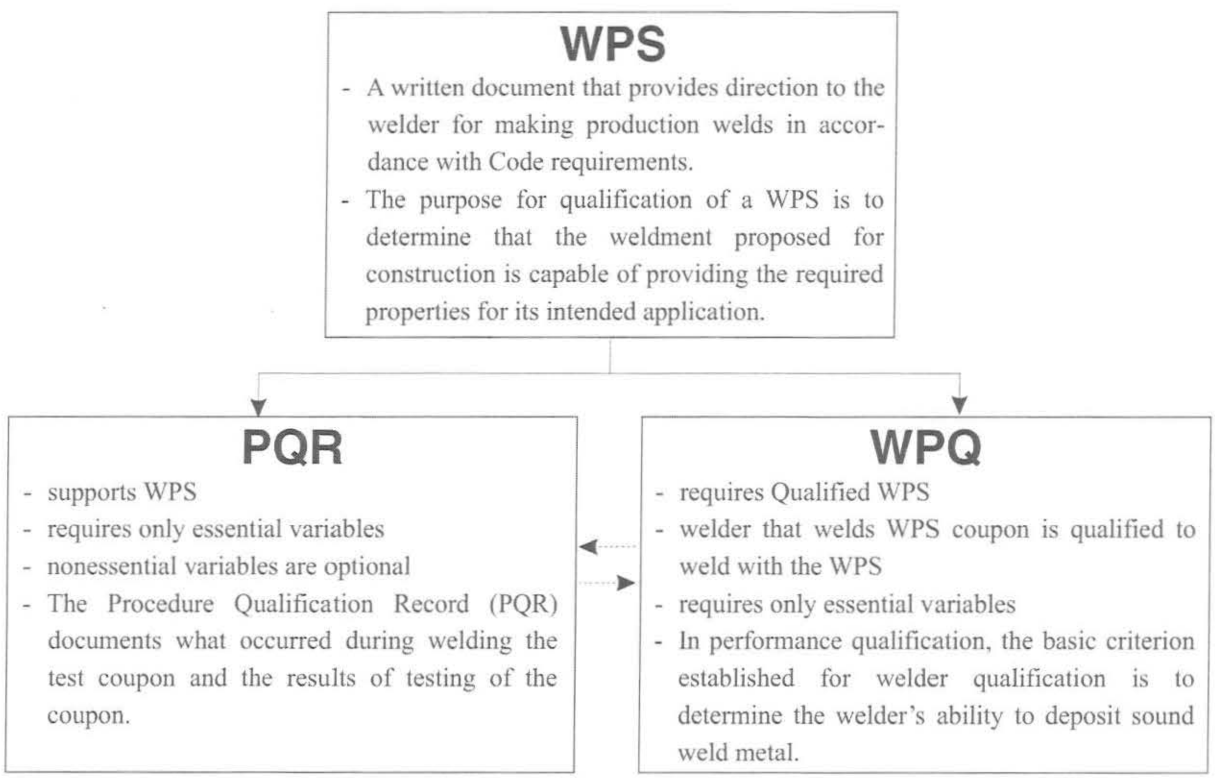


Figure 1 Welding procedure specification hierarchy

Welding General Requirements – Article I

The rules in ASME Section IX are only applied when qualifying either a welding procedure specification (WPS) or a welder/welding operator. These rules do not apply when performing construction code welding. Construction codes, such as ASME Section VIII-1, may specify different requirements than those listed in ASME Section IX. Note that such requirements take precedence over the rules in ASME Section IX and that the manufacturer or contractor must comply with them.

QW-100.1 defines:

> The purpose of the WPS and PQR is to determine that the weldment proposed for construction is capable of providing the required properties for its intended application."

This terse opening statement puts the responsibility on the Code user to assure that welding qualifications are suitable for the welding application.

Note: Section IX does not cover the application, service, or life of the component.

QW-100.1 and QW-100.2 provide definitions of the three documents: the WPS, the PQR, and the WPQ in which all of them are written and not verbal. For example, a WPS is a written document that provides direction to the welder for making production welds in accordance with Code requirements.

QW-100.2 defines the basic criterion established for welder qualification is to determine the welder's ability to deposit sound weld metal. The basic criterion established for welding operator qualification is to determine the welding operator's mechanical ability to operate the welding equipment.

QW-100.3 covers the WPS, PQR, and WPQ, in more detail. QW-100.3 states that these documents, prepared in accordance with Section IX, may be used in any ASME construction.

QW-100.3 also allows the continued use of a WPS, PQR or WPQ, qualified at any time in the past, provided all requirements of the 1962 or later Edition are met. QW-100.3 does not require a WPS, WPQ or a PQR to be amended to include any variables required by later Editions and Addenda. However, QW-100.3 does require the qualification of a new WPS or WPQ, or, the requalification of an existing WPS or WPQ to be performed in full accordance with the latest version of Section IX.

QW-103.1 requires the manufacturer or contractor to conduct the tests used to qualify the welding procedures and welders for welding under this Code.

QW-103.2 Each manufacturer or contractor must maintain a record of the results obtained in welding procedure and welder and welding operator performance qualifications. These records must be certified by a signature or other means as described in the manufacturer's or contractor's Quality Control System and must be accessible to the Authorized Inspector.

Test Positions for Groove Welds – QW-120

It is important to recognize that there are test positions, as described in QW-120, and there are welding application positions.

The test positions in QW-120 and QW-461.3 through 461.8 define the positions that are allowed as one of the test positions. The test positions are labeled, for example, as 1G, 2G, 3G, etc. and 1F, 2F, 3F, etc. (see figure below).

Plate Positions – QW-121

- Flat Position 1G; see figure QW-461.3, illustration (a).
- Horizontal Position 2G; see figure QW-461.3, illustration (b).
- Vertical Position 3G; see figure QW-461.3, illustration (c).
- Overhead Position 4G; see QW-461.3, illustration (d).

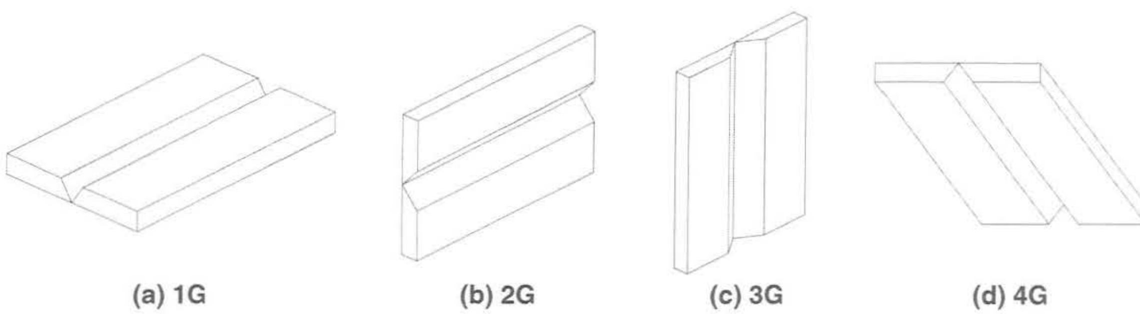


Figure 2 QW-461.3 Groove welds in plate—test positions

Pipe Positions – QW-122

- Flat Position 1G; see figure QW-461.4, illustration (a).
- Horizontal Position 2G (pipe is not be rotated); see figure QW-461.4, illustration (b).
- Multiple Position 5G (pipe is not be rotated); see figure QW-461.4, illustration (c).
- Multiple Position 6G (pipe is not be rotated); see figure QW-461.4, illustration (d).

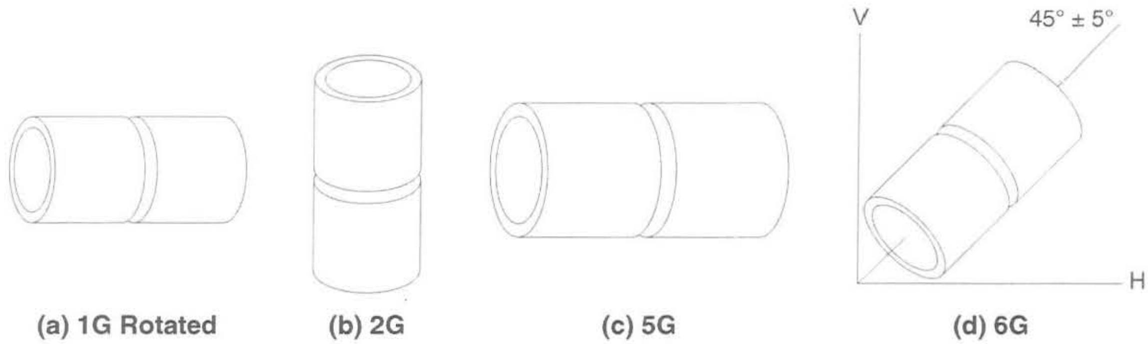


Figure 3 QW-461.4 Groove welds in pipe—test positions

Test Positions for Fillet Welds – QW-130

Plate Positions – QW-131

- Flat Position 1F; see figure QW-461.5, illustration (a).
- Horizontal Position 2F; see figure QW-461.5, illustration (b).
- Vertical Position 3F; see figure QW-461.5, illustration (c).
- Overhead Position 4F; see figure QW-461.5, illustration (d).

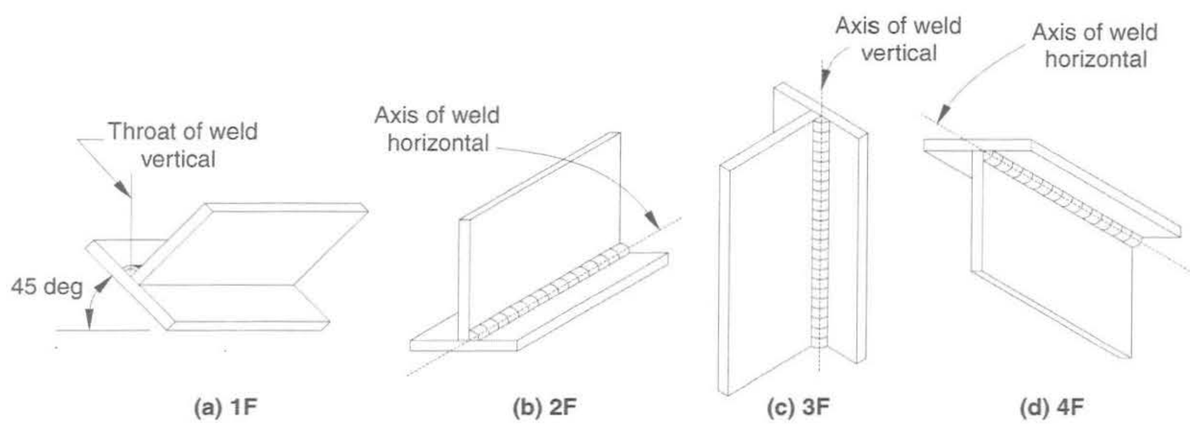


Figure 4 QW-461.5 Fillet welds in plate—test positions.

Pipe Positions – QW-132

- Flat Position 1F; see figure QW-461.6, illustration (a).
- Horizontal Positions:
  (a) Position 2F (pipe is not rotated); see figure QW-461.6, illustration (b).
  (b) Position 2FR (pipe is rotated); see figure QW-461.6, illustration (c).
- Overhead Position 4F (pipe is not rotated). see figure QW-461.6, illustration (d).
- Multiple Position 5F (pipe is not rotated); see figure QW-461.6, illustration (e).

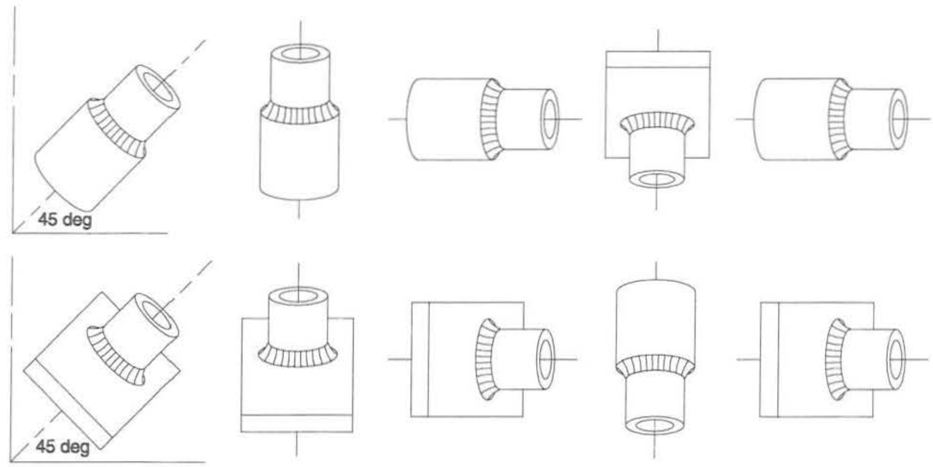


Figure 5 QW-461.6 fillet welds in pipe—test positions

Types and Purposes of Tests and Examinations – QW-140

QW-140 describes the types and purposes of tests and examinations.

Mechanical Tests – QW-141

- Tension tests are used to determine the ultimate strength of groove-weld joints; see QW-150.
- Guided-bend tests are used to determine the degree of soundness and ductility of groove-weld joints; see QW-160.
- Fillet-weld tests are used to determine the size, contour, and degree of soundness of fillet welds; see QW-180.
- Notch-toughness tests (e.g., Charpy impact test) are used to determine the notch toughness of the weldment; in QW-171 and QW-172.
- Stud-weld test include deflection bend, hammering, torque, or tension tests and a macro-examination are used to determine acceptability of stud welds; see QW-466.4, QW-466.5, QW-466.6, and QW-202.5, respectively.

Special Examinations for Welders – QW-142

Radiographic or ultrasonic examination may be substituted for mechanical testing of QW-141 for groove-weld performance qualification as permitted in QW-304 to prove the ability of welders to make sound welds.

P-Number – F-Number – A-Number

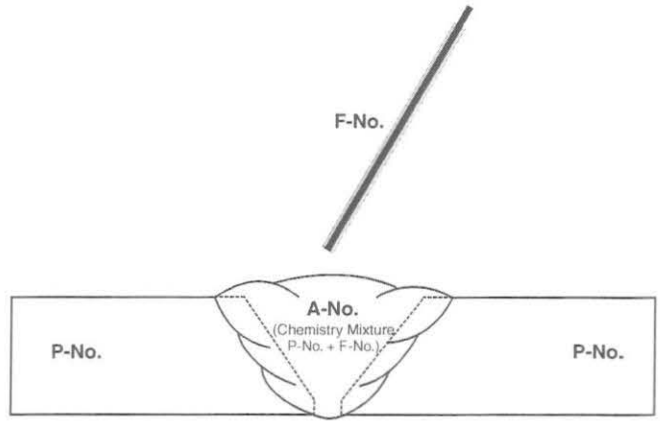


Figure 6 Demonstrating the relationship between the location of P-number, F-number, and A-number materials.

P-Number (P-No.) – QW-420

QW-420 defines a P-Number as a family of base metals logically organized by their characteristics, such as:

- chemical composition,
- weldability, and
- mechanical properties.

P-Numbers were made to reduce the number of welding procedure qualifications.

QW/QB-422 lists all P-No. materials alpha-numerically by specification number, where ferrous metals begin with SA- or A and nonferrous metals begin with SB- or B, e.g., SA-36 and B-16.

Although QW-424.1 allows one metal from a P-Number welded to any metal from the same P-Number to qualify any metals assigned that same P-Number, it also warns the Code user that this cannot be done indiscriminately. QW-420 states that:

> "These assignments (P-Numbers.) do not imply that base metals may be indiscriminately substituted for a base metal that was used in the qualification test without consideration of compatibility from the standpoint of metallurgical properties, postweld heat treatment, design, mechanical properties, and service requirements."

Group Numbers (Within P-Numbers) – QW-420

QW-420 describes Group Numbers as being assigned within a P-Number to ferrous base metals that have specified impact test requirements. The Group Number is a supplementary essential variable, which must be addressed on the PQR whenever impact testing is imposed for low temperature applications by the construction code.

When impact testing is not imposed by the construction code, the Group Number is no longer a variable that is required to be addressed by ASME Section IX (see definition for supplementary essential variable in QW-251.2).

However, good engineering judgment should include a review of all variables to ensure that the weldment proposed for construction is capable of providing the required properties for its intended application (see QW100.1).

The P-Number is an essential variable for WPS and welder performance qualifications.

The complete listing of P-Numbers is found in QW/QB-422 (see excerpt below). Note that base metals for welding and brazing are combined in this table. QW/QB-422 lists each of the base metals in an alpha-numerical sequence based upon the material specification.

Appendix D is a nonmandatory listing of P-Numbers, and lists each of the base metals in a numeric sequence based upon the P-Number. Appendix D is a convenient place to find all the base metals of a given P-Number in one table. Appendix D may be very useful when a Code user is looking for other base metals within a given P-Number for the purpose of qualification.

QW/QB-422 also lists other base material information for qualifying WPS and BPS.

Steps to Find a P-Number – QW/QB-422

Step 1: Find the base metal specification in the left-hand column in QW/QB-422; they are organized in alpha-numerical order, starting with SA-36; (note that the ferrous metal SA-specifications are listed first, followed by the nonferrous metal SB-specifications).
Step 2: Move to the next column and find the Grade or Type.
Step 3: Move horizontal to the Welding P-No., Group No. column.

These steps are shown in the following example. You can proceed to answer the practice problems after the example.

Example Q1: QW/QB-422 – P-No. Group No.

What is the P-No. and Group No. for ASME SA-105 flanges and fittings?

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS
Grouping of Base Metals for Qualification

Ferrous									
Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-36	...	K02600	58 (400)	1	1	101	11.1	C-Mn-Si	Plate, bar & shapes
SA-53	Type F	...	48 (330)	1	1	101	11.1	C	Furnace welded pipe
SA-53	Type S, Gr. A	K02504	48 (330)	1	1	101	11.1	C	Smls. pipe
SA-53	Type E, Gr. A	K02504	48 (330)	1	1	101	11.1	C	Resistance welded pipe
SA-53	Type E, Gr. B	K03005	60 (415)	1	1	101	11.1	C-Mn	Resistance welded pipe
SA-53	Type S, Gr. B	K03005	60 (415)	1	1	101	11.1	C-Mn	Smls. pipe
SA-105	...	K03504	70 (485)	1	2	101	11.1	C	Flanges & fittings
SA-106	A	K02501	48 (330)	1	1	101	1.1	C-Si	Smls. pipe

Practice Problem Q2: QW/QB-422 – UNS No.

What is the UNS No. for ASME SA-182 Type F304?

a) 304
b) S304
c) S304xx
d) S30400

Practice Problem Q3: QW/QB-422 – Minimum Specified Tensile Strength

What is the minimum specified tensile strength of ASME SA-516 Grade 70?

a) 16 ksi
b) 516 ksi
c) 70,000 ksi
d) 70 ksi

Practice Problem Q4: QW/QB-422 – Nominal Composition

What is the nominal composition of ASME SA-333 Grade 6?

a) carbon steel
b) manganese steel
c) C-Mn-Si steel
d) alloy steel

Practice Problem Q5: QW/QB-422 – Product Form

What product form is ASME SA-426 Grade CP11?

a) plate
b) forging
c) centrifugal cast pipe
d) piping fitting

F-Number (F-No.) – QW-430

QW-430 defines F-Numbers as families of filler metals based essentially on usability characteristics.

Similar to P-Numbers, F-Numbers were made to reduce the number of welding procedure and performance qualifications, where it was logical.

However, like P-Numbers, the filler metals within an F-Number does not imply that base metals or filler metals within the same F-Number may be indiscriminately substituted for a metal that was used in the qualification test without consideration of the compatibility of the base and filler metals from the standpoint of metallurgical properties, postweld heat treatment, design, mechanical properties, and service requirements.

The F-Number is an essential variable for WPS and welder performance qualifications.

Steps to Find an F-Number – QW-432

Step 1: A filler metal must be produced to an AWS classification (or other national or international organizations, within an ASME specification, in order to have an F-Number assigned).
Step 2: Using QW-432 find the EXX XX that matches the filler metal being considered.
Step 3: When the EXX XX has been found, move left on this same line, to match the SFA specification number.
Step 4: On the same line as the EXX XX and the SFA specification, move left to read the F-Number.

These steps are shown in the following examples. You can proceed to answer the practice problems after the examples.

Example Q6: QW-432 – F-No.

What is the F-No. of SFA-5.1 classification E6010?

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Steel and Steel Alloys	
1	SFA-5.1	EXX20	...
1	SFA-5.1	EXX22	...
1	SFA-5.1	EXX24	...
1	SFA-5.1	EXX27	...
1	SFA-5.1	EXX28	...
1	SFA-5.4	EXXX(X)-26	...
1	SFA-5.5	EXX20-X	...
1	SFA-5.5	EXX27-X	...
2	SFA-5.1	EXX12	...
2	SFA-5.1	EXX13	...
2	SFA-5.1	EXX14	...
2	SFA-5.1	EXX19	...
2	SFA-5.5	E(X)XX13-X	...
3	SFA-5.1	EXX10	...
3	SFA-5.1	EXX11	...
3	SFA-5.5	E(X)XX10-X	...
3	SFA-5.5	E(X)XX11-X	...
4	SFA-5.1	EXX15	...
4	SFA-5.1	EXX16	...
4	SFA-5.1	EXX18	...
4	SFA-5.1	EXX18M	...
4	SFA-5.1	EXX48	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	...
4	SFA-5.5	E(X)XX15-X	...
4	SFA-5.5	E(X)XX16-X	...
4	SFA-5.5	E(X)XX18-X	...
4	SFA-5.5	E(X)XX18M	...
4	SFA-5.5	E(X)XX18M1	...
4	SFA-5.5	E(X)XX45	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	...
6	SFA-5.2	All classifications	...
6	SFA-5.9	All classifications	...
6	SFA-5.17	All classifications	...
6	SFA-5.18	All classifications	...
6	SFA-5.20	All classifications	...
6	SFA-5.22	All classifications	...
6	SFA-5.23	All classifications	...
6	SFA-5.25	All classifications	...
6	SFA-5.26	All classifications	...
6	SFA-5.28	All classifications	...
6	SFA-5.29	All classifications	...
6	SFA-5.30	INMs-X	...
6	SFA-5.30	IN5XX	...
6	SFA-5.30	IN3XX(X)	...

E8018-C1/C3 for Low Temprature -50°F

Example Q7: QW-432 – F-No.

What is the F-No. of SFA-5.1 classification E7018?

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Steel and Steel Alloys	
1	SFA-5.1	EXX20	...
1	SFA-5.1	EXX22	...
1	SFA-5.1	EXX24	...
1	SFA-5.1	EXX27	...
1	SFA-5.1	EXX28	...
1	SFA-5.4	EXXX(X)-26	...
1	SFA-5.5	EXX20-X	...
1	SFA-5.5	EXX27-X	...
2	SFA-5.1	EXX12	...
2	SFA-5.1	EXX13	...
2	SFA-5.1	EXX14	...
2	SFA-5.1	EXX19	...
2	SFA-5.5	E(X)XX13-X	...
3	SFA-5.1	EXX10	...
3	SFA-5.1	EXX11	...
3	SFA-5.5	E(X)XX10-X	...
3	SFA-5.5	E(X)XX11-X	...
4	SFA-5.1	EXX15	...
4	SFA-5.1	EXX16	...
4	SFA-5.1	EXX18	...
4	SFA-5.1	EXX18M	...
4	SFA-5.1	EXX48	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	...
4	SFA-5.5	E(X)XX15-X	...
4	SFA-5.5	E(X)XX16-X	...
4	SFA-5.5	E(X)XX18-X	...
4	SFA-5.5	E(X)XX18M	...
4	SFA-5.5	E(X)XX18M1	...
4	SFA-5.5	E(X)XX45	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	...
6	SFA-5.2	All classifications	...
6	SFA-5.9	All classifications	...
6	SFA-5.17	All classifications	...
6	SFA-5.18	All classifications	...
6	SFA-5.20	All classifications	...
6	SFA-5.22	All classifications	...
6	SFA-5.23	All classifications	...
6	SFA-5.25	All classifications	...
6	SFA-5.26	All classifications	...
6	SFA-5.28	All classifications	...
6	SFA-5.29	All classifications	...
6	SFA-5.30	INMs-X	...
6	SFA-5.30	IN5XX	...
6	SFA-5.30	IN3XX(X)	...

Practice Problem Q8: QW-432 – F-No.

What is the F-No. of SFA-5.1 classification E6020?

a) F-No. 1
b) F-No. 3
c) F-No. 4
d) F-No. 6

Practice Problem Q9: QW-432 – F-No.

What is the F-No. of SFA-5.5 classification E8018-B3L, low-alloy steel electrodes for shielded metal arc welding?

a) F-No. 1
b) F-No. 3
c) F-No. 4
d) F-No. 5

Practice Problem Q10: QW-432 – F-No.

What is the F-No. of SFA-5.17 classification F43A2-EM12K, carbon steel electrodes and fluxes for submerged arc welding?

a) F-No. 1
b) F-No. 3
c) F-No. 4
d) F-No. 6

Practice Problem Q11: QW-432 – F-No.

What is the F-No. of SFA-5.18 classification ER70S-4, carbon steel electrodes and rods for gas shielded arc welding?

a) F-No. 1
b) F-No. 3
c) F-No. 4
d) F-No. 6

A-Number (A-No.) – QW-442

QW-442 defines an A-Number as families of weld metal have been assigned A-Numbers based essentially on resultant properties of the weld metal (i.e., the filler metal and both base metals that have been mixed together by welding).

The A-Number is an essential variable for WPS, but not for welder qualification. Since the F-Number is an essential variable for welder qualification, however, the A-Number would also have to conform to changes in the F-Number.

Steps to Find an A-Number – QW-442

Step 1: Estimate the chemical composition of the completed weldment (i.e., base metal + filler metal).
Step 2: Using QW-442 find the appropriate matching chemical composition of the weldment (note that the chemical composition ranges can be very wide).
Step 3: Move to the left column to find the A-No.

These steps are shown in the following examples. You can proceed to answer the practice problems after the examples.

Example Q12: QW-442 – A-No.

What is the A-No. when welding P-No. 1 to P-No. 1 using SFA-5.1 classification E7018 (F-No. 4) filler metal?

QW-442
A-NUMBERS
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)]					
		C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	. . .	. . .	. . .	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40-0.65	. . .	1.60	1.00
3	Chrome (0.4% to 2%)-Molybdenum	0.15	0.40-2.00	0.40-0.65	. . .	1.60	1.00
4	Chrome (2% to 6%)-Molybdenum	0.15	2.00-6.00	0.40-1.50	. . .	1.60	2.00
5	Chrome (6% to 10.5%)-Molybdenum	0.15	6.00-10.50	0.40-1.50	. . .	1.20	2.00
6	Chrome-Martensitic	0.15	11.00-15.00	0.70	. . .	2.00	1.00
7	Chrome-Ferritic	0.15	11.00-30.00	1.00	. . .	1.00	3.00
8	Chromium-Nickel	0.15	14.50-30.00	4.00	7.50-15.00	2.50	1.00
9	Chromium-Nickel	0.30	19.00-30.00	6.00	15.00-37.00	2.50	1.00
10	Nickel to 4%	0.15	. . .	0.55	0.80-4.00	1.70	1.00
11	Manganese-Molybdenum	0.17	. . .	0.25-0.75	0.85	1.25-2.25	1.00
12	Nickel-Chromium-Molybdenum	0.15	1.50	0.25-0.80	1.25-2.80	0.75-2.25	1.00

NOTE:
(1) Single values shown above are maximum.

From QW/QB-442, P-No. 1 is carbon steel and from general knowledge SFA-5.1 classification E7018 is also carbon steel.

Example Q13: QW-442 – A-No.

What is the A-No. when welding SA-335 grade P1 using SFA-5.5 classification E7818-A1 (C-0.5Mo alloy steel) filler metal?

QW-442
A-NUMBERS
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)] C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	. . .	. . .	. . .	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40-0.65	. . .	1.60	1.00
3	Chrome (0.4% to 2%)-Molybdenum	0.15	0.40-2.00	0.40-0.65	. . .	1.60	1.00
4	Chrome (2% to 6%)-Molybdenum	0.15	2.00-6.00	0.40-1.50	. . .	1.60	2.00
5	Chrome (6% to 10.5%)-Molybdenum	0.15	6.00-10.50	0.40-1.50	. . .	1.20	2.00
6	Chrome-Martensitic	0.15	11.00-15.00	0.70	. . .	2.00	1.00
7	Chrome-Ferritic	0.15	11.00-30.00	1.00	. . .	1.00	3.00
8	Chromium-Nickel	0.15	14.50-30.00	4.00	7.50-15.00	2.50	1.00
9	Chromium-Nickel	0.30	19.00-30.00	6.00	15.00-37.00	2.50	1.00
10	Nickel to 4%	0.15	. . .	0.55	0.80-4.00	1.70	1.00
11	Manganese-Molybdenum	0.17	. . .	0.25-0.75	0.85	1.25-2.25	1.00
12	Nickel-Chromium-Molybdenum	0.15	1.50	0.25-0.80	1.25-2.80	0.75-2.25	1.00

NOTE:
(1) Single values shown above are maximum.

From QW/QB-442, SA-335 Grade P1 nominal composition is a C-0.5Mo alloy steel and the filler metal is also C-0.5Mo alloy steel.

Practice Problem Q14: QW-442 – A-No.

What is the A-No. when welding SA-240 grade 304L using SFA-5.4 classification E309L (austenitic stainless steel 18Cr-8Ni) filler metal?

a) A-No. 6
b) A-No. 7
c) A-No. 8
d) A-No. 9

Practice Problem Q15: QW-442 – A-No.

What would be the A-No. when welding an ASME SA-105 flange to SA-106 Grade B pipe, using an AWS A 5.1 E7018 electrode?

a) A-No. 1
b) A-No. 2
c) A-No. 3
d) A-No. 4

Practice Problem Q16: QW-442 – A-No.

What would be the A-No. when welding ASME SA-312 Type TP316 pipe using an AWS A 5.4 E316 electrode?

a) A-No. 1
b) A-No. 2
c) A-No. 4
d) A-No. 8

Example Q17: QW-253 SAW WPS Variable – Groove Design

For SAW, what type of variable is a change in groove design for a WPS qualification?

QW-253
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Shielded Metal-Arc Welding (SMAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.4	− Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	*T* Limits impact		X	
	.8	ϕ *T* Qualified	X		
	.9	*t* Pass > ½ in. (13 mm)	X		
	.11	ϕ P-No. qualified	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.7	ϕ Diameter > ¼ in. (6 mm)		X	
	.12	ϕ Classification		X	
	.30	ϕ *t*	X		
	.33	ϕ Classification			X
QW-405 Positions	.1	+ Position			X
	.2	ϕ Position		X	
	.3	ϕ ↑↓ Vertical welding			X
QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.2	ϕ Preheat maint.			X
	.3	Increase > 100°F (55°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	*T* Limits	X		
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
QW-410 Technique	.1	ϕ String/weave			X
	.5	ϕ Method cleaning			X
	.6	ϕ Method back gouge			X
	.9	ϕ Multiple to single pass/side		X	X
	.25	ϕ Manual or automatic			X
	.26	± Peening			X
	.64	Use of thermal processes	X		

Legend:
+ Addition
− Deletion
> Increase/greater than
< Decrease/less than
↑ Uphill
↓ Downhill
← Forehand
→ Backhand
ϕ Change

For SAW, a change in groove design for a WPS is a nonessential variable (see QW-402.1).

P Number is Parent Material Group.

QW-416
WELDING VARIABLES
Welder Performance

Paragraph[1]		Brief of Variables	Essential					
			OFW QW-352	SMAW QW-353	SAW QW-354	GMAW[2] QW-355	GTAW QW-356	PAW QW-357
QW-402 Joints	.4	− Backing		X		X	X	X
	.7	+ Backing	X					
QW-403 Base Metal	.2	Maximum qualified	X					
	.16	Φ Pipe diameter		X	X	X	X	X
	.18	Φ P-Number	X	X	X	X	X	X
QW-404 Filler Metals	.14	± Filler	X				X	X
	.15	Φ F-Number	X	X	X	X	X	X
	.22	± Inserts					X	X
	.23	*t* Solid or metal-cored to flux-cored					X	X
	.30	Φ *t* Weld deposit		X	X	X	X	X
	.31	Φ *t* Weld deposit	X					
	.32	*t* Limit (s. cir. arc)				X		
QW-405 Positions	.1	+ Position	X	X	X	X	X	X
	.3	Φ ↑↓ Vert. welding		X		X	X	X
QW-408 Gas	.7	Φ Type fuel gas	X					
	.8	− Inert backing				X	X	X
QW-409 Electrical	.2	Φ Transfer mode				X		
	.4	Φ Current or polarity					X	

Welding Processes:

OFW	Oxyfuel gas welding
SMAW	Shielded metal-arc welding
SAW	Submerged-arc welding
GMAW	Gas metal-arc welding
GTAW	Gas tungsten-arc welding
PAW	Plasma-arc welding

Legend:

Φ	Change	*t*	Thickness
+	Addition	↑	Uphill
−	Deletion	↓	Downhill

NOTES:

(1) For description, see Section IV.

(2) Flux-cored arc welding as shown in QW-355, with or without additional shielding from an externally supplied gas or gas mixture, is included.

QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATIONS (WPS)
(See QW-200.1, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name ______________________ By: ______________________
Welding Procedure Specification No. ____________ Date ____________ Supporting PQR No.(s) ____________
Revision No. ____________ Date ____________

Welding Process(es) ______________________ Type(s) ______________________
(Automatic, Manual, Machine, or Semi-Auto)

JOINTS (QW-402) Details
Joint Design ______________________
Root Spacing ______________________
Backing: Yes ____________ No ____________
Backing Material (Type) ______________________
(Refer to both backing and retainers.)

☐ Metal ☐ Nonfusing Metal
☐ Nonmetallic ☐ Other

Sketches, Production Drawings, Weld Symbols or Written Description should show the general arrangement of the parts to be welded. Where applicable, the details of weld groove may be specified.

[At the option of the manufacturer, sketches may be attached to illustrate joint design, weld layers and bead sequence (e.g., for notch toughness procedures, for multiple process procedures, etc.)]

---

*BASE METALS (QW-403)
P-No. ____________ Group No. ____________ to P-No. ____________ Group No. ____________
OR
Specification and type/grade or UNS Number ______________________
to Specification and type/grade or UNS Number ______________________
OR
Chem. Analysis and Mech. Prop. ______________________
to Chem. Analysis and Mech. Prop. ______________________
Thickness Range:
Base Metal: Groove ______________________ Fillet ______________________
Maximum Pass Thickness ≤ ½ in. (13 mm) (Yes) ______ (No) ______
Other ______________________

---

*FILLER METALS (QW-404)	1	2
Spec. No. (SFA)		
AWS No. (Class)		
F-No.		
A-No.		
Size of Filler Metals		
Filler Metal Product Form		
Supplemental Filler Metal		
Weld Metal		
Thickness Range:		
Groove		
Fillet		
Electrode-Flux (Class)		
Flux Type		
Flux Trade Name		
Consumable Insert		
Other		

*Each base metal-filler metal combination should be recorded individually.

Figure 2.1 QW-482 Form - Nonmandatory Appendix B (Page 1 of 2)

QW-482 (Back)

WPS No. ______________ **Rev.** ____________

POSITIONS (QW-405)
Position(s) of Groove ____________
Welding Progression: Up ________ Down ________
Position(s) of Fillet ____________
Other ____________

POSTWELD HEAT TREATMENT (QW-407)
Temperature Range ____________
Time Range ____________
Other ____________

PREHEAT (QW-406)
Preheat Temperature, Minimum ____________
Interpass Temperature, Maximum ____________
Preheat Maintenance ____________
Other ____________
(Continuous or special heating where applicable should be recorded)

GAS (QW-408)

	Percent Composition		
	Gas(es)	(Mixture)	Flow Rate
Shielding			
Trailing			
Backing			
Other			

ELECTRICAL CHARACTERISTICS (QW-409)

Weld Pass(es)	Process	Filler Metal		Current Type and Polariy	Amps (Range)	Wire Feed Speed (Range)	Energy or Power (Range)	Volts (Range)	Travel Speed (Range)	Other (e.g., Remarks, Comments, Hot Wire Addition, Technique, Torch Angle, etc.)
		Classification	Diameter							

Amps and volts, or power or energy range, should be recorded for each electrode size, position, and thickness, etc.

Pulsing Current ____________ Heat Input (max.) ____________
Tungsten Electrode Size and Type ____________
(Pure Tungsten, 2% Thoriated, etc.)
Mode of Metal Transfer for GMAW (FCAW) ____________
(Spray Arc, Short Circuiting Arc, etc.)
Other ____________

TECHNIQUE (QW-410)
String or Weave Bead ____________
Orifice, Nozzle, or Gas Cup Size ____________
Initial and Interpass Cleaning (Brushing, Grinding, etc.) ____________

Method of Back Gouging ____________
Oscillation ____________
Contact Tube to work Distance ____________
Multiple or Single Pass (per side) ____________
Multiple or single Electrodes ____________
Electrode Spacing ____________
Peening ____________
Other ____________

Figure 2.1 QW-482 Form - Nonmandatory Appendix B (Page 2 of 2)

QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORDS (PQR)
(See QW-200.2, Section IX, ASME Boiler and Pressure Vessel Code)
Record Actual Conditions Used to Weld Test Coupon.

Company Name ____________________
Procedure Qualification Record No. ____________________ Date ____________________
WPS No. ____________________
Welding Process(es) ____________________
Types (Manual, Automatic, Semi-Auto.) ____________________

JOINTS (QW-402)

Groove Design of Test Coupon
(For combination qualifications, the deposited weld metal thickness shall be recorded for each filler metal and process used.)

BASE METALS (QW-403)
Material Spec. ____________________
Type/Grade, or UNS Number ____________________
P-No. ____ Group No. ____ to P-No. ____ Group No. ____
Thickness of Test Coupon ____________________
Diameter of Test Coupon ____________________
Maximum Pass Thickness ____________________
Other ____________________

FILLER METALS (QW-404)

	1	2
SFA Specification		
AWS Specification		
Filler Metal F-No.		
Weld Metal Analysis A-No.		
Size of Filler Metal		
Filler Metal Product Form		
Supplemental Filler Metal		
Electrode Flux Classification		
Flux Type		
Flux Trade Name		
Weld Metal Thickness		
Other		

POSITION (QW-405)
Position of Groove ____________________
Weld Progression (Uphill, Downhill) ____________________
Other ____________________

PREHEAT (QW-406)
Preheat Temp ____________________
Interpass Temp ____________________
Other ____________________

POSTWELD HEAT TREATMENT (QW-407)
Temperature ____________________
Time ____________________
Other ____________________

GAS (QW-408)

	Gas(es)	Percent Composition (Mixture)	Flow Rate
Shielding			
Trailing			
Backing			
Other			

ELECTRICAL CHARACTERISTICS (QW-409)
Current ____________________
Polarity ____________________
Amps. ____________________ Volts ____________________
Tungsten Electrode Size ____________________
Mode of Metal Transfer for GMAW (FCAW) ____________________
Heat Input ____________________
Other ____________________

TECHNIQUE (QW-410)
Travel Speed ____________________
String or Weave Bead ____________________
Oscillation ____________________
Multipass or Single Pass (per side) ____________________
Single or Multiple Electrodes ____________________
Other ____________________

Figure 2.2 QW-483 Form - Nonmandatory Appendix B (Page 1 of 2)

QW-483 (Back)

PQR No. ____________

Tensile Test (QW-150)

Specimen No.	Width	Thickness	Area	Ultimate Total Load	Ultimate Unit Stress (psi or MPa)	Type of Failure and Location

Guided-Bend Tests (QW-160)

Type and Figure No.	Result

Toughness Tests (QW-170)

Specimen No.	Notch Location	Specimen Size	Test Temp.	Impact Values			Drop Weight Break (Y/N)
				ft-lbs or J	% Shear	Mils (in.) or mm	

Comments: ____________

Fillet-Weld Test (QW-180)

Result - Satisfactory: Yes ________ **No** ________ **Penetration into Parent Metal: Yes** ________ **No** ________

Macro - Results ____________

Other Tests

Type of Test ____________
Deposit Analysis ____________
Other ____________

Welder's Name ____________ Clock No. ________ Stamp No. ________
Tests conducted by: ____________ Laboratory Test No. ________
We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Manufacturer or Contractor ____________

Date ____________ Certified By ____________
(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code.)

Figure 2.2 QW-483 Form - Nonmandatory Appendix B (Page 2 of 2)

Solutions

For ASME Section IX Practice Problems

Answer Key – ASME IX Practice Problems

Practice Problem	Answer	Reference Paragraph
Q2:	d	QW/QB-422
Q3:	d	QW/QB-422
Q4:	c	QW/QB-422
Q5:	c	QW/QB-422
Q8:	a	QW-432
Q9:	c	QW-432
Q10:	d	QW-432
Q11:	d	QW-432
Q14:	c	QW-442
Q15:	a	QW-442
Q16:	d	QW-442

Practice Problem Q2: QW/QB-422 – UNS No. [SOLUTION]

What is the UNS No. for ASME SA-182 Type F304?

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding		Brazing	ISO 15608 Group	Nominal Composition	Product Form
				P-No.	Group No.	P-No.			
SA-179	...	K01200	47 (325)	1	1	101	1.1	C	Smls. tube
SA-181	Cl. 60	K03502	60 (415)	1	1	101	11.1	C–Si	Pipe flange & fittings
SA-181	Cl. 70	K03502	70 (485)	1	2	101	11.1	C–Si	Pipe flange & fittings
SA-182	F12, Cl. 1	K11562	60 (415)	4	1	102	5.1	1Cr–0.5Mo	Forgings
SA-182	F12, Cl. 2	K11564	70 (485)	4	1	102	5.1	1Cr–0.5Mo	Forgings
SA-182	F11, Cl. 2	K11572	70 (485)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forgings
SA-182	F11, Cl. 3	K11572	75 (515)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forgings
SA-182	F11, Cl. 1	K11597	60 (415)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forgings
SA-182	F2	K12122	70 (485)	3	2	101	4.2	0.5Cr–0.5Mo	Forgings
SA-182	F1	K12822	70 (485)	3	2	101	1.1	C–0.5Mo	Forgings
SA-182	F22, Cl. 1	K21590	60 (415)	5A	1	102	5.2	2.25Cr–1Mo	Forgings
SA-182	F22, Cl. 3	K21590	75 (515)	5A	1	102	5.2	2.25Cr–1Mo	Forgings
SA-182	FR	K22035	63 (435)	9A	1	101	9.1	2Ni–1Cu	Forgings
SA-182	F21	K31545	75 (515)	5A	1	102	5.2	3Cr–1Mo	Forgings
SA-182	F3V	K31830	85 (585)	5C	1	102	6.2	3Cr–1Mo–V–Ti–B	Forgings
SA-182	F3VCb	...	85 (585)	5C	1	102	6.2	3Cr–1Mo–0.25V–Cb–Ca	Forgings
SA-182	F22V	K31835	85 (585)	5C	1	102	6.2	2.25Cr–1Mo–V	Forgings
SA-182	F5	K41545	70 (485)	5B	1	102	5.3	5Cr–0.5Mo	Forgings
SA-182	F5a	K42544	90 (620)	5B	1	102	5.3	5Cr–0.5Mo	Forgings
SA-182	F9	K90941	85 (585)	5B	1	102	5.4	9Cr–1Mo	Forgings
SA-182	F91	K90901	85 (585)	15E	1	102	6.4	9Cr–1Mo–V	Forgings
SA-182	F6a, Cl. 1	S41000	70 (485)	6	1	102	7.2	13Cr	Forgings
SA-182	F6a, Cl. 2	S41000	85 (585)	6	3	102	7.2	13Cr	Forgings
SA-182	FXM-19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Forgings
SA-182	FXM-11	S21904	90 (620)	8	3	102	8.3	21Cr–6Ni–9Mn	Forgings
SA-182	F304	S30400	70 (485)	8	1	102	8.1	18Cr–8Ni	Forgings > 5 in. (127 mm)
SA-182	F304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Forgings
SA-182	F304L	S30403	65 (450)	8	1	102	8.1	18Cr–8Ni	Forgings > 5 in. (127 mm)
SA-182	F304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Forgings
SA-182	F304H	S30409	70 (485)	8	1	102	8.1	18Cr–8Ni	Forgings > 5 in. (127 mm)
SA-182	F304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Forgings
SA-182	F304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Forgings
SA-182	F304LN	S30453	70 (485)	8	1	102	8.1	18Cr–8Ni–N	Forgings > 5 in. (127 mm)
SA-182	F304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Forgings
SA-182	F46	S30600	78 (540)	8	1	102	8.1	18Cr–15Ni–4Si	Forgings
SA-182	F45	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Forgings

Practice Problem Q3: QW/QB-422 – Minimum Specified Tensile Strength [SOLUTION]

What is the minimum specified tensile strength of ASME SA-516 Grade 70?

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding		Brazing	ISO 15608 Group	Nominal Composition	Product Form
				P-No.	Group No.	P-No.			
A 514	E	K21604	110 (760)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Plate, 2½ in. (64 mm) max.
A 514	P	K21650	100 (690)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.
A 514	P	K21650	110 (760)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate, 2½ in. (64 mm) max.
A 514	Q	...	100 (690)	11B	9	102	3.1	1.3Ni–1.3Cr–0.5Mo–V	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.
A 514	Q	...	110 (760)	11B	9	102	3.1	1.3Ni–1.3Cr–0.5Mo–V	Plate, 2½ in. (64 mm) max.
SA-515	60	K02401	60 (415)	1	1	101	1.1	C	Plate
SA-515	65	K02800	65 (450)	1	1	101	11.1	C–Si	Plate
SA-515	70	K03101	70 (485)	1	2	101	11.1	C–Si	Plate
SA-516	55	K01800	55 (380)	1	1	101	1.1	C–Si	Plate
SA-516	60	K02100	60 (415)	1	1	101	1.1	C–Mn–Si	Plate
SA-516	65	K02403	65 (450)	1	1	101	1.1	C–Mn–Si	Plate
SA-516	70	K02700	70 (485)	1	2	101	11.1	C–Mn–Si	Plate

Practice Problem Q4: QW/QB-422 – Nominal Composition [SOLUTION]

What is the nominal composition of ASME SA-333 Grade 6?

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-312	TP321	S32100	70 (485)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe > 3/8 in. (10 mm)
SA-312	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe ≤ 3/8 in. (10 mm)
SA-312	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe
SA-312	TP321H	S32109	70 (485)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe > 3/8 in. (10 mm)
SA-312	TP321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe ≤ 3/8 in. (10 mm)
SA-312	TP321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Welded pipe
SA-312	S34565	S34565	115 (795)	8	4	102	8.3	24Cr–17Ni–6Mn–4.5Mo–N	Smls & welded pipe
SA-312	TP347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. & welded pipe
SA-312	TP347H	S34709	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. & welded pipe
SA-312	TP348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. & welded pipe
SA-312	TP348H	S34809	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. & welded pipe
SA-312	TPXM-15	S38100	75 (515)	8	1	102	8.1	18Cr–18Ni–2Si	Smls. & welded pipe
SA-333	6	K03006	60 (415)	1	1	101	11.1	C–Mn–Si	Smls. & welded pipe
SA-333	1	K03008	55 (380)	1	1	101	11.1	C–Mn	Smls. & welded pipe
SA-333	10	...	80 (550)	1	3	101	11.1	C–Mn–Si	Smls. & welded pipe
SA-333	4	K11267	60 (415)	4	2	102	4.1	0.75Cr–0.75Ni–Cu–Al	Smls. & welded pipe
SA-333	7	K21903	65 (450)	9A	1	101	9.1	2.5Ni	Smls. & welded pipe

Practice Problem Q5: QW/QB-422 – Product Form [SOLUTION]

What product form is ASME SA-426 Grade CP11?

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-409	S31726	S31726	80 (550)	8	4	102	8.1	19Cr–15.5Ni–4Mo	Welded pipe
SA-409	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Welded pipe
SA-409	TP347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded pipe
SA-409	S34565	S34565	115 (795)	8	4	102	8.3	24Cr–17Ni–6Mn–4.5Mo–N	Welded pipe
SA-409	TP348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded pipe
SA-414	A	K01501	45 (310)	1	1	101	1.1	C	Sheet
SA-414	B	K02201	50 (345)	1	1	101	1.1	C	Sheet
SA-414	C	K02503	55 (380)	1	1	101	1.1	C	Sheet
SA-414	D	K02505	60 (415)	1	1	101	1.1	C–Mn	Sheet
SA-414	E	K02704	65 (450)	1	1	101	11.1	C–Mn	Sheet
SA-414	F	K03102	70 (485)	1	2	101	11.1	C–Mn	Sheet
SA-414	G	K03103	75 (515)	1	2	101	11.1	C–Mn	Sheet
SA-420	WPL6	K03006	60 (415)	1	1	101	11.1	C–Mn–Si	Piping fitting
SA-420	WPL9	K22035	63 (435)	9A	1	101	9.1	2Ni–1Cu	Piping fitting
SA-420	WPL3	K31918	65 (450)	9B	1	101	9.2	3.5Ni	Piping fitting
SA-420	WPL8	K81340	100 (690)	11A	1	101	9.3	9Ni	Piping fitting
SA-423	1	K11535	60 (415)	4	2	102	5.1	0.75Cr–0.5Ni–Cu	Smls. & welded tube
SA-423	2	K11540	60 (415)	4	2	102	5.1	0.75Ni–0.5Cu–Mo	Smls. & welded tube
SA-426	CP15	J11522	60 (415)	3	1	101	1.1	C–0.5Mo–Si	Centrifugal cast pipe
SA-426	CP2	J11547	60 (415)	3	1	101	4.2	0.5Cr–0.5Mo	Centrifugal cast pipe
SA-426	CP12	J11562	60 (415)	4	1	102	5.1	1Cr–0.5Mo	Centrifugal cast pipe
SA-426	CP11	J12072	70 (485)	4	1	102	5.1	1.25Cr–0.5Mo	Centrifugal cast pipe
SA-426	CP1	J12521	65 (450)	3	1	101	1.1	C–0.5Mo	Centrifugal cast pipe
SA-426	CP22	J21890	70 (485)	5A	1	102	5.2	2.25Cr–1Mo	Centrifugal cast pipe
SA-426	CP21	J31545	60 (415)	5A	1	102	5.2	3Cr–1Mo	Centrifugal cast pipe
SA-426	CP5	J42045	90 (620)	5B	1	102	5.3	5Cr–0.5Mo	Centrifugal cast pipe
SA-426	CP5b	J51545	60 (415)	5B	1	102	5.3	5Cr–1.5Si–0.5Mo	Centrifugal cast pipe
SA-426	CP9	J82090	90 (620)	5B	1	102	5.4	9Cr–1Mo	Centrifugal cast pipe
SA-426	CPCA15	J91150	90 (620)	6	3	102	7.2	13Cr	Centrifugal cast pipe
SA-451	CPF8	J92600	70 (485)	8	1	102	8.1	18Cr–8Ni	Centrifugal cast pipe
SA-451	CPF8A	J92600	77 (530)	8	1	102	8.1	18Cr–8Ni	Centrifugal cast pipe
SA-451	CPF8C	J92710	70 (485)	8	1	102	8.1	18Cr–10Ni–Cb	Centrifugal cast pipe
SA-451	CPF8M	J92900	70 (485)	8	1	102	8.1	18Cr–12Ni–2Mo	Centrifugal cast pipe
SA-451	CPF3	J92500	70 (485)	8	1	102	8.1	18Cr–8Ni	Centrifugal cast pipe
SA-451	CPF3M	J92800	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Centrifugal cast pipe
SA-451	CPF3A	J92500	77 (530)	8	1	102	8.1	18Cr–8Ni	Centrifugal cast pipe

Practice Problem Q8: QW-432 – F-No. [SOLUTION]

What is the F-No. of SFA-5.1 classification E6020?

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
	Steel and Steel Alloys		
1	SFA-5.1	EXX20	...
1	SFA-5.1	EXX22	...
1	SFA-5.1	EXX24	...
1	SFA-5.1	EXX27	...
1	SFA-5.1	EXX28	...
1	SFA-5.4	EXXX(X)-26	...
1	SFA-5.5	EXX20-X	...
1	SFA-5.5	EXX27-X	...
2	SFA-5.1	EXX12	...
2	SFA-5.1	EXX13	...
2	SFA-5.1	EXX14	...
2	SFA-5.1	EXX19	...
2	SFA-5.5	E(X)XX13-X	...
3	SFA-5.1	EXX10	...
3	SFA-5.1	EXX11	...
3	SFA-5.5	E(X)XX10-X	...
3	SFA-5.5	E(X)XX11-X	...
4	SFA-5.1	EXX15	...
4	SFA-5.1	EXX16	...
4	SFA-5.1	EXX18	...
4	SFA-5.1	EXX18M	...
4	SFA-5.1	EXX48	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	...
4	SFA-5.5	E(X)XX15-X	...
4	SFA-5.5	E(X)XX16-X	...
4	SFA-5.5	E(X)XX18-X	...
4	SFA-5.5	E(X)XX18M	...
4	SFA-5.5	E(X)XX18M1	...
4	SFA-5.5	E(X)XX45	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	...
6	SFA-5.2	All classifications	...
6	SFA-5.9	All classifications	...
6	SFA-5.17	All classifications	...
6	SFA-5.18	All classifications	...
6	SFA-5.20	All classifications	...
6	SFA-5.22	All classifications	...
6	SFA-5.23	All classifications	...
6	SFA-5.25	All classifications	...
6	SFA-5.26	All classifications	...
6	SFA-5.28	All classifications	...
6	SFA-5.29	All classifications	...
6	SFA-5.30	INMs-X	...
6	SFA-5.30	IN5XX	...
6	SFA-5.30	IN3XX(X)	...

Practice Problem Q9: QW-432 – F-No. [SOLUTION]

What is the F-No. of SFA-5.5 classification E8018-B3L, low-alloy steel electrodes for shielded metal arc welding?

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Steel and Steel Alloys	
1	SFA-5.1	EXX20	...
1	SFA-5.1	EXX22	...
1	SFA-5.1	EXX24	...
1	SFA-5.1	EXX27	...
1	SFA-5.1	EXX28	...
1	SFA-5.4	EXXX(X)-26	...
1	SFA-5.5	EXX20-X	...
1	SFA-5.5	EXX27-X	...
2	SFA-5.1	EXX12	...
2	SFA-5.1	EXX13	...
2	SFA-5.1	EXX14	...
2	SFA-5.1	EXX19	...
2	SFA-5.5	E(X)XX13-X	...
3	SFA-5.1	EXX10	...
3	SFA-5.1	EXX11	...
3	SFA-5.5	E(X)XX10-X	...
3	SFA-5.5	E(X)XX11-X	...
4	SFA-5.1	EXX15	...
4	SFA-5.1	EXX16	...
4	SFA-5.1	EXX18	...
4	SFA-5.1	EXX18M	...
4	SFA-5.1	EXX48	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	...
4	SFA-5.5	E(X)XX15-X	...
4	SFA-5.5	E(X)XX16-X	...
4	SFA-5.5	E(X)XX18-X	...
4	SFA-5.5	E(X)XX18M	...
4	SFA-5.5	E(X)XX18M1	...
4	SFA-5.5	E(X)XX45	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	...
6	SFA-5.2	All classifications	...
6	SFA-5.9	All classifications	...
6	SFA-5.17	All classifications	...
6	SFA-5.18	All classifications	...
6	SFA-5.20	All classifications	...
6	SFA-5.22	All classifications	...
6	SFA-5.23	All classifications	...
6	SFA-5.25	All classifications	...
6	SFA-5.26	All classifications	...
6	SFA-5.28	All classifications	...
6	SFA-5.29	All classifications	...
6	SFA-5.30	INMs-X	...
6	SFA-5.30	IN5XX	...
6	SFA-5.30	IN3XX(X)	...

Practice Problem Q10: QW-432 – F-No. [SOLUTION]

What is the F-No. of SFA-5.17 classification F43A2-EM12K, carbon steel electrodes and fluxes for submerged arc welding?

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Steel and Steel Alloys	
1	SFA-5.1	EXX20	...
1	SFA-5.1	EXX22	...
1	SFA-5.1	EXX24	...
1	SFA-5.1	EXX27	...
1	SFA-5.1	EXX28	...
1	SFA-5.4	EXXX(X)-26	...
1	SFA-5.5	EXX20-X	...
1	SFA-5.5	EXX27-X	...
2	SFA-5.1	EXX12	...
2	SFA-5.1	EXX13	...
2	SFA-5.1	EXX14	...
2	SFA-5.1	EXX19	...
2	SFA-5.5	E(X)XX13-X	...
3	SFA-5.1	EXX10	...
3	SFA-5.1	EXX11	...
3	SFA-5.5	E(X)XX10-X	...
3	SFA-5.5	E(X)XX11-X	...
4	SFA-5.1	EXX15	...
4	SFA-5.1	EXX16	...
4	SFA-5.1	EXX18	...
4	SFA-5.1	EXX18M	...
4	SFA-5.1	EXX48	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	...
4	SFA-5.5	E(X)XX15-X	...
4	SFA-5.5	E(X)XX16-X	...
4	SFA-5.5	E(X)XX18-X	...
4	SFA-5.5	E(X)XX18M	...
4	SFA-5.5	E(X)XX18M1	...
4	SFA-5.5	E(X)XX45	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	...
6	SFA-5.2	All classifications	...
6	SFA-5.9	All classifications	...
6	SFA-5.17	All classifications	...
6	SFA-5.18	All classifications	...
6	SFA-5.20	All classifications	...
6	SFA-5.22	All classifications	...
6	SFA-5.23	All classifications	...
6	SFA-5.25	All classifications	...
6	SFA-5.26	All classifications	...
6	SFA-5.28	All classifications	...
6	SFA-5.29	All classifications	...
6	SFA-5.30	INMs-X	...
6	SFA-5.30	IN5XX	...
6	SFA-5.30	IN3XX(X)	...

Practice Problem Q11: QW-432 – F-No. [SOLUTION]

What is the F-No. of SFA-5.18 classification ER70S-4, carbon steel electrodes and rods for gas shielded arc welding?

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
	Steel and Steel Alloys		
1	SFA-5.1	EXX20	. . .
1	SFA-5.1	EXX22	. . .
1	SFA-5.1	EXX24	. . .
1	SFA-5.1	EXX27	. . .
1	SFA-5.1	EXX28	. . .
1	SFA-5.4	EXXX(X)-26	. . .
1	SFA-5.5	EXX20-X	. . .
1	SFA-5.5	EXX27-X	. . .
2	SFA-5.1	EXX12	. . .
2	SFA-5.1	EXX13	. . .
2	SFA-5.1	EXX14	. . .
2	SFA-5.1	EXX19	. . .
2	SFA-5.5	E(X)XX13-X	. . .
3	SFA-5.1	EXX10	. . .
3	SFA-5.1	EXX11	. . .
3	SFA-5.5	E(X)XX10-X	. . .
3	SFA-5.5	E(X)XX11-X	. . .
4	SFA-5.1	EXX15	. . .
4	SFA-5.1	EXX16	. . .
4	SFA-5.1	EXX18	. . .
4	SFA-5.1	EXX18M	. . .
4	SFA-5.1	EXX48	. . .
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	. . .
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	. . .
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	. . .
4	SFA-5.5	E(X)XX15-X	. . .
4	SFA-5.5	E(X)XX16-X	. . .
4	SFA-5.5	E(X)XX18-X	. . .
4	SFA-5.5	E(X)XX18M	. . .
4	SFA-5.5	E(X)XX18M1	. . .
4	SFA-5.5	E(X)XX45	. . .
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	. . .
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	. . .
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	. . .
6	SFA-5.2	All classifications	. . .
6	SFA-5.9	All classifications	. . .
6	SFA-5.17	All classifications	. . .
6	SFA-5.18	All classifications	. . .
6	SFA-5.20	All classifications	. . .
6	SFA-5.22	All classifications	. . .
6	SFA-5.23	All classifications	. . .
6	SFA-5.25	All classifications	. . .
6	SFA-5.26	All classifications	. . .
6	SFA-5.28	All classifications	. . .
6	SFA-5.29	All classifications	. . .
6	SFA-5.30	INMs-X	. . .
6	SFA-5.30	IN5XX	. . .
6	SFA-5.30	IN3XX(X)	. . .

Practice Problem Q14: QW-442 – A-No. [SOLUTION]

What is the A-No. when welding SA-240 grade 304L using SFA-5.4 classification E309L (austenitic stainless steel 18Cr-8Ni) filler metal?

QW-442
A-NUMBERS
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)]					
		C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	. . .	. . .	. .	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40-0.65	. . .	1.60	1.00
3	Chrome (0.4% to 2%)-Molybdenum	0.15	0.40-2.00	0.40-0.65	. . .	1.60	1.00
4	Chrome (2% to 6%)-Molybdenum	0.15	2.00-6.00	0.40-1.50	. . .	1.60	2.00
5	Chrome (6% to 10.5%)-Molybdenum	0.15	6.00-10.50	0.40-1.50	. . .	1.20	2.00
6	Chrome-Martensitic	0.15	11.00-15.00	0.70	. . .	2.00	1.00
7	Chrome-Ferritic	0.15	11.00-30.00	1.00	. . .	1.00	3.00
8	Chromium-Nickel	0.15	14.50-30.00	4.00	7.50-15.00	2.50	1.00
9	Chromium-Nickel	0.30	19.00-30.00	6.00	15.00-37.00	2.50	1.00
10	Nickel to 4%	0.15	. . .	0.55	0.80-4.00	1.70	1.00
11	Manganese-Molybdenum	0.17	. . .	0.25-0.75	0.85	1.25-2.25	1.00
12	Nickel-Chromium-Molybdenum	0.15	1.50	0.25-0.80	1.25-2.80	0.75-2.25	1.00

NOTE:
(1) Single values shown above are maximum.

Practice Problem Q15: QW-422 – A-No. [SOLUTION]

What would be the A-No. when welding an ASME SA-105 flange to SA-106 Grade B pipe, using an AWS A 5.1 E7018 electrode?

ASME SA-105 can be found in Table QW/QB-422.

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS
Grouping of Base Metals for Qualification

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-36	...	K02600	58 (400)	1	1	101	11.1	C-Mn-Si	Plate, bar & shapes
SA-53	Type F	...	48 (330)	1	1	101	11.1	C	Furnace welded pipe
SA-53	Type S, Gr. A	K02504	48 (330)	1	1	101	11.1	C	Smls. pipe
SA-53	Type E, Gr. A	K02504	48 (330)	1	1	101	11.1	C	Resistance welded pipe
SA-53	Type E, Gr. B	K03005	60 (415)	1	1	101	11.1	C-Mn	Resistance welded pipe
SA-53	Type S, Gr. B	K03005	60 (415)	1	1	101	11.1	C-Mn	Smls. pipe
SA-105	...	K03504	70 (485)	1	2	101	11.1	C	Flanges & fittings
SA-106	A	K02501	48 (330)	1	1	101	1.1	C-Si	Smls. pipe
SA-106	B	K03006	60 (415)	1	1	101	11.1	C-Mn-Si	Smls. pipe
SA-106	C	K03501	70 (485)	1	2	101	11.1	C-Mn-Si	Smls. pipe

The A-No. can be found in Table QW-442.

QW-442
A-NUMBERS
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	C	Cr	Mo	Ni	Mn	Si
		Analysis, % [Note (1)]					
1	Mild Steel	0.20	...	...	...	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40–0.65	...	1.60	1.00
3	Chrome (0.4% to 2%)–Molybdenum	0.15	0.40–2.00	0.40–0.65	...	1.60	1.00
4	Chrome (2% to 4%)–Molybdenum	0.15	2.00–4.00	0.40–1.50	...	1.60	2.00
5	Chrome (4% to 10.5%)–Molybdenum	0.15	4.00–10.50	0.40–1.50	...	1.20	2.00
6	Chrome-Martensitic	0.15	11.00–15.00	0.70	...	2.00	1.00
7	Chrome-Ferritic	0.15	11.00–30.00	1.00	...	1.00	3.00
8	Chromium–Nickel	0.15	14.50–30.00	4.00	7.50–15.00	2.50	1.00
9	Chromium–Nickel	0.30	19.00–30.00	6.00	15.00–37.00	2.50	1.00
10	Nickel to 4%	0.15	...	0.55	0.80–4.00	1.70	1.00
11	Manganese–Molybdenum	0.17	...	0.25–0.75	0.85	1.25–2.25	1.00
12	Nickel–Chrome—Molybdenum	0.15	1.50	0.25–0.80	1.25–2.80	0.75–2.25	1.00

NOTE:
(1) Single values shown above are maximum.

Practice Problem Q16: QW-422 – A-No. **[SOLUTION]**

What would be the A-No. when welding ASME SA-312 Type TP316 pipe using an AWS A 5.4 E316 electrode?

ASME SA-312 Type TP316 can be found in Table QW/QB-422.

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-302	A	K12021	75 (515)	3	2	101	1.1	Mn–0.5Mo	Plate
SA-302	B	K12022	80 (550)	3	3	101	1.2	Mn–0.5Mo	Plate
SA-302	C	K12039	80 (550)	3	3	101	. . .	Mn–0.5Mo–0.5Ni	Plate
SA-302	D	K12054	80 (550)	3	3	101	. . .	Mn–0.5Mo–0.75Ni	Plate
SA-312	TPXM-19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Smls. & welded pipe
SA-312	TPXM-11	S21904	90 (620)	8	3	102	8.3	21Cr–6Ni–9Mn	Smls. & welded pipe
SA-312	TPXM-29	S24000	100 (690)	8	3	102	8.3	18Cr–3Ni–12Mn	Smls. & welded pipe
SA-312	TP304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Smls. & welded pipe
SA-312	TP304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Smls. & welded pipe
SA-312	TP304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Smls. & welded pipe
SA-312	TP304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Smls. & welded pipe
SA-312	TP304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Smls. & welded pipe
SA-312	S30600	S30600	78 (540)	8	1	102	8.1	18Cr–15Ni–4Si	Smls. & welded pipe
SA-312	S30815	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Smls. & welded pipe
SA-312	S32615	S32615	80 (550)	8	1	102	8.1	18Cr–20Ni–5.5Si	Smls. & welded pipe
SA-312	TP309S	S30908	75 (515)	8	2	102	8.2	23Cr–12Ni	Smls. & welded pipe
SA-312	TP309H	S30909	75 (515)	8	2	102	8.2	23Cr–12Ni	Smls. & welded pipe
SA-312	TP309Cb	S30940	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Smls. & welded pipe
SA-312	TP309HCb	S30941	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Smls. & welded pipe
SA-312	TP310S	S31008	75 (515)	8	2	102	8.2	25Cr–20Ni	Smls. & welded pipe
SA-312	TP310H	S31009	75 (515)	8	2	102	8.2	25Cr–20Ni	Smls. & welded pipe
SA-312	TP310Cb	S31040	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Smls. & welded pipe
SA-312	TP310HCb	S31041	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Smls. & welded pipe
SA-312	TP310MoLN	S31050	78 (540)	8	2	102	8.2	25Cr–22Ni–2Mo–N	Smls. & welded pipe, $t > \frac{1}{4}$ in. (6 mm)
SA-312	TP310MoLN	S31050	84 (580)	8	2	102	8.2	25Cr–22Ni–2Mo–N	Smls. & welded pipe, $t \le \frac{1}{4}$ in. (6 mm)
SA-312	S31254	S31254	95 (655)	8	4	102	8.2	20Cr–18Ni–6Mo	Smls. & welded pipe, $t > \frac{3}{16}$ in. (5 mm)
SA-312	S31254	S31254	98 (675)	8	4	102	8.2	20Cr–18Ni–6Mo	Smls. & welded pipe, $t \le \frac{3}{16}$ in. (5 mm)
SA-312	TP316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. & welded pipe
SA-312	TP316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. & welded pipe
SA-312	TP316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. & welded pipe

The A-No. can be found in Table QW-442.

QW-442
A-NUMBERS
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)] C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	. . .	. . .	. . .	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40–0.65	. . .	1.60	1.00
3	Chrome (0.4% to 2%)–Molybdenum	0.15	0.40–2.00	0.40–0.65	. . .	1.60	1.00
4	Chrome (2% to 4%)–Molybdenum	0.15	2.00–4.00	0.40–1.50	. . .	1.60	2.00
5	Chrome (4% to 10.5%)–Molybdenum	0.15	4.00–10.50	0.40–1.50	. . .	1.20	2.00
6	Chrome-Martensitic	0.15	11.00–15.00	0.70	. . .	2.00	1.00
7	Chrome-Ferritic	0.15	11.00–30.00	1.00	. . .	1.00	3.00
8	Chromium–Nickel	0.15	14.50–30.00	4.00	7.50–15.00	2.50	1.00
9	Chromium–Nickel	0.30	19.00–30.00	6.00	15.00–37.00	2.50	1.00
10	Nickel to 4%	0.15	. . .	0.55	0.80–4.00	1.70	1.00
11	Manganese–Molybdenum	0.17	. . .	0.25–0.75	0.85	1.25–2.25	1.00
12	Nickel–Chrome—Molybdenum	0.15	1.50	0.25–0.80	1.25–2.80	0.75–2.25	1.00

NOTE:
(1) Single values shown above are maximum.

WPS/PQR Review # CS-2
Practice Problems

QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATION (WPS)
(See QW-200.1, Section IX, ASME Boiler & Pressure Vessel Code)

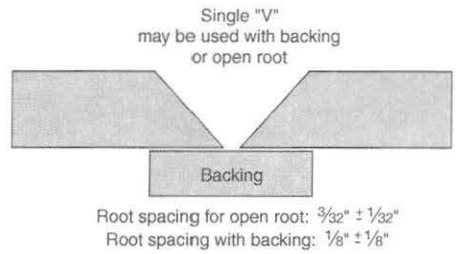
Company Name: Company Inc. **By:** Pea Green
Welding Procedure Spec. No.: *CS-2* **Date:** 09-10-13 **Supporting PQR No. (s):** CS-2, Rev. 0
WPS Revision No.: Rev. 0 **Rev. Date:** 09-10-13
Welding Process(s): SMAW **Type(s):** Manual
(Automatic, Manual, Machine, or Semi-Auto)

JOINTS (QW-402)

Joint Design: ______
Backing: (Yes) X **(No)** X
Backing Material: (Type): SA-516 – Gr. 70
(Refer to both backing & retainers)

X **Metal** ___ **Nonfusing Metal**
___ **Nonmetallic** ___ **Other**
No nonmetallic retainers permitted.

Joint Design



*BASE METALS (QW-403)

P-No. 1 **Group No.** 1, 2 and 3 **to P-No.** 1 **Group No.** 1, 2 and 3
OR
Specification type and grade ______
to Specification type and grade ______
OR
Chem. Analysis and Mech. Prop. ______
to Chem. Analysis and Mech. Prop. ______

Thickness range:

Base Metal:	**Groove:**	0.188 in. to 1.5 in.	**Fillet:**	All
Pipe Dia. Range:	**Groove:**	All	**Fillet:**	All

* FILLER METALS (QW-404)

Spec. No. (SFA):	5.1		
AWS No. (Class):	E7018		
Filler Metal F-No.:	F-No. 4		
Chem. Comp. - A No.:	A-No. 1		
Size of Filler Metals:	3/32 in., 1/8 in., 5/32 in.		

Weld Metal
Thickness range: **Note: single pass thickness 0.500 in. maximum.**

Groove:	1.5 in. maximum		
Fillet:	all sizes		
Electrode-Flux (Class):			
Flux Trade Name:			
Consumable Insert:			
Other:			

* Each base metal-filler metal combination should be recorded individually.

QW-482 (Back)

WPS No.: CS-2 Rev. No.: 0

POSITIONS (QW-405)

Position(s) of Groove: ALL
Welding Progression: Up X Down X
Positions(s) of Fillet: ALL

POSTWELD HEAT TREATMENT (QW-407)

Temperature Range: No PWHT
Time Range: No PWHT

PREHEAT (QW-406)

Preheat Temp. Min.: 175°F
Interpass Temp. Max.:
Preheat Maint.: None

(Continuous or special heating where applicable should be recorded.)

GAS ((QW-408)

Percent Composition:

	Gas(es)	(Mixture)	Flow Rate
Shielding:			
Trailing:			
Backing:			

ELECTRICAL CHARACTERISTICS (QW-409)

Current AC or DC: DC Polarity: Reverse
Amps Range: 75 to 200 Volts (Range): 18 to 30

(Amps and volts range should be recorded for each electrode size, position, and thickness, etc. This information may be listed in a tabular form similar to that shown below.)

Tungsten Electrode Size and Type
(Pure Tungsten, 2% Thoriated, etc.)

Mode of metal Transfer for GMAW
(Spray arc, short circuiting arc, etc.)

Electrode Wire feed speed range

TECHNIQUE (QW-410)

String or Weave Bead: String or Weave; with weave not greater than 3 times electrode diameter
Orifice or Gas Cup Size:
Initial and Interpass Cleaning (Brushing, Grinding, etc.): Brush, grind, file as required
Note: weld preparation must be cleaned at least 1 in. back from weld surfaces
Method of Back Gouging: grinding or arc gouging allowed
Oscillation:
Contact Tube to Work Distance:
Multiple or Single Pass (per side): Multiple
Multiple or Single Electrodes: Single
Travel Speed (Range):
Peening: Strictly no peening allowed
Other:

Weld Layer(s)	Process	Class	Filler Metal Dia.	Filler Metal Type Polar.	Current Amp Range	Current Volt Range	Travel Speed Range	Other (e.g., Remarks, Comments, Hot Wire, Technique, Torch Angle, etc.)
ALL	SMAW	E-7018	3/32 in.	DC - RP	75 to 115	18 - 21		
ALL	SMAW	E-7018	1/8 in.	DC - RP	100 to 150	20 - 25		
ALL	SMAW	E-7018	5/32 in.	DC - RP	150 to 200	20 - 28		

QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORDS (PQR)
(See QW-200.2, Section IX, ASME Boiler and Pressure vessel Code)
Record Actual Conditions Used to Weld Test Coupon

Company Name: Company Inc.
Procedure Qualification Record No.: CS-2, Rev. 0 **Date:** 09-10-13
WPS No.: CS-2 Rev. 0
Welding Process(s): SMAW
Types (Manual, Automatic, Semi-Auto.): MANUAL

JOINTS (QW-402)

Groove Design of Test Coupon
(For combination qualifications, the deposited weld metal thickness shall be recorded for each filler metal or process used.)

BASE METALS (QW-403)
Material Spec.: SA-516
Type or Grade: Grade 70
P-No.: 1 **to P-No.:** 1
Thickness of Test Coupon: 0.750 in.
Diameter of Test Coupon: Plate
Other:

FILLER METALS (QW-404)
SFA Specification: 5.1
AWS Classification: E6010
Filler Metal F No.: 4
Weld metal Analysis No.: 1
Size of Filler metal: 1/8 in. and 5/32 in. diameter
Other:

Weld Metal Thickness: 0.750 in.
Note: No single pass > 3/8 in.

POSITION (QW-405)
Position of Groove: 1G
Weld Progression (Uphill, Downhill): N/A
Other:

PREHEAT (QW-406)
Preheat Temp.: 200°F minimum
Interpass temp.:
Other:

POSTWELD HEAT TREATMENT (QW-407)
Temperature: None performed
Time:
Other:

GAS (QW-408)

	Percent Composition Gas(es)	(Mixture)	Flow Rate
Shielding:			
Trailing:			
Backing:			

ELECTRICAL CHARACTERISTICS (QW-409)
Current: not recorded
Polarity: not recorded
Amps.: not recorded **Volts:** not recorded
Tungsten Electrode Size:
Other:

TECHNIQUE (QW-410)
Travel Speed: not recorded
String or Weave Bead: string root pass (see Other)
Oscillation:
Multipass or Single Pass (per side):
Single or Multiple Electrodes:
Other: weave limited to 3 times electrode diameter
no peening done.

QW-483 (Back)

PQR No.: CS-2 Rev. 0

Tensile Test (QW-150)

Specimen No.	Width	Thickness	Area	Ultimate Total Load Lb.	Ultimate Unit Stress psi	Type of Failure & Location
1	0.755	0.749	0.565	40,555	71,779	Weld Metal
2	0.752	0.748	0.562	37,173	66,575	*Base Metal

*Specimen 2 fractured in the base metal outside the weld and weld interface.

Guided Bend Tests (QW-160)

Type and Figure No.	Result
Side Bend per QW-462.2	5/32 in. open discontinuity on one corner of specimen, no sign of internal discontinuity
Side Bend per QW-462.2	No discontinuity
Side Bend per QW-462.2	3/32 in. discontinuity in the heat affected zone
Side Bend per QW-462.2	No discontinuity

Toughness Tests (QW-170)

Specimen No.	Notch Location	Specimen Size	Test Temp.	Impact Values			Drop Weight Break (Y/N)
				Ft. Lbs.	% Shear	Mils	

Comments: no impact testing performed

Fillet Weld Test (QW-180)

Result --- Satisfactory: Yes: ______ **No:** ______ **Penetration Into Parent Metal: Yes:** ______ **No:** ______

Macro --- Results: ______

Other Tests

Type of Test: ______

Deposit Analysis: ______

Other: ______

Welder's Name: Pierrine Nau **Clock No.:** 00ZE **Stamp No.:** PN

Tests conducted by: Pea Green **Laboratory Test No.:** 091013

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Code.

Organization: Company Inc.

Date: 09-10-13 **By:** Bill Smith

Practice Problem 1: WPS # CS-2 – Joint Design QW-402

Are the joint design variables (QW-402) properly addressed on the WPS and PQR to meet ASME Sec. IX?

a) No, must also list the welding pass sequence for each electrode size.
b) No, angle of V-groove is not specified.
c) No, backing size is not specified.
d) Yes.

Practice Problem 2: WPS # CS-2 – Base Metal P-No. QW-403, QW-420, and QW/QB-422

Does the PQR support the WPS with the base metal P-No. qualified?

a) No, the Group Number is not listed in the PQR.
b) No, the Group Number 4 is not listed in the WPS.
c) No, SA-516 grade 70 is not a P-No. 1 material.
d) Yes.

Practice Problem 3: WPS # CS-2 – Weld Metal F-No. QW-404, QW-430, QW-432

Does the PQR support the WPS with the weld metal F-No. qualified?

a) No, the SFA number is incorrect on the PQR.
b) No, the electrode AWS classification is incorrect on the PQR.
c) No, the A-No is incorrect.
d) No, since SFA 5.1 classification E6010 is not a F-No. 4.

Practice Problem 4: WPS # CS-2 – Weld Metal A-No. QW-442

Does the PQR support the WPS with the A-No. qualified?

a) No, the WPS specifies an A-No. of 4
b) No, the WPS specifies an A-No. of 1
c) No, an A-No. is not given in the PQR
d) Yes, the A-No. is correct.

Practice Problem 5: WPS # CS-2 – Base Metal Thickness (T) QW-403 and QW-451.1

Does the PQR support the WPS with the base metal thickness range qualified?

a) No, it should be 1/16 in. to 1.5 in.
b) No, it should be 3/16 in. to 0.750 in.
c) No, it should be 0.750 in maximum only.
d) Yes.

Practice Problem 6: WPS # CS-2 – Individual Weld Metal Pass QW-403.9

Does the PQR support the WPS with the individual weld pass thickness requirement?

a) No, the minimum value of 3/16 in. is not supported.
b) No, the maximum thickness of 1.5 in. is not supported.
c) No, the thickness range is not supported.
d) Yes.

Practice Problem 7: WPS # CS-2 – Weld Metal Thickness (t) QW-404 and QW-451.1

Does the PQR support the WPS with the weld metal thickness range qualified?

a) No, the WPS minimum value was exceed.
b) No, the PQR value was too low.
c) No, both the WPS and PQR values must be identical.
d) Yes.

Practice Problem 8: WPS # CS-2 – Fillet Weld Size QW-403 and QW-451.4

Does the PQR support the WPS for fillet weld sizes qualified?

a) No, since a fillet weld coupon was not used in the PQR.
b) No, fillet weld size should be limited to 1/16 in. to 1.5 in.
c) No, fillet weld size should be limited to 3/16 in. to 1.5 in.
d) Yes.

Practice Problem 9: WPS # CS-2 – Welding Position QW-405 and QW-461.3

Does the PQR support the WPS with the welding position qualified?

a) No, since the 1G position in the PQR does not support all positions listed in the WPS.
b) No, since only the 6G position can qualify all positions.
c) No, since only the 2G, 3G, and 4G positions together can qualify all positions.
d) Yes, since position is not an essential variable for WPS qualification.

Practice Problem 10: WPS # CS-2 – Welding Preheat QW-406

Does the PQR support the WPS with the preheat qualified?

a) No, since the PQR preheat was higher than allowed in the WPS.
b) No, since the WPS and PQR preheats need to be identical.
c) No, since the interpass temperature was not recorded on the PQR.
d) Yes, since the PQR preheat temperature was above the minimum required in the WPS.

Practice Problem 11: WPS # CS-2 – PWHT QW-407.1

Does the PQR support the WPS with the PWHT?

a) No, PWHT is required.
b) No, PWHT is required for thickness above 0.750 in.
c) No, PWHT is required for thickness above 1.0 in.
d) Yes.

Practice Problem 12: WPS # CS-2 – Electrical Characteristics QW-409

Does the PQR support the WPS with the electrical characteristics variables qualified?

a) No, since amperage was not recorded.
b) No, since voltage was not recorded.
c) No, since both amperage and voltage were not recorded.
d) Yes, since electrical characteristics are nonessential variables for SMAW.

Practice Problem 13: WPS # CS-2 – Technique QW-410

Does the PQR support the WPS with the technique variables qualified?

a) No, since the travel speed was not recorded.
b) No, since oscillation was not recorded.
c) No, since the PQR weave technique did not meet the WPS requirements.
d) Yes, since technique variables are nonessential variables for SMAW, although the weave requirement was met.

Practice Problem 14: WPS # CS-2 – Tensile Test QW-153.1(d) and QW-451.1

Does the PQR support the WPS with the tensile test results?

a) No, specimen number 1 failed in the weld metal.
b) No, specimen number 2 was below the minimum specified tensile strength (70,000 psi).
c) Yes, the tensile tests are acceptable.
d) No, specimen number 2 was below the 5% tolerance of the minimum specified tensile strength (66,500 psi).

Practice Problem 15: WPS # CS-2 – Guided Bend Tests QW-163 and QW-451.1

Does the PQR support the WPS with the guided bend test results?

a) No, 2 face and two root bend should have been tested.
b) No, since the 3/32 in. defect in the heat affected zone is unacceptable.
c) No, since the 5/32 in. defect on the corner is unacceptable.
d) Yes.

CUSTOMER PURCHASE ORDER NUMBER	ENTRY DATE	SHIP DATE	SHIPPERS NUMBER	CARRIER	PAGE NO	MILL ORDER
9965	DEC 11/87	88-02-29	02 5010		3 of 7	64213

CHARGE TO CUSTOMER NAME AND ADDRESS

SHIP TO CUSTOMER NAME AND ADDRESS

TEST REPORTS

WE HEREBY CERTIFY THAT THE MATERIAL HEREIN DESCRIBED WAS MADE AND TESTED IN ACCORDANCE WITH THE RULES OF THE SPECIFICATION SHOWN HEREIN AND AS CONTAINED IN THE CORPORATION RECORDS

MAR - 1 1988

CUSTOMER SPECIFICATION

HR PLATE - CARBON - ASME SA 516 70 (86 A86) - PVQ - SHEARED

SUPPLEMENTARY INSTRUCTIONS

RESALE

MILL SN/TR

RESALE

NN-NN-NN

SENIOR METALLURGIST

PLATE MILL

HEAT AND INGOT NUMBER	IDENTIFICATION OF PIECE TESTED	WEIGHT	NUMBER OF PIECES	THICKNESS OF TEST	CONDITION OF TEST	TENSILE PROPERTIES YIELD PSI	TENSILE PSI	% ELONGATION 2"	4"	8"	BEND	MC QUAID	TYPE DIRECT	IMPACT PROPERTIES 1 FTLB	2 FTLB	3 FTLB	TEMP °F
CUST ITEM 2 OUR ITEM 002 .375 X 120 X 384 "																	
4440M-03	15428	9801	2	.375		47840	74160		22								
4690M-03	19325	9801	2	.375		50670	74070		25								
4690M-54	19324	9801	2	.375		49700	73650		23								
CUST ITEM 3 OUR ITEM 003 .500 X 120 X 384 "																	
4345M-03	14277	13068	2	.500		51900	78740		23								
4345M-51	14278	13068	2	.500		51130	75420		20								

4345M-03 C .25.MN 1.10.S .016.P .020.SI .21.CR .10.NI .01.CU .01.MO .01.AL .060.CB <.01.V <.01
4345M-51 C .25.MN 1.10.S .016.P .020.SI .21.CR .10.NI .01.CU .01.MO .01.AL .060.CB <.01.V <.01

CONTINUED ON NEXT PAGE

SPECIFICATION FOR CARBON STEEL ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.1/SFA-5.1M

(Identical with AWS Specification A5.1/A5.1M:2004. In case of dispute, the original AWS text applies.)

1. Scope

1.1 This specification prescribes requirements for the classification of carbon steel electrodes for shielded metal arc welding.

1.2 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in the Nonmandatory Annex Sections A5 and A10. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*,[1] and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to material properties. The specification with the designation A5.1 uses U.S. Customary Units. The specification A5.1M uses SI Units. The latter are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for sizing of filler metal or packaging or both under A5.1 or A5.1M specifications.

PART A — GENERAL REQUIREMENTS

2. Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreement based on this AWS standard are encouraged to investigate the possibility of applying the most recent editions of the documents shown below. For undated references, the latest edition of the standard reference applies.

The following documents are referenced in the mandatory sections of this document:

(a) ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*[2]

(b) ASTM E 142, *Standard Method for Controlling Quality of Radiographic Testing*

(c) ASTM E 350, *Standard Method for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron*

(d) AWS A1.1, *Metric Practice Guide for the Welding Industry*[3]

(e) AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

(f) AWS A4.4, *Standard Procedure for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*

(g) AWS A5.01, *Filler Metal Procurement Guidelines*

(h) AWS B4.0 or B4.0M, *Standard Methods for Mechanical Testing of Welds*

(i) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

(j) ISO 544, *Welding consumables–Technical delivery conditions for welding filler materials–Type of product, dimensions, tolerances and markings*[4]

[1] This ANSI standard can be obtained from Global Engineering Documents, an Information Handling Services (IHS) Group Company, 15 Inverness Way East, Englewood, CO 80112-5776.

[2] ASTM standards can be obtained from American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[3] AWS standards can be obtained from Global Engineering Documents, an Information Handling Services (IHS) Group Company, 15 Inverness Way East, Englewood, CO 80112-5776.

[4] ISO standards can be obtained from American National Standards Institute, 11 West 42nd Street, New York, NY 10036-8002.

TABLE 1
ELECTRODE CLASSIFICATION

AWS Classification				
A5.1	A5.1M	Type of Covering	Welding Position[1]	Type of Current[2]
E6010	E4310	High cellulose sodium	F, V, OH, H	dcep
E6011	E4311	High cellulose potassium	F, V, OH, H	ac or dcep
E6012	E4312	High titania sodium	F, V, OH, H	ac or dcen
E6013	E4313	High titania potassium	F, V, OH, H	ac, dcep or dcen
E6018[3]	E4318[3]	Low-hydrogen potassium, iron powder	F, V, OH, H	ac or dcep
E6019	E4319	Iron oxide titania potassium	F, V, OH, H	ac decp or dcen
E6020	E4320	High iron oxide	H-fillet F	ac or dcen ac, dcep or dcen
E6022[4]	E4322[4]	High iron oxide	F, H-fillet	ac or dcen
E6027	E4327	High iron oxide, iron powder	H-fillet F	ac or dcen ac, dcep or dcen
E7014	E4914	Iron powder, titania	F, V, OH, H	ac, dcep or dcen
E7015	E4915	Low-hydrogen sodium	F, V, OH, H	dcep
E7016[3]	E4916[3]	Low hydrogen potassium	F, V, OH, H	ac or dcep
E7018[3]	E4918[3]	Low-hydrogen potassium, iron powder	F, V, OH, H	ac or dcep
E7018M	E4918M	Low-hydrogen iron powder	F, V, OH, H	dcep
E7024[3]	E4924[3]	Iron powder, titania	H-fillet, F	ac, dcep or dcen
E7027	E4927	High iron oxide, iron powder	H-fillet F	ac or dcen ac, dcep or dcen
E7028[3]	E4928[3]	Low-hydrogen potassium, iron powder	H-fillet, F	ac or dcep
E7048	E4948	Low-hydrogen potassium, iron powder	F, OH, H, V-down	ac or dcep

NOTES:

(1) The abbreviations, F, H, H-fillet, V, V-down, and OH indicate the welding positions as follows: F = Flat, H = Horizontal, H-fillet = Horizontal fillet, V = Vertical, progression upwards (for electrodes $^3/_{16}$ in. [5.0 mm] and under, except $^5/_{32}$ in. [4.0 mm] and under for classifications E6018 [E4318], E7014 [E4914], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7048 [E4948]). V-down = Vertical, progression downwards (for electrodes $^3/_{16}$ in. [5.0 mm] and under, except $^5/_{32}$ in. [4.0 mm] and under for classifications E6018 [E4318], E7014 [E4914], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7048 [E4948]), OH = Overhead (for electrodes $^3/_{16}$ in. [5.0 mm] and under, except $^5/_{32}$ in. [4.0 mm] and under for classifications E6018 [E4318], E7014 [E4914], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7048 [E4948]).

(2) The term "dcep" refers to direct current electrode positive (dc, reverse polarity). The term "dcen" refers to direct current electrode negative (dc, straight polarity).

(3) Electrodes with supplemental elongation, notch toughness, absorbed moisture, and diffusible hydrogen requirements may be further identified as shown in Tables 2, 3, 10, and 11.

(4) Electrodes of the E6022 [E4322] classification are intended for single-pass welds only.

TABLE 3
CHARPY V-NOTCH IMPACT REQUIREMENTS

AWS Classification		Limits for 3 out of 5 Specimens[1]	
A5.1	A5.1M	Average, Min.	Single Value, Min.
E6010, E6011, E6018, E6027, E7015, E7016[2], E7018[2], E7027, E7048	E4310, E4311, E4318 E4327, E4915, E4916[2], E4918[2], E4927, E4948	20 ft-lbf at −20°F [27 J at −30°C]	15 ft-lbf at −20°F [20 J at −30°C]
E6019 E7028	E4319 E4928	20 ft-lbf at 0°F [27 J at −20°C]	15 ft-lbf at 0°F [20 J at −20°C]
E6012, E6013, E6020, E6022, E7014, E7024[2]	E4312, E4313 E4320, E4322 E4914, E4924[2]	Not specified	Not specified
AWS Classification		**Limits for 5 out of 5 Specimens[3]**	
A5.1	A5.1M	Average, Min.	Single Value, Min.
E7018M	E4918M	50 ft-lbf at −20°F [67 J at −30°C]	40 ft-lbf at −20°F [54 J at −30°C]

NOTES:
(1) Both the highest and lowest test values obtained shall be disregarded in computing the average. Two of these remaining three values shall equal or exceed 20 ft-lbf [27 J].
(2) Electrodes with the following optional supplemental designations shall meet the lower temperature impact requirements specified below.

AWS Classification		Electrode Designation		Charpy V-Notch Impact Requirements, Limits for 3 out of 5 specimens [Refer to Note (1) above]	
A5.1	A5.1M	A5.1	A5.1M	Average, Min.	Single Value, Min.
E7016 E7018	E4916 E4918	E7016-1 E7018-1	E4916-1 E4918-1	20 ft-lbf at −50°F [27 J at −45°C]	15 ft-lbf at −50°F [20 J at −45°C]
E7024	E4924	E7024-1	E4924-1	20 ft-lbf at 0°F [27 J at −20°C]	15 ft-lbf at 0°F [20 J at −20°C]

(3) All five values obtained shall be used in computing the average. Four of the five values shall equal, or exceed, 50 ft-lbf [67 J].

rounded to the nearest 1000 psi for tensile and yield strength for A5.1, or to the nearest 10 MPa for tensile and yield strength for A5.1M and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities in accordance with the rounding-off method given in ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

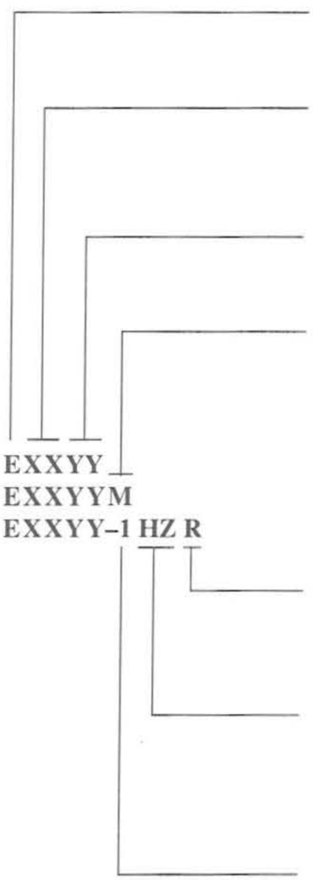
7. Summary of Tests

The tests required for each classification are specified in Table 4. The purpose of these tests is to determine the chemical composition, mechanical properties, and soundness of the weld metal, moisture content of the low-hydrogen electrode covering, and the usability of the electrode. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Sections 9 through 18. The supplemental tests for absorbed moisture, in Section 17, and diffusible hydrogen, in Section 18, are not required for classification of the low-hydrogen electrodes except for E7018M [E4918M], where these are required [see Notes (9) and (13) of Table 4].

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for retest may be taken from the original test assembly or from a new test assembly. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retests fail to meet the

FIG. 10 ORDER OF MANDATORY AND OPTIONAL SUPPLEMENTAL DESIGNATORS



Mandatory Classification Designators [Note (1)]

Designates an electrode. This designator may be deleted from the product imprint required for identification of the electrode.

Designates the tensile strength (minimum), in ksi, or MPa ÷ 10 of the weld metal when produced in accordance with the test assembly preparation of this specification (see Table 2).

Designates the welding position in which electrodes are usable, the type of covering, and the kind of welding current for which the electrodes are suitable (see Table 1).

Designates an electrode (E7018M) [E4918M] intended to meet most military requirements (greater toughness, lower moisture content — both as-received and after exposure — and mandatory diffusible hydrogen limits for weld metal). (See Tables 3, 10, and 11.)

Optional Classification Designators

Designates that the electrode meets the requirements of the absorbed moisture test [an optional supplemental test for all low hydrogen electrodes except the E7018M (E4918M) classification, for which the test is required]. (See Table 10.)

Designates that the electrode meets the requirements of the diffusible hydrogen test (an optional supplemental test of the weld metal from low hydrogen electrodes — as-received or conditioned — with an average value not exceeding "Z" mL of H_2 per 100 g of deposited metal, where "Z" is 4, 8, or 16). (See Table 11.)

Designates that the electrode (E7016, E7018, or E7024) [E4916, E4918, or E4924] meets the requirements for improved toughness — and ductility in the case of E7024 [E4924] (optional supplemental test requirements shown in Tables 2 and 3). (See Notes to Tables 2 and 3.)

NOTE:
(1) The combination of these designators constitutes the electrode classification.

SUBPART 1
STRESS TABLES

(13) STATEMENT OF POLICY ON INFORMATION PROVIDED IN THE STRESS TABLES

The purpose of this Statement of Policy is to clarify which information in the stress tables is mandatory and which is not. The information and restrictions provided in the Notes found throughout the various stress tables provided in Subpart 1 of Section II, Part D are mandatory. It is vital to recognize that lines of information in Tables 1A, 1B, 2A, 2B, 3, 4, 5A, and 5B frequently have essential information referenced in the Notes column. These Notes are organized as follows:

(a) EXX: defining onset of values based on successful experience in service

(b) GXX: general requirements

(c) HXX: heat treatment requirements

(d) SXX: size requirements

(e) TXX: defining onset of time-dependent behavior

(f) WXX: welding requirements

The specifications and grades or types, coupled with the assigned Notes for each line, provide the complete description of material in the context of the allowable stresses or design stress intensities. Additional requirements for particular types of construction must also be obtained from the rules governing the construction.

In Tables 1A, 2A, and 5A, the information in the Nominal Composition column is nonmandatory and is for information only. However, these nominal compositions are the primary sorting used in these three tables. See the Guideline on Locating Materials in Stress Tables, and in Tables of Mechanical and Physical Properties. The information in the Alloy Designation/UNS Number column is nonmandatory for specifications for which a grade or type is provided. This is primarily true for the non-stainless steel alloys in these tables. For specifications for which no type or grade is listed, the UNS number is mandatory. Particularly for the stainless steels, for which no type or grade is listed, the UNS number is the grade.

The only difference between Tables 1A, 2A, and 5A, and Tables 1B, 2B, and 5B, with regard to the mandatory/nonmandatory nature of the information, is that in Tables 1B, 2B, and 5B, the UNS number information is used as the basis of the sorting scheme for materials and is almost always mandatory.

Where provided, the information in the columns for Product Form, Specification Number, Type/Grade, Class/Condition/Temper, Size/Thickness, and External Pressure Chart Number is mandatory. The information in the P-Number and Group Number columns is also mandatory; however, the primary source for this information is Table QW/QB-422 in Section IX. When there is a conflict between the P-number and Group number information in these stress tables and that in Section IX, the numbers in Section IX shall govern.

The information in the Minimum Tensile Strength and Minimum Yield Strength columns is nonmandatory. These values are a primary basis for establishing the allowable stresses and design stress intensities. When there is a conflict between the tensile and yield strength values in the stress tables and those in the material specifications in Section II, Parts A and B, the values in Parts A and B shall govern.

The information in the Applicability and Maximum Temperature Limits columns is mandatory. Where a material is permitted for use in more than one Construction Code, and in the SI units version of these tables, the maximum use temperature limit in these columns is critical. The temperature to which allowable stress or design stress intensity values are listed is not necessarily the temperature to which use is permitted by a particular Construction Code. Different Construction Codes often have different use temperature limits for the same material and condition. Further, in the SI units version of the stress tables, values may be listed in the table at temperatures above the maximum use temperature limit. These stress values are provided to permit interpolation to be used to determine the allowable stress or design stress intensity at temperatures between the next lowest temperature for which stress values are listed and the maximum-use temperature limit listed in these columns.

GUIDELINE ON LOCATING MATERIALS IN STRESS TABLES, AND IN TABLES OF MECHANICAL AND PHYSICAL PROPERTIES

1 INTRODUCTION

The goal of this Guideline is to assist the users of Section II, Part D in locating materials in stress tables (Tables 1A, 1B, 2A, 2B, 3, 4, 5A, and 5B), tables of mechanical properties (Tables U, U-2, and Y-1), and tables of physical properties (Tables TE-1 through TE-5, TCD, TM-1 through TM-5, and PRD). This Guideline defines the logic used to place materials within these tables.

2 STRESS TABLES

Stress tables are all found within Subpart 1 of Section II, Part D. Tables 1A, 1B, 3, 5A, and 5B cover allowable stresses, while Tables 2A, 2B, and 4 cover design stress intensities. Although Subpart 1 also covers ultimate tensile strength and yield strength, the organization of those mechanical property tables will be discussed separately in para. 3. A table-by-table listing of the materials-organization logic used to place materials within the designated tables follows.

2.1 TABLE 1A

Table 1A provides allowable stresses for ferrous[1] materials used in Section I; Section III, Division 1, Classes 2 and 3; Section VIII, Division 1; and Section XII construction. Within Table 1A, the first step in ordering materials is to use their nominal compositions. These nominal compositions are nothing more than accepted compositional fingerprints or widely recognized designators for each alloy or alloy class. These nominal compositions are arranged in Table 1A as follows:

(a) carbon steels

(b) carbon steels with small additions of Cb, Ti, and V (microalloyed steels)

(c) C–$^1/_2$Mo steels

(d) chromium steels, including ferritic stainless steels, by increasing Cr content [$^1/_2$Cr, $^3/_4$Cr, 1Cr, 1$^1/_4$Cr, 2$^1/_4$Cr, 3Cr, 5Cr, 9Cr, 11Cr, 12Cr, 13Cr, 15Cr, 17Cr (including 17Cr–4Ni–4Cu and 17Cr–4Ni–6Mn), 18Cr, 26Cr, 27Cr, and 29Cr]

(e) manganese steels (Mn–$^1/_4$Mo, Mn–$^1/_2$Mo, Mn–$^1/_2$Ni, and Mn–V)

(f) silicon steel (1$^1/_2$Si–$^1/_2$Mo)

(g) nickel steels ($^1/_2$Ni, $^3/_4$Ni, 1Ni, 1$^1/_4$Ni, 2Ni, 2$^1/_2$Ni, 2$^3/_4$Ni, 3Ni, 3$^1/_2$Ni, 4Ni, 5Ni, 8Ni, and 9Ni)

(h) other high nickel steels [25Ni–15Cr–2Ti (Grade 660) and 29Ni–20Cr–3Cu–2Mo (CN7M)]

(i) high alloy steels, including the duplex stainless steels, in order of increasing chromium content [beginning with 16Cr–9Mn–2Ni–N, then 16Cr–12Ni–2Mo (316L), etc.], then by increasing nickel content within a given chromium or other alloy content [18Cr–8Ni, 18Cr–8Ni–N, 18Cr–8Ni–4Si–N, 18Cr–10Ni–Cb (first S34700, then S34709, S34800, and S34809), 18Cr–10Ni–Ti, 18Cr–11Ni, etc., ending with 25Cr–22Ni–2Mo–N].

Unfortunately, most specifications for materials do not give nominal compositions — and without that information, one may not know the nominal composition for a particular material in Table 1A. If the specification number and alloy grade or type designation are known, then one can go to Table QW/QB-422 of Section IX of the Code and find the corresponding nominal composition.

Now, for a given nominal composition, Table 1A is arranged by increasing tensile strength. For a given nominal composition and tensile strength, stress listings are provided in order of increasing specification number. Sometimes, for a given nominal composition, tensile strength, yield strength, and specification number/grade or type, there may be more than one line of stresses. At this point, the Notes referenced on the second page of each page set within Table 1A will define why there are two or more lines of stresses and when each applies.

2.2 TABLE 1B

Table 1B provides allowable stresses for nonferrous materials used in Section I; Section III, Division 1, Classes 2 and 3; Section VIII, Division 1; and Section XII construction. Aluminum alloys (UNS AXXXXX materials) are the first materials covered in Table 1B, followed by copper alloys (UNS CXXXXX), nickel alloys (UNS NXXXXX), and the reactive and refractory metals and alloys (UNS RXXXXX). Within this latter category there are the following:

(a) chromium alloys (R2XXXX)

(b) cobalt alloys (R3XXXX)

(c) titanium alloys (R5XXXX)

(d) zirconium alloys (R6XXXX)

Within each of these material class groupings, stress lines are first organized by increasing UNS (Unified Numbering System) number. The nonferrous specifications now show these numbers in association with grade designations. Then, for a given UNS number, stress lines are next ordered by strength — first tensile strength and then yield strength. Finally, for a given UNS number, tensile strength, and yield strength, stress lines are ordered by increasing specification number. Again, some materials may have two or more stress lines even if their UNS number, tensile strength, yield strength, and specification number are the same. The Notes provide direction for the applicability of each line.

For those material specifications that may not show UNS numbers associated with alloy grades, one again can refer to Section IX's Table QW/QB-422 for that information.

For Table 1B, nominal compositions are shown only for the NXXXXX and RXXXXX materials, but they have no influence on the location of alloys in the table. In this table, the nominal compositions are simply for information.

2.3 TABLE 2A

Table 2A provides design stress intensities for ferrous materials for Section III, Division 1, Classes 1, TC, and SC construction. This table is organized in the same manner as Table 1A. Refer back to para. 2.1 for that description.

2.4 TABLE 2B

Table 2B provides design stress intensities for nonferrous materials for Section III, Division 1, Classes 1, TC, and SC construction. Table 2B materials are ordered in the same manner as in Table 1B. Refer back to para. 2.2 for that description.

2.5 TABLE 3

Table 3 provides allowable stresses for bolting materials for use in Section III, Division 1, Classes 2 and 3; Section VIII, Division 1; Section VIII, Division 2 (using Part 4.16 of Section VIII, Division 2); and Section XII construction. The table first covers ferrous materials and then nonferrous materials. For the ferrous materials, the ordering logic parallels that used in Tables 1A and 2A — first by nominal composition, then by increasing ultimate tensile strength, then by increasing yield strength, and finally by increasing specification number. Again, refer back to para. 2.1 for a discussion on nominal composition.

Nonferrous materials are presented using the same logic as in Tables 1B and 2B; see para. 2.2 for that discussion.

2.6 TABLE 4

Table 4 provides design stress intensities for bolting materials used in Section III, Division 1, Classes 1, TC, and SC; and in Section VIII, Division 2 (using Part 5 and Annex 5.F of Section VIII, Division 2).

Table 4 is organized in the same manner as Table 3 — first covering ferrous materials and then nonferrous materials — except that Table 4 covers far fewer materials. For the ordering logic, again refer to paras. 2.1 and 2.2 for ferrous and nonferrous materials, respectively.

2.7 TABLE 5A

Table 5A provides allowable stresses for ferrous materials for Section VIII, Division 2 construction. This Table is organized in the same manner as Table 1A. Refer back to para. 2.1 for that description.

2.8 TABLE 5B

Table 5B provides allowable stresses for nonferrous materials for Section VIII, Division 2 construction. This Table is organized in the same manner as Table 1B. Refer back to para. 2.2 for that description.

3 MECHANICAL PROPERTY TABLES

Ultimate tensile strength values and yield strength values are to be used in design calculations according to the rules of the Construction Codes. However, they are not to be construed as minimum strength values at temperature. This is explained in the General Notes to these tables. Paragraphs 3.1 through 3.3 provide a table-by-table listing of the materials-organization logic.

3.1 TABLE U

Table U provides tensile strength values for ferrous and nonferrous materials, in that order. The ordering logic for ferrous materials is the same as used in Table 1A, except yield strength level is not shown. Using the logic described in para. 2.1, stress lines are organized by nominal composition, then by increasing tensile strength level, and then by increasing specification number.

Nonferrous materials coverage begins following the last of the high alloy steels (25Cr–22Ni–2Mo–N). Coverage of nonferrous alloys begins with the UNS CXXXXX alloys, followed by NXXXXX and RXXXXX alloys. No tensile strength values are available at this time for the aluminum alloys. The ordering of materials within these three groups has been previously described in para. 2.2.

3.2 TABLE U-2

Table U-2 provides ultimate tensile strengths for special ferrous materials used in Section VIII, Division 3 construction. The only material covered is wire produced to either SA-231 or SA-232, and lines are arranged in order of decreasing tensile strength, resulting from increasing wire diameter.

3.3 TABLE Y-1

Table Y-1 provides yield strength values for ferrous and nonferrous materials, in that order. Again, the ordering of yield strength lines parallels the logic described for ferrous and nonferrous materials in paras. 2.1 and 2.2, respectively. Unlike Table U, for ferrous materials, the tensile strength level does enter into the ordering process, again following nominal composition designation. And, unlike Table U, Table Y-1's nonferrous materials listings do begin with the aluminum-base alloys (UNS AXXXXX).

Table 1A (Cont'd)
Section I; Section III, Classes 2 and 3;* Section VIII, Division 1; and Section XII
Maximum Allowable Stress Values *S* for Ferrous Materials
(*See Maximum Temperature Limits for Restrictions on Class)

	Line No.	Nominal Composition	Product Form	Spec. No.	Type/Grade	Alloy Desig./ UNS No.	Class/Condition/ Temper	Size/Thickness, in.	P-No.	Group No.
	1	Carbon steel	Forgings	SA–541	1	K03506	...	...	1	2
	2	Carbon steel	Forgings	SA–541	1A	K03020	...	...	1	2
	3	Carbon steel	Cast pipe	SA–660	WCB	J03003	...	...	1	2
	4	Carbon steel	Forgings	SA–765	II	K03047	...	...	1	2
	5	Carbon steel	Plate	SA–515	70	K03101	...	...	1	2
	6	Carbon steel	Plate	SA–516	70	K02700	...	...	1	2
	7	Carbon steel	Wld. pipe	SA–671	CB70	K03101	...	...	1	2
	8	Carbon steel	Wld. pipe	SA–671	CC70	K02700	...	...	1	2
	9	Carbon steel	Wld. pipe	SA–672	B70	K03101	...	...	1	2
	10	Carbon steel	Wld. pipe	SA–672	C70	K02700	...	...	1	2
	11	Carbon steel	Plate	SA/JIS G3118	SGV480	...	...	...	1	2
	12	Carbon steel	Smls. pipe	SA–106	C	K03501	...	...	1	2
	13	Carbon steel	Wld. tube	SA–178	D	...	...	...	1	2
	14	Carbon steel	Wld. tube	SA–178	D	...	...	...	1	2
	15	Carbon steel	Wld. tube	SA–178	D	...	...	...	1	2
	16	Carbon steel	Smls. tube	SA–210	C	K03501	...	...	1	2
	17	Carbon steel	Castings	SA–216	WCC	J02503	...	...	1	2
	18	Carbon steel	Smls. & wld. fittings	SA–234	WPC	K03501	...	...	1	2
	19	Carbon steel	Castings	SA–352	LCC	J02505	...	...	1	2
	20	Carbon steel	Castings	SA–487	16	...	A	...	1	2
	21	Carbon steel	Plate	SA–537	...	K12437	3	$4 < t \le 6$	1	3
	22	Carbon steel	Smls. tube	SA–556	C2	K03006	...	...	1	2
	23	Carbon steel	Wld. tube	SA–557	C2	K03505	...	...	1	2
	24	Carbon steel	Cast pipe	SA–660	WCC	J02505	...	...	1	2
(13)	25	...	...	...	...	...	...	...	...	...
	26	Carbon steel	Bar	SA–696	C	K03200	...	...	1	2
	27	Carbon steel	Sheet	SA–414	F	K03102	...	...	1	2
	28	Carbon steel	Plate	SA–662	C	K02007	...	...	1	2
	29	Carbon steel	Plate	SA–537	...	K12437	2	$4 < t \le 6$	1	3
	30	Carbon steel	Plate	SA–738	C	K02008	...	$4 < t \le 6$	1	3
	31	Carbon steel	Plate	SA–537	...	K12437	1	$\le 2^1/_2$	1	2
	32	Carbon steel	Wld. pipe	SA–671	CD70	K12437	...	$\le 2^1/_2$	1	2
	33	Carbon steel	Wld. pipe	SA–672	D70	K12437	...	$\le 2^1/_2$	1	2
	34	Carbon steel	Wld. pipe	SA–691	CMSH–70	K12437	...	$\le 2^1/_2$	1	2
	35	Carbon steel	Plate	SA–841	A	...	1	$\le 2^1/_2$	1	2
(13)	36	Carbon steel	Plate	SA/GB 713	Q345R	...	...	$2^1/_4 < t \le 4$	1	2
(13)	37	Carbon steel	Plate	SA/EN 10028–2	P355GH	...	...	$2.5 < t \le 4$	1	2
(13)	38	Carbon steel	Plate	SA/GB 713	Q345R	...	...	$1.5 < t \le 2^1/_4$	1	2
(13)	39	...	...	...	...	...	...	...	...	...

Table 1A (Cont'd)
Section I; Section III, Classes 2 and 3;* Section VIII, Division 1; and Section XII Maximum Allowable Stress Values *S* for Ferrous Materials (*See Maximum Temperature Limits for Restrictions on Class)

Line No.	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Applicability and Max. Temperature Limits (NP = Not Permitted) (SPT = Supports Only) I	III	VIII-1	XII	External Pressure Chart No.	Notes
1	70	36	NP	700	1000	650	CS-2	G10, T2
2	70	36	NP	700	1000	650	CS-2	G10, T2
3	70	36	1000	700	NP	NP	CS-2	G1, G10, G17, S1, T2
4	70	36	NP	NP	1000	650	CS-2	G10, T2
5	70	38	1000	700	1000	650	CS-2	G10, S1, T2
6	70	38	850	700	1000	650	CS-2	G10, S1, T2
7	70	38	NP	700	NP	NP	CS-2	S5, W10, W12
8	70	38	NP	700	NP	NP	CS-2	S6, W10, W12
9	70	38	NP	700	NP	NP	CS-2	S5, W10, W12
10	70	38	NP	700	NP	NP	CS-2	S6, W10, W12
11	70	38	850	NP	NP	NP	CS-2	G10, S1, T2
12	70	40	1000	700	1000	650	CS-2	G10, S1, T1
13	70	40	1000	NP	NP	NP	CS-2	G10, S1, T1, W13
14	70	40	1000	NP	NP	NP	CS-2	G4, G10, S1, T4
15	70	40	1000	NP	NP	NP	CS-2	G3, G10, S1, T2
16	70	40	1000	NP	1000	650	CS-2	G10, S1, T1
17	70	40	1000	700	1000	650	CS-2	G1, G10, G17, S1, T1
18	70	40	800	700	800	650	CS-2	G10, T1, W14
19	70	40	NP	700	NP	NP	CS-2	G17, T1
20	70	40	NP	700	NP	NP	CS-2	...
21	70	40	NP	NP	700	650	CS-2	G23, W11
22	70	40	NP	NP	800	650	CS-2	G10, T1
23	70	40	NP	NP	1000	650	CS-2	G24, T2, W6
24	70	40	1000	700	NP	NP	CS-2	G1, G10, G17, S1, T1
25	...	...	...	...	...	...	...	...
26	70	40	NP	700	NP	NP	CS-2	T1
27	70	42	NP	NP	900	650	CS-2	G10, T1
28	70	43	NP	NP	700	650	CS-3	T1
29	70	46	NP	700	700	650	CS-3	G23, T1, W11
30	70	46	NP	650	650	650	CS-3	G23, W11
31	70	50	NP	700	650	650	CS-3	G23, T1
32	70	50	NP	700	NP	NP	CS-3	S6, T1, W10, W12
33	70	50	NP	700	NP	NP	CS-3	S6, T1, W10, W12
34	70	50	NP	700	NP	NP	CS-3	S6, T1, W10, W12
35	70	50	NP	NP	650	NP	CS-3	...
36	71	44	800	NP	800	NP	CS-2	T1
37	71	45.5	850	NP	1000	NP	CS-2	G10, S1, T1
38	71	45.5	800	NP	800	NP	CS-2	T1
39	...	...	...	...	...	...	...	...

Table 1A (Cont'd)
Section I; Section III, Classes 2 and 3;* Section VIII, Division 1; and Section XII
Maximum Allowable Stress Values *S* for Ferrous Materials
(*See Maximum Temperature Limits for Restrictions on Class)

Line No.	Maximum Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding													
	−20 to 100	150	200	250	300	400	500	600	650	700	750	800	850	900
1	20.0	20.0	20.0	...	20.0	20.0	19.6	18.4	17.8	17.2	*14.8*	*12.0*	*9.3*	*6.7*
2	20.0	20.0	20.0	...	20.0	20.0	19.6	18.4	17.8	17.2	*14.8*	*12.0*	*9.3*	*6.7*
3	20.0	...	20.0	...	20.0	20.0	19.6	18.4	17.8	17.2	*14.8*	*12.0*	*9.3*	*6.7*
4	20.0	20.0	20.0	...	20.0	20.0	19.6	18.4	17.8	17.2	*14.8*	*12.0*	*9.3*	*6.7*
5	20.0	20.0	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	*14.8*	*12.0*	*9.3*	*6.7*
6	20.0	20.0	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	*14.8*	*12.0*	*9.3*	*6.7*
7	20.0	...	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	...	...	...	...
8	20.0	...	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	...	...	...	...
9	20.0	...	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	...	...	...	...
10	20.0	...	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	...	...	...	...
11	20.0	20.0	20.0	...	20.0	20.0	20.0	19.4	18.8	18.1	*14.8*	*12.0*	*9.3*	...
12	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	*18.3*	*14.8*	*12.0*	*9.3*	*6.7*
13	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	*18.3*	*14.8*	*12.0*	*9.3*	*6.7*
14	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	18.3	14.8	12.0	9.3	*5.7*
15	17.0	...	17.0	...	17.0	17.0	17.0	17.0	16.8	15.5	*12.6*	*10.2*	*7.9*	*5.7*
16	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	*18.3*	*14.8*	*12.0*	*9.3*	*6.7*
17	20.0	20.0	20.0	...	20.0	20.0	20.0	20.0	19.8	*18.3*	*14.8*	*12.0*	*9.3*	*6.7*
18	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	*18.3*	*14.8*	*12.0*	...	...
19	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	*18.3*	...	...	...	...
20	20.0	...	19.9	...	18.8	18.1	17.9	17.9	17.9	17.9	...	...	...	...
21	20.0	20.0	20.0	...	19.7	19.5	18.9	18.0	17.6	17.2	...	...	...	...
22	20.0	20.0	20.0	...	20.0	20.0	20.0	20.0	19.8	*18.3*	*14.8*	*12.0*	...	...
23	17.0	17.0	17.0	...	17.0	17.0	17.0	17.0	16.8	15.5	*12.6*	*10.2*	*7.9*	*5.7*
24	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	*18.3*	*14.8*	*12.0*	*9.3*	*6.7*
25	...	...	...	...	...	...	...	...	...	...	...	...	...	...
26	20.0	...	20.0	...	20.0	20.0	20.0	20.0	19.8	*18.3*	...	...	...	...
27	20.0	20.0	20.0	...	20.0	20.0	20.0	20.0	20.0	*18.3*	*14.8*	*12.0*	*9.3*	*6.7*
28	20.0	20.0	20.0	...	20.0	20.0	20.0	20.0	20.0	*18.3*	...	...	...	...
29	20.0	...	20.0	...	19.7	19.5	19.5	19.5	19.5	*18.3*	...	...	...	...
30	20.0	...	20.0	...	19.7	19.5	19.5	19.5	19.5	...	...	...	...	...
31	20.0	...	20.0	...	19.7	19.5	19.5	19.5	19.5	*18.3*	...	...	...	...
32	20.0	...	20.0	...	19.7	19.5	19.5	19.5	19.5	*18.3*	...	...	...	...
33	20.0	...	20.0	...	19.7	19.5	19.5	19.5	19.5	*18.3*	...	...	...	...
34	20.0	...	20.0	...	19.7	19.5	19.5	19.5	19.5	*18.3*	...	...	...	...
35	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	...	...	...	...	...
36	20.3	...	20.3	...	20.3	20.3	20.3	20.3	20.3	*18.3*	*14.8*	*12.0*	...	...
37	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	*18.3*	*14.8*	*12.0*	*9.3*	*6.7*
38	20.3	...	20.3	...	20.3	20.3	20.3	20.3	20.3	*18.3*	*14.8*	*12.0*	...	...
39	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Table 1A (Cont'd)
Section I; Section III, Classes 2 and 3;* Section VIII, Division 1; and Section XII
Maximum Allowable Stress Values *S* for Ferrous Materials
(*See Maximum Temperature Limits for Restrictions on Class)

Line No.	Maximum Allowable Stress, ksi (Multiply by 1000 to Obtain psi), for Metal Temperature, °F, Not Exceeding															
	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600	1650	
1	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
2	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
3	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
4	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
5	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
6	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
12	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
13	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
14	*3.4*	*2.1*	...	...	...	...	...	...	...	...	...	...	...	...	...	
15	*3.4*	*2.1*	...	...	...	...	...	...	...	...	...	...	...	...	...	
16	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
17	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
18	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
19	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
20	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
21	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
23	*3.4*	*2.1*	...	...	...	...	...	...	...	...	...	...	...	...	...	
24	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	
25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	(**13**)
26	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
27	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
28	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
29	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
30	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
31	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
32	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
33	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
34	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
35	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
36	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	(**13**)
37	*4.0*	*2.5*	...	...	...	...	...	...	...	...	...	...	...	...	...	(**13**)
38	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	(**13**)
39	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	(**13**)

NOTES TO TABLE 1A
GENERAL NOTES

(a) The following abbreviations are used: Norm. rld., Normalized rolled; Smls., Seamless; Sol. ann., Solution annealed; and Wld., Welded.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures. The values at intermediate temperatures shall be rounded to the same number of decimal places as the value at the higher temperature between which values are being interpolated. The rounding rule is: when the next digit beyond the last place to be retained is less than 5, retain unchanged the digit in the last place retained; when the digit next beyond the last place to be retained is 5 or greater, increase by 1 the digit in the last place retained.

(c) For Section VIII and XII applications, stress values in restricted shear such as dowel bolts or similar construction in which the shearing member is so restricted that the section under consideration would fail without reduction of area shall be 0.80 times the values in the above Table.

(d) For Section VIII and XII applications, stress values in bearing shall be 1.60 times the values in the above Table.

(e) Stress values for −20°F to 100°F are applicable for colder temperatures when the toughness requirements of Section III, VIII, or XII are met.

(f) An alternative typeface is used for stress values obtained from time-dependent properties (see Notes T1 through T11).

(g) Where specifications, grades, classes, and types are listed in this Table, and where the material specification in Section II, Part A or Part B is a dual-unit specification (e.g., SA-516/SA-516M), the values listed in this Table shall be applicable to either the customary U.S. version of the material specification or the SI units version of the material specification. For example, the values listed for SA-516 Grade 70 shall be used when SA-516M Grade 485 is used in construction.

(h) The properties of steels are influenced by the processing history, heat treatment, melting practice, and level of residual elements. See Nonmandatory Appendix A for more information.

(**13**) (i) Where a size limit appears in the Size/Thickness column, the limit applies to the dimension appropriate to the product form: wall thickness of tubing, pipe, pipe fittings, and hollow forgings; thickness of plate, flat bar and forgings, and polygonal bar; diameter of solid bar and bolting; and thickest cross-section of other pressure parts, e.g., castings and forgings.

NOTES – GENERAL REQUIREMENTS

G1 To these stress values a casting quality factor as specified in PG-25 of Section I; UG-24 of Section VIII, Division 1; or TM-190 of Section XII shall be applied.

G2 These stress values include a joint efficiency factor of 0.60.

G3 These stress values include a joint efficiency factor of 0.85.

G4 For Section I applications, these stresses apply when used for boiler, water wall, superheater, and economizer tubes that are enclosed within a setting. A joint efficiency factor of 0.85 is included in values above 850°F.

G5 Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the short-time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The stress values in this range exceed $66^2/_3$% but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction. For Section III applications, Table Y-2 lists multiplying factors that, when applied to the yield strength values shown in Table Y-1, will give allowable stress values that will result in lower levels of permanent strain.

G6 Creep-fatigue, thermal ratcheting, and environmental effects are increasingly significant failure modes at temperatures in excess of 1500°F and shall be considered in the design.

(**13**) G7 For Section VIII applications, these stress values are based on expected minimum values of 45,000 psi tensile strength and yield strength of 20,000 psi resulting from loss of strength due to thermal treatment required for the glass coating operation. UG-85 does not apply.

(**13**) G8 These stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the flexibility of the flange and bolts and corresponding relaxation properties.

G9 For Section III applications, the use of these materials shall be limited to materials for tanks covered in Subsections NC and ND, component supports, and for nonpressure-retaining attachments (NC/ND-2190).

G10 Upon prolonged exposure to temperatures above 800°F, the carbide phase of carbon steel may be converted to graphite. See Nonmandatory Appendix A, A-201 and A-202.

G11 Upon prolonged exposure to temperatures above 875°F, the carbide phase of carbon-molybdenum steel may be converted to graphite. See Nonmandatory Appendix A, A-201 and A-202.

G12 At temperatures above 1000°F, these stress values apply only when the carbon is 0.04% or higher on heat analysis.

G13 These stress values at 1050°F and above shall be used only when the grain size is ASTM No. 6 or coarser.

G14 These stress values shall be used when the grain size is not determined or is determined to be finer than ASTM No. 6.

G15 For Section I applications, use is limited to stays as defined in PG-13 except as permitted by PG-11.

G16 For Section III Class 3 applications, these S values do not include a casting quality factor. Statically and centrifugally cast products meeting the requirements of NC-2570 shall receive a casting quality factor of 1.00.

G17 For Section III Class 3 applications, statically and centrifugally cast products meeting the requirements of NC-2571(a) and (b), and cast pipe fittings, pumps, and valves with inlet piping connections of 2 in. nominal pipe size and less, shall receive a casting quality factor of 1.00. Other casting quality factors shall be in accordance with the following:

(a) for visual examination, 0.80;
(b) for magnetic particle examination, 0.85;
(c) for liquid penetrant examination, 0.85;
(d) for radiography, 1.00;
(e) for ultrasonic examination, 1.00;
(f) for magnetic particle or liquid penetrant plus ultrasonic examination or radiography, 1.00.

G18 See Table Y-1 for yield strength values as a function of thickness over this range. Allowable stresses are independent of yield strength in this thickness range.

NOTES TO TABLE 1A (CONT'D)

NOTES – GENERAL REQUIREMENTS (CONT'D)

(**13**) G19 This steel may be expected to develop embrittlement after service at moderately elevated temperature; see Nonmandatory Appendix A, A-207 and A-208.

(**13**) G20 These stresses are based on weld metal properties.

(**13**) G21 For Section I, use is limited to PEB-5.3. See PG-5.5 for cautionary note.

G22 For Section I applications, use of external pressure charts for material in the form of bar stock is permitted for stiffening rings only.

G23 For temperatures above the maximum temperature shown on the external pressure chart for this material, Fig. CS-2 may be used for the design using this material.

G24 A factor of 0.85 has been applied in arriving at the maximum allowable stress values in tension for this material. Divide tabulated values by 0.85 for maximum allowable longitudinal tensile stress.

G25 For Section III applications, for both Class 2 and Class 3, the completed vessel after final heat treatment shall be examined by the ultrasonic method in accordance with NB-2542 except that angle beam examination in both the circumferential and the axial directions may be performed in lieu of the straight beam examination in the axial direction. The tensile strength shall not exceed 125,000 psi.

G26 Material that conforms to Class 10, 11, or 12 is not permitted.

G27 Material that conforms to Class 11 or 12 is not permitted.

G28 Supplementary Requirement S15 of SA-781, Alternate Mechanical Test Coupons and Specimen Locations for Castings, is mandatory.

G29 For Section III applications, impact testing in accordance with the requirements of NC-2300 is required for Class 2 components and in accordance with ND-2300 for Class 3 components.

NOTES – HEAT TREATMENT REQUIREMENTS

H1 For temperatures above 1000°F, these stress values may be used only if the material is heat treated by heating to the minimum temperature specified in the material specification, but not lower than 1900°F, and quenching in water or rapidly cooling by other means.

H2 For temperatures above 1000°F, these stress values may be used only if the material is heat treated by heating to a minimum temperature of 2000°F, and quenching in water or rapidly cooling by other means.

(**13**) H3 Normalized and tempered.

(**13**) H4 Solution treated and quenched.

H5 For Section III applications, if heat treatment is performed after forming or fabrication, it shall be performed at 1500°F to 1850°F for a period of time not to exceed 10 min at temperature, followed by rapid cooling.

H6 Material shall be solution annealed at 2010°F to 2140°F, followed by a rapid cooling in water or air.

NOTES – SIZE REQUIREMENTS

S1 For Section I applications, stress values at temperatures of 850°F and above are permissible but, except for tubular products 3 in. O.D. or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.

S2 For Section I applications, stress values at temperatures of 900°F and above are permissible but, except for tubular products 3 in. O.D. or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.

S3 For Section I applications, stress values at temperatures of 1000°F and above are permissible but, except for tubular products 3 in. O.D. or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.

S4 For Section I applications, stress values at temperatures of 1150°F and above are permissible but, except for tubular products 3 in. O.D. or less enclosed within the boiler setting, use of these materials at these temperatures is not current practice.

S5 Material that conforms to Class 10, 11, or 12 is not permitted when the nominal thickness of the material exceeds ¾ in.

S6 Material that conforms to Class 10, 11, or 12 is not permitted when the nominal thickness of the material exceeds 1¼ in.

S7 The maximum thickness of unheat-treated forgings shall not exceed 3¾ in. The maximum thickness as-heat-treated may be 4 in.

S8 The maximum section thickness shall not exceed 3 in. for double-normalized-and-tempered forgings, or 5 in. for quenched-and-tempered forgings.

S9 Both NPS 8 and larger, and schedule 140 and heavier.

S10 The maximum pipe size shall be NPS 4 (DN 100) and the maximum thickness in any pipe size shall be Schedule 80.

(**13**) S11 Either NPS 8 and larger and less than schedule 140 wall, or less than NPS 8 and all wall thicknesses.

NOTES – TIME-DEPENDENT PROPERTIES [See General Note (f)]

T1 Allowable stresses for temperatures of 700°F and above are values obtained from time-dependent properties.

T2 Allowable stresses for temperatures of 750°F and above are values obtained from time-dependent properties.

T3 Allowable stresses for temperatures of 850°F and above are values obtained from time-dependent properties.

T4 Allowable stresses for temperatures of 900°F and above are values obtained from time-dependent properties.

T5 Allowable stresses for temperatures of 950°F and above are values obtained from time-dependent properties.

T6 Allowable stresses for temperatures of 1000°F and above are values obtained from time-dependent properties.

T7 Allowable stresses for temperatures of 1050°F and above are values obtained from time-dependent properties.

T8 Allowable stresses for temperatures of 1100°F and above are values obtained from time-dependent properties.

T9 Allowable stresses for temperatures of 1150°F and above are values obtained from time-dependent properties.

T10 Allowable stresses for temperatures of 800°F and above are values obtained from time-dependent properties.

(**13**) T11 Allowable stresses for temperatures of 650°F and above are values obtained from time-dependent properties.

NOTES – WELDING REQUIREMENTS

W1 Not for welded construction.

W2 Not for welded construction in Section III.

W3 Welded.

W4 Nonwelded, or welded if the tensile strength of the Section IX reduced section tension test is not less than 100 ksi.

NOTES TO TABLE 1A (CONT'D)

NOTES – WELDING REQUIREMENTS (CONT'D)

W5 Welded, with the tensile strength of the Section IX reduced tension test less than 100 ksi but not less than 95 ksi.

W6 This material may be welded by the resistance technique.

W7 In welded construction for temperatures above 850°F, the weld metal shall have a carbon content of greater than 0.05%.

W8 Welding and oxygen or other thermal cutting processes are not permitted when carbon content exceeds 0.35% by heat analysis.

W9 For Section I applications, for pressure retaining welds in 2¼Cr–1Mo materials, other than circumferential butt welds less than or equal to 3½ in. in outside diameter, when the design metal temperatures exceed 850°F, the weld metal shall have a carbon content greater than 0.05%.

W10 For Section III applications, material that conforms to Class 10, 13, 20, 23, 30, 33, 40, 43, 50, or 53 is not permitted for Class 2 and Class 3 construction when a weld efficiency factor of 1.00 is used in accordance with Note W12.

W11 For Section VIII applications, Section IX, QW–250 Variables QW–404.12, QW–406.3, QW–407.2, and QW–409.1 shall also apply to this material. These variables shall be applied in accordance with the rules for welding of Part UF.

W12 These S values do not include a longitudinal weld efficiency factor. For Section III applications, for materials welded without filler metal, ultrasonic examination, radiographic examination, or eddy current examination, in accordance with NC–2550, shall provide a longitudinal weld efficiency factor of 1.00. Materials welded with filler metal meeting the requirements of NC–2560 shall receive a longitudinal weld efficiency factor of 1.00. Other longitudinal weld efficiency factors shall be in accordance with the following:

(a) for single butt weld, with filler metal, 0.80;

(b) for single or double butt weld, without filler metal, 0.85;

(c) for double butt weld, with filler metal, 0.90;

(d) for single or double butt weld, with radiography, 1.00.

W13 For Section I applications, electric resistance and autogenous welded tubing may be used with these stresses, provided the following additional restrictions and requirements are met:

(a) The tubing shall be used for boiler, waterwall, superheater, and economizer tubes that are enclosed within the setting.

(b) The maximum outside diameter shall be 3½ in.

(c) The weld seam of each tube shall be subjected to an angle beam ultrasonic inspection per SA–450.

(d) A complete volumetric inspection of the entire length of each tube shall be performed in accordance with SA–450.

(e) Material test reports shall be supplied.

W14 These S values do not include a weld factor. For Section VIII, Division 1 and Section XII applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW–12 for Section VIII, Division 1, or TW–130.4 for Section XII, as applicable.

W15 The Nondestructive Electric Test requirements of SA–53 Type E pipe are required for all sizes. The pipe shall be additionally marked "NDE" and so noted on the material certification.

Part UW of ASME. Requirements to fabricate pressure vessels by welding methods.

→ UW-2: service requirements. If the pressure vessels contain Lethal (مرگ آور) materials, All welds needs to be inspected %100 Radiography. ERW weld type is not Permitted.

→ UW-3: weld Joint Category. Category "A" has highest stress due to pressure. (Figure UW-3 on Page 111 of Version 2013) Page 64 of this note book

→ ASME Section ~~VIII~~ did not accept ultrasonic test for cracks, but B31.3 accept that one.

→ UW-18: Fillet welds. weld effeciency strength factor is only 0.55

UW-20: Tube-to tubesheet welds.

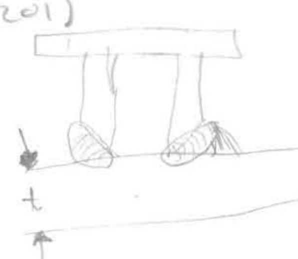
→ Tack welds mean welds with length less than 3/4": begining and ending of the Tack welds shall be grind cut to mitigate stress concentration.

→ For Peening: use a spherical hammer. 10 mm diameter ball is recommended. 4kg hammer. let the hammer do the work. preheat to 200°F befor hammering. do both weld deposit and diffuse line. do not peen on roote or toe of the welds.

→ UHX: Unfired Heat Exchanger. This part is new and published in 2013.

Hot Tap steps API 2201 has a very good check list.

1- we need a minimum Required thickness (1/2" As per API 2201)
2- PT befor hot tap
3- volumetry UT for internal flaws.
4- Check ID surface Geometry using UTSW inspection
5- operation & Safety peoples shall be on site for helping
6- Area Preaparation, All drains needs to be plugged.
7- Talk to welder to practice this weld. use low He electrod and oven in site.
8- Drug Test for welder is recommended.
9- Delay cracking check after 48 hours. by WFMT method.



E-PCC-2

ASME BOILER AND PRESSURE VESSEL CODE, SECTION IX – WELDING QUALIFICATION

"This standard was not exist befor 1968"

Scope

The scope of Section IX specifies the requirements for the qualification of welders, brazers, and the welding and brazing procedure specifications employed when welding or brazing in accordance with the ASME Boiler and Pressure Code, and the ASME B31 Code for Pressure Piping.

A Code user may be directed to use Section IX by any of the construction codes of ASME, such as Sections I, III, IV, VIII, XI, and by the ASME B31 Pressure Piping codes, such as B31.1 or B31.3. Section IX may also be referenced by the API Petrochemical and Refinery codes such as API 510, API 570, and API 653. Or it may simply be required by purchase order.

Qualification of welders and the welding procedure specifications they use in code construction involves many factors that are difficult to outline in a code or standard. The CASTI Guidebook to ASME Section IX - *Welding Qualifications,* is a guide to the requirements of the ASME Boiler and Pressure Vessel Code Section IX - Welding and Brazing Qualifications.

Organization of Section IX

Section IX is divided into two parts: welding and brazing. The welding part is divided into five articles, as outlined in Table 1.1 and explained further in the pages that follow. The brazing part is divided into four articles, also explained further in the pages that follow.

Table 1 Organization of Section IX

Foreword	Brief history, Code operations, committee activities, Code user responsibility, Code cases, revisions, jurisdiction precautions, the National Board of Boiler and Pressure Vessel Inspectors, inquiries and materials.
Introduction	Brief guide and explanation of Code rules and parts.
Article I QW-100 General	General rules which apply to the qualification of welding procedure specifications (WPS) and to the qualification of the performance of the welders who will use the WPSs.
Article II QW-200 Welding Procedure Qualifications	Rules for responsibility, variables and tests for the preparation of a WPS, the qualification of the WPS and recording the qualification on PQR forms.
Article III QW-300 Performance	Rules for responsibility, variables and tests for the preparation of a WPQ, rules for the expiration, renewal and continuity records for welders.
Article IV QW-400 Data	Specific data for variables, P-Nos., S-Nos., F-Nos. & A-Nos., thickness ranges, diameters, positions, types of specimens, removal of specimens, test equipment, etching and definitions.
Article V QW-500 SWPS	Rules for the use of standard welding procedure specifications (SWPS).
Appendices	Technical Inquiries, Forms, Materials by P-No. and Group No.
QB-Brazing	QB has the first four articles as in QW, except related to brazing and labeled as QB-100, QB-200, QB-300 and QB-400.

Summary of Articles

Article I – Welding General Requirements QW-100

Article I covers the scope of Section IX; the purpose and use of the WPS, PQR and WPQ; responsibility; test positions; types and purposes of tests and examinations; test procedures; acceptance criteria; visual examination; radiographic examination; and stud, laser, and resistance welding tests.

Article II – Welding Procedure Qualifications QW-200

Article II covers the rules for the preparation of welding procedure specifications (WPS) and of procedure qualification records (PQR).

Each process is listed separately in QW-250 with the essential, nonessential, and supplementary essential variables as they apply to that process. The WPS must specify a value or range for each essential, nonessential and, when required, each supplementary essential variable listed for each welding process.

The PQR records the value for each essential and, when required, each supplementary essential variable used for each welding process.

If a change is made in a nonessential variable, the WPS must be revised, or amended, but does not need to be requalified.

When a change is made in an essential variable, the WPS must be revised, and the revised WPS must be qualified with a new PQR, or the revision must be supported by an existing, valid PQR.

Article III – Welding Performance Qualifications QW-300

Article III covers the preparation of welder performance qualification (WPQ) records. Each process is listed separately in QW-350 with the essential variables as they apply to that process. The WPQ form must record a value for each essential variable used and must list a qualified range for each of these essential variables.

Items addressed are; Code users' responsibility, simultaneous qualifications of welders and welding operators, types of tests, records, welder identification requirements, welding positions, diameter limitations, qualifications expiration, and renewal of qualifications.

The rules for welders versus welding operators qualifications are clearly separated. Welders and Welding Operators may be qualified by visual and mechanical tests, or by radiography of a test coupon. Radiography of the initial production weld, depending upon the welding process used, is also allowed.

Article IV – Welding Data QW-400

Article IV covers welding data that must be applied to the preparation and qualification of the WPS, PQR, and the WPQ depending on the process. The welding data groups the variables into the categories of: joints, base materials, filler materials, positions, preheat, postweld heat treatment, gas, electrical characteristics, and technique.

Article IV also includes assignments of P-Numbers (ASME base materials), S-Numbers (other materials), F-Numbers (grouping of filler metals) and A-Numbers (weld metal chemical analysis).

Tables for welding procedure specification qualification thickness limits, and welder performance qualification thickness and diameter limits are provided.

Welding positions also are specified in QW-400. Qualification ranges for welder positions are defined

Article IV also gives guidance for test coupons, the removal of test specimens, and requirements for the test jig dimensions.

Article V – Standard Welding Procedure Specifications (SWPS) QW-500

Article V covers rules for the adoption, demonstration, and application of the Standard Welding Procedure Specifications, (SWPSs), listed in Appendix E. See details in Chapter 15. Welder qualifications for using SWPSs are the same as when using Section IX qualified procedures.

Table 2 Scopes of the WPS, PQR, and WPQ

Welding Application	**WPS** Specify: Variable ranges Essential variables Nonessential variables Other directions	**PQR** Record: Actual values Essential variables Tests and results Other data	**WPQ** Record: value tested / Specify: range qualified Record tests and test results
Example 1.2.1			
What do each of these documents provide?	A WPS provides direction for making welds, specifies what material is to be welded and how it is to be welded.	A PQR provides support (proof) of the mechanical and other weldability properties of the WPS.	A WPQ provides proof of the welder's ability to make sound welds.
How are these documents prepared and/or qualified?	A WPS is prepared by specifying what is to be welded and how it is to be welded by specifying values or ranges for each variable on the WPS.	A WPS is qualified by welding a test coupon, preparing test specimens, recording the tests and test results on a PQR.	A welder is qualified by welding a test coupon, preparing test specimens, recording the tests performed, the results and ranges qualified on a WPQ.
What must be documented, specified or recorded?	A WPS must specify, for each process, the ranges of all essential and nonessential variables that must be followed.	A PQR must record, for each process, all essential variables used to weld the test coupon, the tests performed and the test results.	A WPQ must record the essential variables used to weld the test coupon, the tests performed, the test results, and the ranges qualified.
What happens when changes are made?	The WPS must be revised or rewritten for any change in an essential or nonessential variable.	A PQR must be prepared to support any change made to an essential variable in a WPS.	A WPQ must be prepared to support each performance variable change in a welder's WPQ.

Welding Procedure Specification Hierarchy

There are three steps and documents involved in qualifying welding procedure specifications and welders/welding operators for Code construction.

- The first step requires the Code user to prepare the first document, a **welding procedure specification (WPS)**. The WPS must contain the minimum requirements that are specified by the construction or repair code. The WPS is intended to provide guidance for welding by specifying ranges for each variable. The WPS must be supported by a procedure qualification record (PQR).

- The second step requires the Code user to qualify the WPS by welding procedure qualification test coupon. The Code user must record the variables and tests used, and must certify the tests and test results on the second document, the **procedure qualification record (PQR)**.

- The third step requires the Code user to qualify the performance of the welders by welding performance qualification test coupons. The Code user must record the variables and tests used, specify the variable ranges qualified, and must certify the tests and tests results on the third document, a **welders performance qualification (WPQ)** record.

The majority of the rules in Section IX involve one of these three documents, the WPS, PQR or WPQ. One of the biggest sources of confusion with Section IX is mixing the rules between these three documents. So be careful when reading exam questions and answers to be sure which document is being referenced.

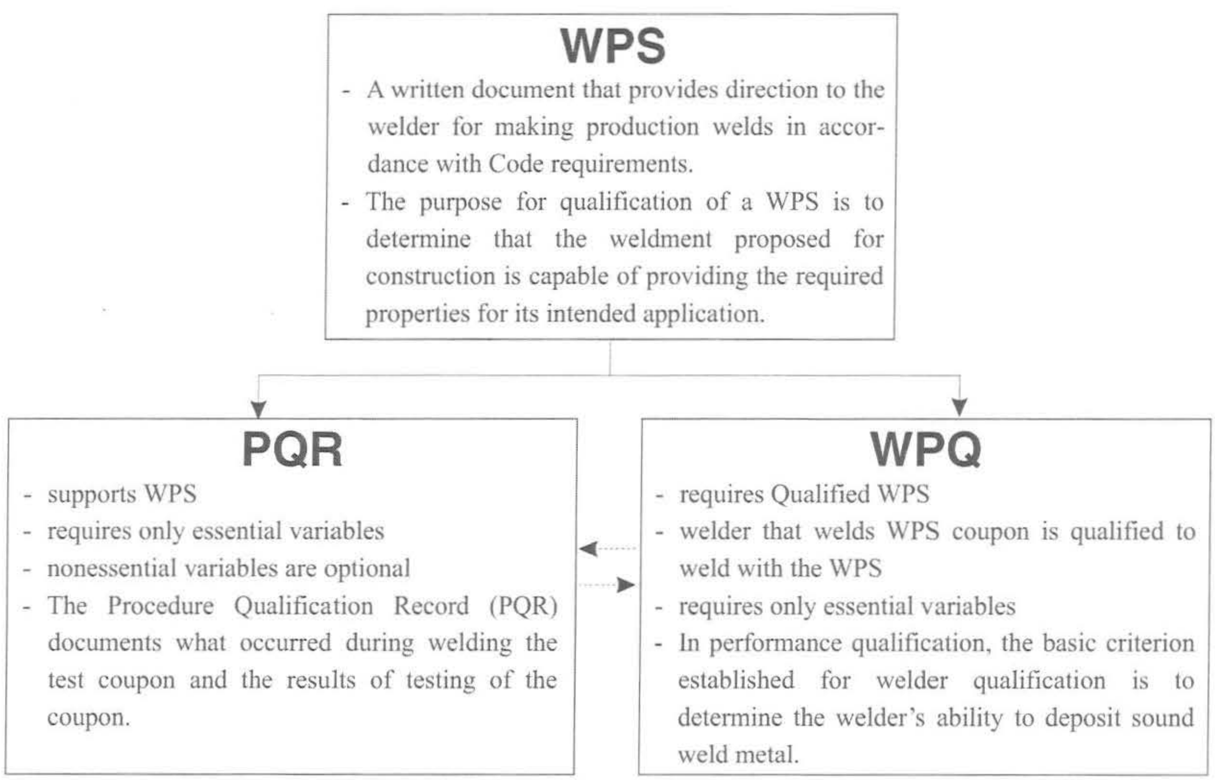


Figure 1 Welding procedure specification hierarchy

Welding General Requirements – Article I

The rules in ASME Section IX are only applied when qualifying either a welding procedure specification (WPS) or a welder/welding operator. These rules do not apply when performing construction code welding. Construction codes, such as ASME Section VIII-1, may specify different requirements than those listed in ASME Section IX. Note that such requirements take precedence over the rules in ASME Section IX and that the manufacturer or contractor must comply with them.

QW-100.1 defines:

> The purpose of the WPS and PQR is to determine that the weldment proposed for construction is capable of providing the required properties for its intended application."

This terse opening statement puts the responsibility on the Code user to assure that welding qualifications are suitable for the welding application.

Note: Section IX does not cover the application, service, or life of the component.

QW-100.1 and QW-100.2 provide definitions of the three documents: the WPS, the PQR, and the WPQ in which all of them are written and not verbal. For example, a WPS is a written document that provides direction to the welder for making production welds in accordance with Code requirements.

QW-100.2 defines the basic criterion established for welder qualification is to determine the welder's ability to deposit sound weld metal. The basic criterion established for welding operator qualification is to determine the welding operator's mechanical ability to operate the welding equipment.

QW-100.3 covers the WPS, PQR, and WPQ, in more detail. QW-100.3 states that these documents, prepared in accordance with Section IX, may be used in any ASME construction.

QW-100.3 also allows the continued use of a WPS, PQR or WPQ, qualified at any time in the past, provided all requirements of the 1962 or later Edition are met. QW-100.3 does not require a WPS, WPQ or a PQR to be amended to include any variables required by later Editions and Addenda. However, QW-100.3 does require the qualification of a new WPS or WPQ, or, the requalification of an existing WPS or WPQ to be performed in full accordance with the latest version of Section IX.

QW-103.1 requires the manufacturer or contractor to conduct the tests used to qualify the welding procedures and welders for welding under this Code.

QW-103.2 Each manufacturer or contractor must maintain a record of the results obtained in welding procedure and welder and welding operator performance qualifications. These records must be certified by a signature or other means as described in the manufacturer's or contractor's Quality Control System and must be accessible to the Authorized Inspector.

Test Positions for Groove Welds – QW-120

It is important to recognize that there are test positions, as described in QW-120, and there are welding application positions.

The test positions in QW-120 and QW-461.3 through 461.8 define the positions that are allowed as one of the test positions. The test positions are labeled, for example, as 1G, 2G, 3G, etc. and 1F, 2F, 3F, etc. (see figure below).

Plate Positions – QW-121

- Flat Position 1G; see figure QW-461.3, illustration (a).
- Horizontal Position 2G; see figure QW-461.3, illustration (b).
- Vertical Position 3G; see figure QW-461.3, illustration (c).
- Overhead Position 4G; see QW-461.3, illustration (d).

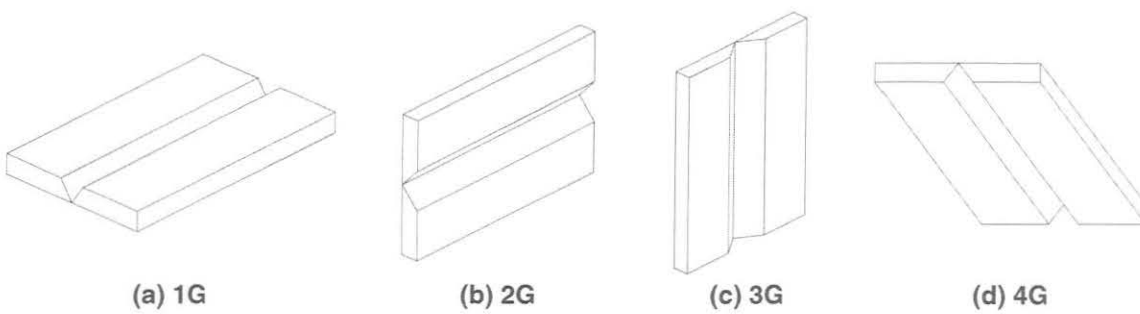


Figure 2 QW-461.3 Groove welds in plate—test positions

Pipe Positions – QW-122

- Flat Position 1G; see figure QW-461.4, illustration (a).
- Horizontal Position 2G (pipe is not be rotated); see figure QW-461.4, illustration (b).
- Multiple Position 5G (pipe is not be rotated); see figure QW-461.4, illustration (c).
- Multiple Position 6G (pipe is not be rotated); see figure QW-461.4, illustration (d).

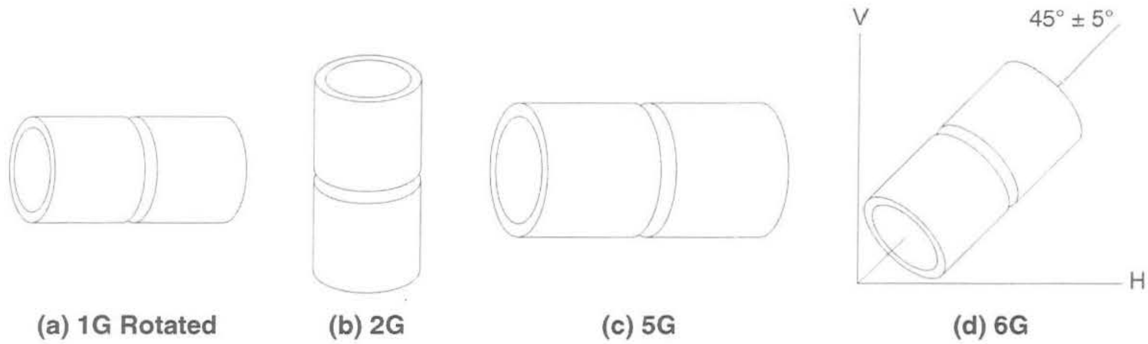


Figure 3 QW-461.4 Groove welds in pipe—test positions

Test Positions for Fillet Welds – QW-130

Plate Positions – QW-131

- Flat Position 1F; see figure QW-461.5, illustration (a).
- Horizontal Position 2F; see figure QW-461.5, illustration (b).
- Vertical Position 3F; see figure QW-461.5, illustration (c).
- Overhead Position 4F; see figure QW-461.5, illustration (d).

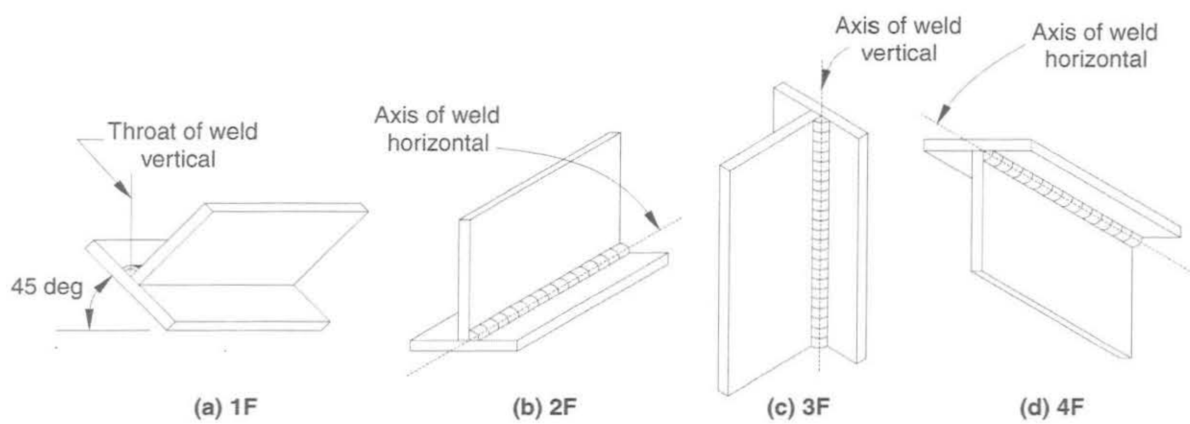


Figure 4 QW-461.5 Fillet welds in plate—test positions.

Pipe Positions – QW-132

- Flat Position 1F; see figure QW-461.6, illustration (a).
- Horizontal Positions:
  (a) Position 2F (pipe is not rotated); see figure QW-461.6, illustration (b).
  (b) Position 2FR (pipe is rotated); see figure QW-461.6, illustration (c).
- Overhead Position 4F (pipe is not rotated). see figure QW-461.6, illustration (d).
- Multiple Position 5F (pipe is not rotated); see figure QW-461.6, illustration (e).

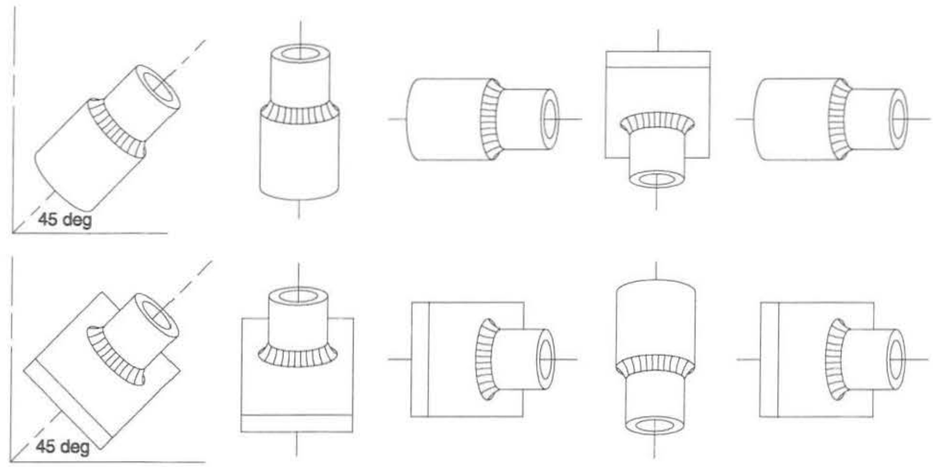


Figure 5 QW-461.6 fillet welds in pipe—test positions

Types and Purposes of Tests and Examinations – QW-140

QW-140 describes the types and purposes of tests and examinations.

Mechanical Tests – QW-141

- Tension tests are used to determine the ultimate strength of groove-weld joints; see QW-150.
- Guided-bend tests are used to determine the degree of soundness and ductility of groove-weld joints; see QW-160.
- Fillet-weld tests are used to determine the size, contour, and degree of soundness of fillet welds; see QW-180.
- Notch-toughness tests (e.g., Charpy impact test) are used to determine the notch toughness of the weldment; in QW-171 and QW-172.
- Stud-weld test include deflection bend, hammering, torque, or tension tests and a macro-examination are used to determine acceptability of stud welds; see QW-466.4, QW-466.5, QW-466.6, and QW-202.5, respectively.

Special Examinations for Welders – QW-142

Radiographic or ultrasonic examination may be substituted for mechanical testing of QW-141 for groove-weld performance qualification as permitted in QW-304 to prove the ability of welders to make sound welds.

P-Number – F-Number – A-Number

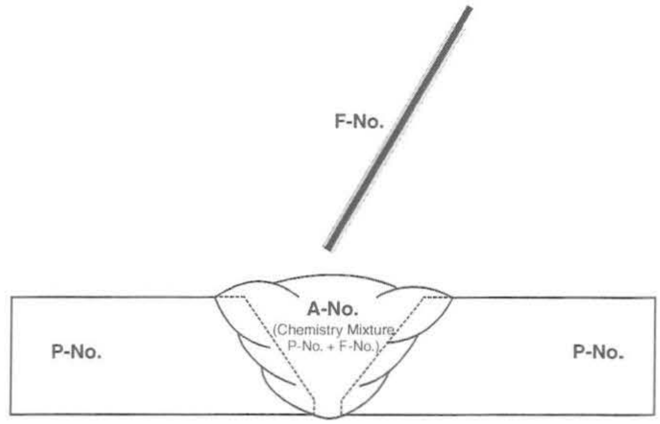


Figure 6 Demonstrating the relationship between the location of P-number, F-number, and A-number materials.

P-Number (P-No.) – QW-420

QW-420 defines a P-Number as a family of base metals logically organized by their characteristics, such as:

- chemical composition,
- weldability, and
- mechanical properties.

P-Numbers were made to reduce the number of welding procedure qualifications.

QW/QB-422 lists all P-No. materials alpha-numerically by specification number, where ferrous metals begin with SA- or A and nonferrous metals begin with SB- or B, e.g., SA-36 and B-16.

Although QW-424.1 allows one metal from a P-Number welded to any metal from the same P-Number to qualify any metals assigned that same P-Number, it also warns the Code user that this cannot be done indiscriminately. QW-420 states that:

> "These assignments (P-Numbers.) do not imply that base metals may be indiscriminately substituted for a base metal that was used in the qualification test without consideration of compatibility from the standpoint of metallurgical properties, postweld heat treatment, design, mechanical properties, and service requirements."

Group Numbers (Within P-Numbers) – QW-420

QW-420 describes Group Numbers as being assigned within a P-Number to ferrous base metals that have specified impact test requirements. The Group Number is a supplementary essential variable, which must be addressed on the PQR whenever impact testing is imposed for low temperature applications by the construction code.

When impact testing is not imposed by the construction code, the Group Number is no longer a variable that is required to be addressed by ASME Section IX (see definition for supplementary essential variable in QW-251.2).

However, good engineering judgment should include a review of all variables to ensure that the weldment proposed for construction is capable of providing the required properties for its intended application (see QW100.1).

The P-Number is an essential variable for WPS and welder performance qualifications.

The complete listing of P-Numbers is found in QW/QB-422 (see excerpt below). Note that base metals for welding and brazing are combined in this table. QW/QB-422 lists each of the base metals in an alpha-numerical sequence based upon the material specification.

Appendix D is a nonmandatory listing of P-Numbers, and lists each of the base metals in a numeric sequence based upon the P-Number. Appendix D is a convenient place to find all the base metals of a given P-Number in one table. Appendix D may be very useful when a Code user is looking for other base metals within a given P-Number for the purpose of qualification.

QW/QB-422 also lists other base material information for qualifying WPS and BPS.

Steps to Find a P-Number – QW/QB-422

Step 1: Find the base metal specification in the left-hand column in QW/QB-422; they are organized in alpha-numerical order, starting with SA-36; (note that the ferrous metal SA-specifications are listed first, followed by the nonferrous metal SB-specifications).
Step 2: Move to the next column and find the Grade or Type.
Step 3: Move horizontal to the Welding P-No., Group No. column.

These steps are shown in the following example. You can proceed to answer the practice problems after the example.

Example Q1: QW/QB-422 – P-No. Group No.

What is the P-No. and Group No. for ASME SA-105 flanges and fittings?

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS
Grouping of Base Metals for Qualification

Ferrous									
				Welding		Brazing			
Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	P-No.	Group No.	P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-36	...	K02600	58 (400)	1	1	101	11.1	C–Mn–Si	Plate, bar & shapes
SA-53	Type F	...	48 (330)	1	1	101	11.1	C	Furnace welded pipe
SA-53	Type S, Gr. A	K02504	48 (330)	1	1	101	11.1	C	Smls. pipe
SA-53	Type E, Gr. A	K02504	48 (330)	1	1	101	11.1	C	Resistance welded pipe
SA-53	Type E, Gr. B	K03005	60 (415)	1	1	101	11.1	C–Mn	Resistance welded pipe
SA-53	Type S, Gr. B	K03005	60 (415)	1	1	101	11.1	C–Mn	Smls. pipe
SA-105	...	K03504	70 (485)	1	2	101	11.1	C	Flanges & fittings
SA-106	A	K02501	48 (330)	1	1	101	1.1	C–Si	Smls. pipe

Practice Problem Q2: QW/QB-422 – UNS No.

What is the UNS No. for ASME SA-182 Type F304?

a) 304
b) S304
c) S304xx
d) S30400

Practice Problem Q3: QW/QB-422 – Minimum Specified Tensile Strength

What is the minimum specified tensile strength of ASME SA-516 Grade 70?

a) 16 ksi
b) 516 ksi
c) 70,000 ksi
d) 70 ksi

Practice Problem Q4: QW/QB-422 – Nominal Composition

What is the nominal composition of ASME SA-333 Grade 6?

a) carbon steel
b) manganese steel
c) C-Mn-Si steel
d) alloy steel

Practice Problem Q5: QW/QB-422 – Product Form
What product form is ASME SA-426 Grade CP11? a) plate b) forging c) centrifugal cast pipe d) piping fitting

F-Number (F-No.) – QW-430

QW-430 defines F-Numbers as families of filler metals based essentially on usability characteristics.

Similar to P-Numbers, F-Numbers were made to reduce the number of welding procedure and performance qualifications, where it was logical.

However, like P-Numbers, the filler metals within an F-Number does not imply that base metals or filler metals within the same F-Number may be indiscriminately substituted for a metal that was used in the qualification test without consideration of the compatibility of the base and filler metals from the standpoint of metallurgical properties, postweld heat treatment, design, mechanical properties, and service requirements.

The F-Number is an essential variable for WPS and welder performance qualifications.

Steps to Find an F-Number – QW-432

Step 1: A filler metal must be produced to an AWS classification (or other national or international organizations, within an ASME specification, in order to have an F-Number assigned).
Step 2: Using QW-432 find the EXX XX that matches the filler metal being considered.
Step 3: When the EXX XX has been found, move left on this same line, to match the SFA specification number.
Step 4: On the same line as the EXX XX and the SFA specification, move left to read the F-Number.

These steps are shown in the following examples. You can proceed to answer the practice problems after the examples.

Example Q6: QW-432 – F-No.

What is the F-No. of SFA-5.1 classification E6010?

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Steel and Steel Alloys	
1	SFA-5.1	EXX20	...
1	SFA-5.1	EXX22	...
1	SFA-5.1	EXX24	...
1	SFA-5.1	EXX27	...
1	SFA-5.1	EXX28	...
1	SFA-5.4	EXXX(X)-26	...
1	SFA-5.5	EXX20-X	...
1	SFA-5.5	EXX27-X	...
2	SFA-5.1	EXX12	...
2	SFA-5.1	EXX13	...
2	SFA-5.1	EXX14	...
2	SFA-5.1	EXX19	...
2	SFA-5.5	E(X)XX13-X	...
3	SFA-5.1	EXX10	...
3	SFA-5.1	EXX11	...
3	SFA-5.5	E(X)XX10-X	...
3	SFA-5.5	E(X)XX11-X	...
4	SFA-5.1	EXX15	...
4	SFA-5.1	EXX16	...
4	SFA-5.1	EXX18	...
4	SFA-5.1	EXX18M	...
4	SFA-5.1	EXX48	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	...
4	SFA-5.5	E(X)XX15-X	...
4	SFA-5.5	E(X)XX16-X	...
4	SFA-5.5	E(X)XX18-X	...
4	SFA-5.5	E(X)XX18M	...
4	SFA-5.5	E(X)XX18M1	...
4	SFA-5.5	E(X)XX45	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	...
6	SFA-5.2	All classifications	...
6	SFA-5.9	All classifications	...
6	SFA-5.17	All classifications	...
6	SFA-5.18	All classifications	...
6	SFA-5.20	All classifications	...
6	SFA-5.22	All classifications	...
6	SFA-5.23	All classifications	...
6	SFA-5.25	All classifications	...
6	SFA-5.26	All classifications	...
6	SFA-5.28	All classifications	...
6	SFA-5.29	All classifications	...
6	SFA-5.30	INMs-X	...
6	SFA-5.30	IN5XX	...
6	SFA-5.30	IN3XX(X)	...

E8018-C1/C3 for Low Temprature -50°F

Example Q7: QW-432 – F-No.

What is the F-No. of SFA-5.1 classification E7018?

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Steel and Steel Alloys	
1	SFA-5.1	EXX20	. . .
1	SFA-5.1	EXX22	. . .
1	SFA-5.1	EXX24	. . .
1	SFA-5.1	EXX27	. . .
1	SFA-5.1	EXX28	. . .
1	SFA-5.4	EXXX(X)-26	. . .
1	SFA-5.5	EXX20-X	. . .
1	SFA-5.5	EXX27-X	. . .
2	SFA-5.1	EXX12	. . .
2	SFA-5.1	EXX13	. . .
2	SFA-5.1	EXX14	. . .
2	SFA-5.1	EXX19	. . .
2	SFA-5.5	E(X)XX13-X	. . .
3	SFA-5.1	EXX10	. . .
3	SFA-5.1	EXX11	. . .
3	SFA-5.5	E(X)XX10-X	. . .
3	SFA-5.5	E(X)XX11-X	. . .
4	SFA-5.1	EXX15	. . .
4	SFA-5.1	EXX16	. . .
4	SFA-5.1	EXX18	. . .
4	SFA-5.1	EXX18M	. . .
4	SFA-5.1	EXX48	. . .
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	. . .
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	. . .
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	. . .
4	SFA-5.5	E(X)XX15-X	. . .
4	SFA-5.5	E(X)XX16-X	. . .
4	SFA-5.5	E(X)XX18-X	. . .
4	SFA-5.5	E(X)XX18M	. . .
4	SFA-5.5	E(X)XX18M1	. . .
4	SFA-5.5	E(X)XX45	. . .
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	. . .
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	. . .
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	. . .
6	SFA-5.2	All classifications	. . .
6	SFA-5.9	All classifications	. . .
6	SFA-5.17	All classifications	. . .
6	SFA-5.18	All classifications	. . .
6	SFA-5.20	All classifications	. . .
6	SFA-5.22	All classifications	. . .
6	SFA-5.23	All classifications	. . .
6	SFA-5.25	All classifications	. . .
6	SFA-5.26	All classifications	. . .
6	SFA-5.28	All classifications	. . .
6	SFA-5.29	All classifications	. . .
6	SFA-5.30	INMs-X	. . .
6	SFA-5.30	IN5XX	. . .
6	SFA-5.30	IN3XX(X)	. . .

Practice Problem Q8: QW-432 – F-No.

What is the F-No. of SFA-5.1 classification E6020?

a) F-No. 1
b) F-No. 3
c) F-No. 4
d) F-No. 6

Practice Problem Q9: QW-432 – F-No.

What is the F-No. of SFA-5.5 classification E8018-B3L, low-alloy steel electrodes for shielded metal arc welding?

a) F-No. 1
b) F-No. 3
c) F-No. 4
d) F-No. 5

Practice Problem Q10: QW-432 – F-No.

What is the F-No. of SFA-5.17 classification F43A2-EM12K, carbon steel electrodes and fluxes for submerged arc welding?

a) F-No. 1
b) F-No. 3
c) F-No. 4
d) F-No. 6

Practice Problem Q11: QW-432 – F-No.

What is the F-No. of SFA-5.18 classification ER70S-4, carbon steel electrodes and rods for gas shielded arc welding?

a) F-No. 1
b) F-No. 3
c) F-No. 4
d) F-No. 6

A-Number (A-No.) – QW-442

QW-442 defines an A-Number as families of weld metal have been assigned A-Numbers based essentially on resultant properties of the weld metal (i.e., the filler metal and both base metals that have been mixed together by welding).

The A-Number is an essential variable for WPS, but not for welder qualification. Since the F-Number is an essential variable for welder qualification, however, the A-Number would also have to conform to changes in the F-Number.

Steps to Find an A-Number – QW-442

Step 1: Estimate the chemical composition of the completed weldment (i.e., base metal + filler metal).
Step 2: Using QW-442 find the appropriate matching chemical composition of the weldment (note that the chemical composition ranges can be very wide).
Step 3: Move to the left column to find the A-No.

These steps are shown in the following examples. You can proceed to answer the practice problems after the examples.

Example Q12: QW-442 – A-No.

What is the A-No. when welding P-No. 1 to P-No. 1 using SFA-5.1 classification E7018 (F-No. 4) filler metal?

QW-442
A-NUMBERS
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)]					
		C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	...	...	...	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40-0.65	...	1.60	1.00
3	Chrome (0.4% to 2%)-Molybdenum	0.15	0.40-2.00	0.40-0.65	...	1.60	1.00
4	Chrome (2% to 6%)-Molybdenum	0.15	2.00-6.00	0.40-1.50	...	1.60	2.00
5	Chrome (6% to 10.5%)-Molybdenum	0.15	6.00-10.50	0.40-1.50	...	1.20	2.00
6	Chrome-Martensitic	0.15	11.00-15.00	0.70	...	2.00	1.00
7	Chrome-Ferritic	0.15	11.00-30.00	1.00	...	1.00	3.00
8	Chromium-Nickel	0.15	14.50-30.00	4.00	7.50-15.00	2.50	1.00
9	Chromium-Nickel	0.30	19.00-30.00	6.00	15.00-37.00	2.50	1.00
10	Nickel to 4%	0.15	...	0.55	0.80-4.00	1.70	1.00
11	Manganese-Molybdenum	0.17	...	0.25-0.75	0.85	1.25-2.25	1.00
12	Nickel-Chromium-Molybdenum	0.15	1.50	0.25-0.80	1.25-2.80	0.75-2.25	1.00

NOTE:
(1) Single values shown above are maximum.

From QW/QB-442, P-No. 1 is carbon steel and from general knowledge SFA-5.1 classification E7018 is also carbon steel.

Example Q13: QW-442 – A-No.

What is the A-No. when welding SA-335 grade P1 using SFA-5.5 classification E7818-A1 (C-0.5Mo alloy steel) filler metal?

QW-442
A-NUMBERS
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)] C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	. . .	. . .	. . .	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40-0.65	. . .	1.60	1.00
3	Chrome (0.4% to 2%)-Molybdenum	0.15	0.40-2.00	0.40-0.65	. . .	1.60	1.00
4	Chrome (2% to 6%)-Molybdenum	0.15	2.00-6.00	0.40-1.50	. . .	1.60	2.00
5	Chrome (6% to 10.5%)-Molybdenum	0.15	6.00-10.50	0.40-1.50	. . .	1.20	2.00
6	Chrome-Martensitic	0.15	11.00-15.00	0.70	. . .	2.00	1.00
7	Chrome-Ferritic	0.15	11.00-30.00	1.00	. . .	1.00	3.00
8	Chromium-Nickel	0.15	14.50-30.00	4.00	7.50-15.00	2.50	1.00
9	Chromium-Nickel	0.30	19.00-30.00	6.00	15.00-37.00	2.50	1.00
10	Nickel to 4%	0.15	. . .	0.55	0.80-4.00	1.70	1.00
11	Manganese-Molybdenum	0.17	. . .	0.25-0.75	0.85	1.25-2.25	1.00
12	Nickel-Chromium-Molybdenum	0.15	1.50	0.25-0.80	1.25-2.80	0.75-2.25	1.00

NOTE:
(1) Single values shown above are maximum.

From QW/QB-442, SA-335 Grade P1 nominal composition is a C-0.5Mo alloy steel and the filler metal is also C-0.5Mo alloy steel.

Practice Problem Q14: QW-442 – A-No.

What is the A-No. when welding SA-240 grade 304L using SFA-5.4 classification E309L (austenitic stainless steel 18Cr-8Ni) filler metal?

a) A-No. 6
b) A-No. 7
c) A-No. 8
d) A-No. 9

Practice Problem Q15: QW-442 – A-No.

What would be the A-No. when welding an ASME SA-105 flange to SA-106 Grade B pipe, using an AWS A 5.1 E7018 electrode?

a) A-No. 1
b) A-No. 2
c) A-No. 3
d) A-No. 4

Practice Problem Q16: QW-442 – A-No.

What would be the A-No. when welding ASME SA-312 Type TP316 pipe using an AWS A 5.4 E316 electrode?

a) A-No. 1
b) A-No. 2
c) A-No. 4
d) A-No. 8

Example Q17: QW-253 SAW WPS Variable – Groove Design

For SAW, what type of variable is a change in groove design for a WPS qualification?

QW-253
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Shielded Metal-Arc Welding (SMAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	φ Groove design			X
	.4	− Backing			X
	.10	φ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	φ Group Number		X	
	.6	*T* Limits impact		X	
	.8	φ *T* Qualified	X		
	.9	*t* Pass > ½ in. (13 mm)	X		
	.11	φ P-No. qualified	X		
QW-404 Filler Metals	.4	φ F-Number	X		
	.5	φ A-Number	X		
	.6	φ Diameter			X
	.7	φ Diameter > ¼ in. (6 mm)		X	
	.12	φ Classification		X	
	.30	φ *t*	X		
	.33	φ Classification			X
QW-405 Positions	.1	+ Position			X
	.2	φ Position		X	
	.3	φ ↑↓ Vertical welding			X
QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.2	φ Preheat maint.			X
	.3	Increase > 100°F (55°C) (IP)		X	
QW-407 PWHT	.1	φ PWHT	X		
	.2	φ PWHT (T & T range)		X	
	.4	*T* Limits	X		
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.4	φ Current or polarity		X	X
	.8	φ I & E range			X
QW-410 Technique	.1	φ String/weave			X
	.5	φ Method cleaning			X
	.6	φ Method back gouge			X
	.9	φ Multiple to single pass/side		X	X
	.25	φ Manual or automatic			X
	.26	± Peening			X
	.64	Use of thermal processes	X		

Legend:
+ Addition − Deletion
> Increase/greater than < Decrease/less than
↑ Uphill ↓ Downhill
← Forehand → Backhand
φ Change

For SAW, a change in groove design for a WPS is a nonessential variable (see QW-402.1).

P Number is Parent Material Group.

QW-416
WELDING VARIABLES
Welder Performance

Paragraph[1]		Brief of Variables	Essential					
			OFW QW-352	SMAW QW-353	SAW QW-354	GMAW[2] QW-355	GTAW QW-356	PAW QW-357
QW-402 Joints	.4	− Backing		X		X	X	X
	.7	+ Backing	X					
QW-403 Base Metal	.2	Maximum qualified	X					
	.16	Φ Pipe diameter		X	X	X	X	X
	.18	Φ P-Number	X	X	X	X	X	X
QW-404 Filler Metals	.14	± Filler	X				X	X
	.15	Φ F-Number	X	X	X	X	X	X
	.22	± Inserts					X	X
	.23	t Solid or metal-cored to flux-cored					X	X
	.30	Φ t Weld deposit		X	X	X	X	X
	.31	Φ t Weld deposit	X					
	.32	t Limit (s. cir. arc)				X		
QW-405 Positions	.1	+ Position	X	X	X	X	X	X
	.3	Φ ↑↓ Vert. welding		X		X	X	X
QW-408 Gas	.7	Φ Type fuel gas	X					
	.8	− Inert backing				X	X	X
QW-409 Electrical	.2	Φ Transfer mode				X		
	.4	Φ Current or polarity					X	

Welding Processes:

OFW	Oxyfuel gas welding
SMAW	Shielded metal-arc welding
SAW	Submerged-arc welding
GMAW	Gas metal-arc welding
GTAW	Gas tungsten-arc welding
PAW	Plasma-arc welding

Legend:

Φ	Change	t	Thickness
+	Addition	↑	Uphill
−	Deletion	↓	Downhill

NOTES:

(1) For description, see Section IV.

(2) Flux-cored arc welding as shown in QW-355, with or without additional shielding from an externally supplied gas or gas mixture, is included.

QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATIONS (WPS)
(See QW-200.1, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name ______________________ By: ______________________
Welding Procedure Specification No. __________ Date __________ Supporting PQR No.(s) __________
Revision No. __________ Date __________

Welding Process(es) ______________________ Type(s) ______________________
(Automatic, Manual, Machine, or Semi-Auto)

JOINTS (QW-402) Details

Joint Design ______________________
Root Spacing ______________________
Backing: Yes __________ No __________
Backing Material (Type) ______________________
(Refer to both backing and retainers.)

☐ Metal ☐ Nonfusing Metal
☐ Nonmetallic ☐ Other

Sketches, Production Drawings, Weld Symbols or Written Description should show the general arrangement of the parts to be welded. Where applicable, the details of weld groove may be specified.

[At the option of the manufacturer, sketches may be attached to illustrate joint design, weld layers and bead sequence (e.g., for notch toughness procedures, for multiple process procedures, etc.)]

*BASE METALS (QW-403)

P-No. __________ Group No. __________ to P-No. __________ Group No. __________
OR
Specification and type/grade or UNS Number ______________________
to Specification and type/grade or UNS Number ______________________
OR
Chem. Analysis and Mech. Prop. ______________________
to Chem. Analysis and Mech. Prop. ______________________
Thickness Range:
Base Metal: Groove __________ Fillet __________
Maximum Pass Thickness ≤ ½ in. (13 mm) (Yes) ______ (No) ______
Other ______________________

*FILLER METALS (QW-404)	1	2
Spec. No. (SFA)		
AWS No. (Class)		
F-No.		
A-No.		
Size of Filler Metals		
Filler Metal Product Form		
Supplemental Filler Metal		
Weld Metal		
Thickness Range:		
Groove		
Fillet		
Electrode-Flux (Class)		
Flux Type		
Flux Trade Name		
Consumable Insert		
Other		

*Each base metal-filler metal combination should be recorded individually.

Figure 2.1 QW-482 Form - Nonmandatory Appendix B (Page 1 of 2)

QW-482 (Back)

WPS No. ______________ **Rev.** ____________

POSITIONS (QW-405)
Position(s) of Groove ____________
Welding Progression: Up ________ Down ________
Position(s) of Fillet ____________
Other ____________

POSTWELD HEAT TREATMENT (QW-407)
Temperature Range ____________
Time Range ____________
Other ____________

PREHEAT (QW-406)
Preheat Temperature, Minimum ____________
Interpass Temperature, Maximum ____________
Preheat Maintenance ____________
Other ____________
(Continuous or special heating where applicable should be recorded)

GAS (QW-408)

	Percent Composition		
	Gas(es)	(Mixture)	Flow Rate
Shielding			
Trailing			
Backing			
Other			

ELECTRICAL CHARACTERISTICS (QW-409)

Weld Pass(es)	Process	Filler Metal		Current Type and Polariy	Amps (Range)	Wire Feed Speed (Range)	Energy or Power (Range)	Volts (Range)	Travel Speed (Range)	Other (e.g., Remarks, Comments, Hot Wire Addition, Technique, Torch Angle, etc.)
		Classification	Diameter							

Amps and volts, or power or energy range, should be recorded for each electrode size, position, and thickness, etc.

Pulsing Current ____________ Heat Input (max.) ____________
Tungsten Electrode Size and Type ____________
(Pure Tungsten, 2% Thoriated, etc.)
Mode of Metal Transfer for GMAW (FCAW) ____________
(Spray Arc, Short Circuiting Arc, etc.)
Other ____________

TECHNIQUE (QW-410)
String or Weave Bead ____________
Orifice, Nozzle, or Gas Cup Size ____________
Initial and Interpass Cleaning (Brushing, Grinding, etc.) ____________
Method of Back Gouging ____________
Oscillation ____________
Contact Tube to work Distance ____________
Multiple or Single Pass (per side) ____________
Multiple or single Electrodes ____________
Electrode Spacing ____________
Peening ____________
Other ____________

Figure 2.1 QW-482 Form - Nonmandatory Appendix B (Page 2 of 2)

QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORDS (PQR)
(See QW-200.2, Section IX, ASME Boiler and Pressure Vessel Code)
Record Actual Conditions Used to Weld Test Coupon.

Company Name ______________________
Procedure Qualification Record No. ______________________ Date ______________
WPS No. ______________________
Welding Process(es) ______________________
Types (Manual, Automatic, Semi-Auto.) ______________________

JOINTS (QW-402)

Groove Design of Test Coupon
(For combination qualifications, the deposited weld metal thickness shall be recorded for each filler metal and process used.)

BASE METALS (QW-403)
Material Spec. ______________
Type/Grade, or UNS Number ______________
P-No. ____ Group No. ____ to P-No.____ Group No. ______
Thickness of Test Coupon ______________
Diameter of Test Coupon ______________
Maximum Pass Thickness ______________
Other ______________

FILLER METALS (QW-404) 1 2
SFA Specification ________ ________
AWS Specification ________ ________
Filler Metal F-No. ________ ________
Weld Metal Analysis A-No. ________ ________
Size of Filler Metal ________ ________
Filler Metal Product Form ________ ________
Supplemental Filler Metal ________ ________
Electrode Flux Classification ________ ________
Flux Type ________ ________
Flux Trade Name ________ ________
Weld Metal Thickness ________ ________
Other ________ ________

POSITION (QW-405)
Position of Groove ______________
Weld Progression (Uphill, Downhill) ______________
Other ______________

PREHEAT (QW-406)
Preheat Temp ______________
Interpass Temp ______________
Other ______________

POSTWELD HEAT TREATMENT (QW-407)
Temperature ______________
Time ______________
Other ______________

GAS (QW-408)

	Gas(es)	Percent Composition (Mixture)	Flow Rate
Shielding			
Trailing			
Backing			
Other			

ELECTRICAL CHARACTERISTICS (QW-409)
Current ______________
Polarity ______________
Amps. ______________ Volts ______________
Tungsten Electrode Size ______________
Mode of Metal Transfer for GMAW (FCAW) ______________
Heat Input ______________
Other ______________

TECHNIQUE (QW-410)
Travel Speed ______________
String or Weave Bead ______________
Oscillation ______________
Multipass or Single Pass (per side) ______________
Single or Multiple Electrodes ______________
Other ______________

Figure 2.2 QW-483 Form - Nonmandatory Appendix B (Page 1 of 2)

QW-483 (Back)

PQR No. ____________________

Tensile Test (QW-150)

Specimen No.	Width	Thickness	Area	Ultimate Total Load	Ultimate Unit Stress (psi or MPa)	Type of Failure and Location

Guided-Bend Tests (QW-160)

Type and Figure No.	Result

Toughness Tests (QW-170)

Specimen No.	Notch Location	Specimen Size	Test Temp.	Impact Values			Drop Weight Break (Y/N)
				ft-lbs or J	% Shear	Mils (in.) or mm	

Comments: ____________________

Fillet-Weld Test (QW-180)

Result - Satisfactory: Yes ________ **No** ________ **Penetration into Parent Metal: Yes** ________ **No** ________

Macro - Results ____________________

Other Tests

Type of Test ____________________
Deposit Analysis ____________________
Other ____________________

Welder's Name ____________________ Clock No. ____________ Stamp No. ____________
Tests conducted by: ____________________ Laboratory Test No. ____________
We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Manufacturer or Contractor ____________________

Date ____________________ Certified By ____________________
(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code.)

Figure 2.2 QW-483 Form - Nonmandatory Appendix B (Page 2 of 2)

Solutions

For ASME Section IX Practice Problems

Answer Key – ASME IX Practice Problems

Practice Problem	Answer	Reference Paragraph
Q2:	d	QW/QB-422
Q3:	d	QW/QB-422
Q4:	c	QW/QB-422
Q5:	c	QW/QB-422
Q8:	a	QW-432
Q9:	c	QW-432
Q10:	d	QW-432
Q11:	d	QW-432
Q14:	c	QW-442
Q15:	a	QW-442
Q16:	d	QW-442

Practice Problem Q2: QW/QB-422 – UNS No. [SOLUTION]

What is the UNS No. for ASME SA-182 Type F304?

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

				Welding		Brazing			
Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	P-No.	Group No.	P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-179	. . .	K01200	47 (325)	1	1	101	1.1	C	Smls. tube
SA-181	Cl. 60	K03502	60 (415)	1	1	101	11.1	C–Si	Pipe flange & fittings
SA-181	Cl. 70	K03502	70 (485)	1	2	101	11.1	C–Si	Pipe flange & fittings
SA-182	F12, Cl. 1	K11562	60 (415)	4	1	102	5.1	1Cr–0.5Mo	Forgings
SA-182	F12, Cl. 2	K11564	70 (485)	4	1	102	5.1	1Cr–0.5Mo	Forgings
SA-182	F11, Cl. 2	K11572	70 (485)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forgings
SA-182	F11, Cl. 3	K11572	75 (515)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forgings
SA-182	F11, Cl. 1	K11597	60 (415)	4	1	102	5.1	1.25Cr–0.5Mo–Si	Forgings
SA-182	F2	K12122	70 (485)	3	2	101	4.2	0.5Cr–0.5Mo	Forgings
SA-182	F1	K12822	70 (485)	3	2	101	1.1	C–0.5Mo	Forgings
SA-182	F22, Cl. 1	K21590	60 (415)	5A	1	102	5.2	2.25Cr–1Mo	Forgings
SA-182	F22, Cl. 3	K21590	75 (515)	5A	1	102	5.2	2.25Cr–1Mo	Forgings
SA-182	FR	K22035	63 (435)	9A	1	101	9.1	2Ni–1Cu	Forgings
SA-182	F21	K31545	75 (515)	5A	1	102	5.2	3Cr–1Mo	Forgings
SA-182	F3V	K31830	85 (585)	5C	1	102	6.2	3Cr–1Mo–V–Ti–B	Forgings
SA-182	F3VCb	. . .	85 (585)	5C	1	102	6.2	3Cr–1Mo–0.25V–Cb–Ca	Forgings
SA-182	F22V	K31835	85 (585)	5C	1	102	6.2	2.25Cr–1Mo–V	Forgings
SA-182	F5	K41545	70 (485)	5B	1	102	5.3	5Cr–0.5Mo	Forgings
SA-182	F5a	K42544	90 (620)	5B	1	102	5.3	5Cr–0.5Mo	Forgings
SA-182	F9	K90941	85 (585)	5B	1	102	5.4	9Cr–1Mo	Forgings
SA-182	F91	K90901	85 (585)	15E	1	102	6.4	9Cr–1Mo–V	Forgings
SA-182	F6a, Cl. 1	S41000	70 (485)	6	1	102	7.2	13Cr	Forgings
SA-182	F6a, Cl. 2	S41000	85 (585)	6	3	102	7.2	13Cr	Forgings
SA-182	FXM-19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Forgings
SA-182	FXM-11	S21904	90 (620)	8	3	102	8.3	21Cr–6Ni–9Mn	Forgings
SA-182	F304	S30400	70 (485)	8	1	102	8.1	18Cr–8Ni	Forgings > 5 in. (127 mm)
SA-182	F304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Forgings
SA-182	F304L	S30403	65 (450)	8	1	102	8.1	18Cr–8Ni	Forgings > 5 in. (127 mm)
SA-182	F304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Forgings
SA-182	F304H	S30409	70 (485)	8	1	102	8.1	18Cr–8Ni	Forgings > 5 in. (127 mm)
SA-182	F304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Forgings
SA-182	F304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Forgings
SA-182	F304LN	S30453	70 (485)	8	1	102	8.1	18Cr–8Ni–N	Forgings > 5 in. (127 mm)
SA-182	F304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Forgings
SA-182	F46	S30600	78 (540)	8	1	102	8.1	18Cr–15Ni–4Si	Forgings
SA-182	F45	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Forgings

Practice Problem Q3: QW/QB-422 – Minimum Specified Tensile Strength [SOLUTION]

What is the minimum specified tensile strength of ASME SA-516 Grade 70?

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

				Welding		Brazing			
Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	P-No.	Group No.	P-No.	ISO 15608 Group	Nominal Composition	Product Form
A 514	E	K21604	110 (760)	11B	2	102	3.1	1.75Cr–0.5Mo–Cu	Plate, 2½ in. (64 mm) max.
A 514	P	K21650	100 (690)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.
A 514	P	K21650	110 (760)	11B	8	102	3.1	1.25Ni–1Cr–0.5Mo	Plate, 2½ in. (64 mm) max.
A 514	Q	. . .	100 (690)	11B	9	102	3.1	1.3Ni–1.3Cr–0.5Mo–V	Plate > 2½ in.–6 in. (64 mm–152 mm), incl.
A 514	Q	. . .	110 (760)	11B	9	102	3.1	1.3Ni–1.3Cr–0.5Mo–V	Plate, 2½ in. (64 mm) max.
SA-515	60	K02401	60 (415)	1	1	101	1.1	C	Plate
SA-515	65	K02800	65 (450)	1	1	101	11.1	C–Si	Plate
SA-515	70	K03101	70 (485)	1	2	101	11.1	C–Si	Plate
SA-516	55	K01800	55 (380)	1	1	101	1.1	C–Si	Plate
SA-516	60	K02100	60 (415)	1	1	101	1.1	C–Mn–Si	Plate
SA-516	65	K02403	65 (450)	1	1	101	1.1	C–Mn–Si	Plate
SA-516	70	K02700	70 (485)	1	2	101	11.1	C–Mn–Si	Plate

Practice Problem Q4: QW/QB-422 – Nominal Composition [SOLUTION]

What is the nominal composition of ASME SA-333 Grade 6?

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-312	TP321	S32100	70 (485)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe > 3/8 in. (10 mm)
SA-312	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe ≤ 3/8 in. (10 mm)
SA-312	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe
SA-312	TP321H	S32109	70 (485)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe > 3/8 in. (10 mm)
SA-312	TP321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Smls. & welded pipe ≤ 3/8 in. (10 mm)
SA-312	TP321H	S32109	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Welded pipe
SA-312	S34565	S34565	115 (795)	8	4	102	8.3	24Cr–17Ni–6Mn–4.5Mo–N	Smls & welded pipe
SA-312	TP347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. & welded pipe
SA-312	TP347H	S34709	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. & welded pipe
SA-312	TP348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. & welded pipe
SA-312	TP348H	S34809	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Smls. & welded pipe
SA-312	TPXM–15	S38100	75 (515)	8	1	102	8.1	18Cr–18Ni–2Si	Smls. & welded pipe
SA-333	6	K03006	60 (415)	1	1	101	11.1	C–Mn–Si	Smls. & welded pipe
SA-333	1	K03008	55 (380)	1	1	101	11.1	C–Mn	Smls. & welded pipe
SA-333	10	...	80 (550)	1	3	101	11.1	C–Mn–Si	Smls. & welded pipe
SA-333	4	K11267	60 (415)	4	2	102	4.1	0.75Cr–0.75Ni–Cu–Al	Smls. & welded pipe
SA-333	7	K21903	65 (450)	9A	1	101	9.1	2.5Ni	Smls. & welded pipe

Practice Problem Q5: QW/QB-422 – Product Form [SOLUTION]

What product form is ASME SA-426 Grade CP11?

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-409	S31726	S31726	80 (550)	8	4	102	8.1	19Cr–15.5Ni–4Mo	Welded pipe
SA-409	TP321	S32100	75 (515)	8	1	102	8.1	18Cr–10Ni–Ti	Welded pipe
SA-409	TP347	S34700	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded pipe
SA-409	S34565	S34565	115 (795)	8	4	102	8.3	24Cr–17Ni–6Mn–4.5Mo–N	Welded pipe
SA-409	TP348	S34800	75 (515)	8	1	102	8.1	18Cr–10Ni–Cb	Welded pipe
SA-414	A	K01501	45 (310)	1	1	101	1.1	C	Sheet
SA-414	B	K02201	50 (345)	1	1	101	1.1	C	Sheet
SA-414	C	K02503	55 (380)	1	1	101	1.1	C	Sheet
SA-414	D	K02505	60 (415)	1	1	101	1.1	C–Mn	Sheet
SA-414	E	K02704	65 (450)	1	1	101	11.1	C–Mn	Sheet
SA-414	F	K03102	70 (485)	1	2	101	11.1	C–Mn	Sheet
SA-414	G	K03103	75 (515)	1	2	101	11.1	C–Mn	Sheet
SA-420	WPL6	K03006	60 (415)	1	1	101	11.1	C–Mn–Si	Piping fitting
SA-420	WPL9	K22035	63 (435)	9A	1	101	9.1	2Ni–1Cu	Piping fitting
SA-420	WPL3	K31918	65 (450)	9B	1	101	9.2	3.5Ni	Piping fitting
SA-420	WPL8	K81340	100 (690)	11A	1	101	9.3	9Ni	Piping fitting
SA-423	1	K11535	60 (415)	4	2	102	5.1	0.75Cr–0.5Ni–Cu	Smls. & welded tube
SA-423	2	K11540	60 (415)	4	2	102	5.1	0.75Ni–0.5Cu–Mo	Smls. & welded tube
SA-426	CP15	J11522	60 (415)	3	1	101	1.1	C–0.5Mo–Si	Centrifugal cast pipe
SA-426	CP2	J11547	60 (415)	3	1	101	4.2	0.5Cr–0.5Mo	Centrifugal cast pipe
SA-426	CP12	J11562	60 (415)	4	1	102	5.1	1Cr–0.5Mo	Centrifugal cast pipe
SA-426	CP11	J12072	70 (485)	4	1	102	5.1	1.25Cr–0.5Mo	Centrifugal cast pipe
SA-426	CP1	J12521	65 (450)	3	1	101	1.1	C–0.5Mo	Centrifugal cast pipe
SA-426	CP22	J21890	70 (485)	5A	1	102	5.2	2.25Cr–1Mo	Centrifugal cast pipe
SA-426	CP21	J31545	60 (415)	5A	1	102	5.2	3Cr–1Mo	Centrifugal cast pipe
SA-426	CP5	J42045	90 (620)	5B	1	102	5.3	5Cr–0.5Mo	Centrifugal cast pipe
SA-426	CP5b	J51545	60 (415)	5B	1	102	5.3	5Cr–1.5Si–0.5Mo	Centrifugal cast pipe
SA-426	CP9	J82090	90 (620)	5B	1	102	5.4	9Cr–1Mo	Centrifugal cast pipe
SA-426	CPCA15	J91150	90 (620)	6	3	102	7.2	13Cr	Centrifugal cast pipe
SA-451	CPF8	J92600	70 (485)	8	1	102	8.1	18Cr–8Ni	Centrifugal cast pipe
SA-451	CPF8A	J92600	77 (530)	8	1	102	8.1	18Cr–8Ni	Centrifugal cast pipe
SA-451	CPF8C	J92710	70 (485)	8	1	102	8.1	18Cr–10Ni–Cb	Centrifugal cast pipe
SA-451	CPF8M	J92900	70 (485)	8	1	102	8.1	18Cr–12Ni–2Mo	Centrifugal cast pipe
SA-451	CPF3	J92500	70 (485)	8	1	102	8.1	18Cr–8Ni	Centrifugal cast pipe
SA-451	CPF3M	J92800	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Centrifugal cast pipe
SA-451	CPF3A	J92500	77 (530)	8	1	102	8.1	18Cr–8Ni	Centrifugal cast pipe

Practice Problem Q8: QW-432 – F-No. [SOLUTION]

What is the F-No. of SFA-5.1 classification E6020?

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Steel and Steel Alloys	
1	SFA-5.1	EXX20	. . .
1	SFA-5.1	EXX22	. . .
1	SFA-5.1	EXX24	. . .
1	SFA-5.1	EXX27	. . .
1	SFA-5.1	EXX28	. . .
1	SFA-5.4	EXXX(X)-26	. . .
1	SFA-5.5	EXX20-X	. . .
1	SFA-5.5	EXX27-X	. . .
2	SFA-5.1	EXX12	. . .
2	SFA-5.1	EXX13	. . .
2	SFA-5.1	EXX14	. . .
2	SFA-5.1	EXX19	. . .
2	SFA-5.5	E(X)XX13-X	. . .
3	SFA-5.1	EXX10	. . .
3	SFA-5.1	EXX11	. . .
3	SFA-5.5	E(X)XX10-X	. . .
3	SFA-5.5	E(X)XX11-X	. . .
4	SFA-5.1	EXX15	. . .
4	SFA-5.1	EXX16	. . .
4	SFA-5.1	EXX18	. . .
4	SFA-5.1	EXX18M	. . .
4	SFA-5.1	EXX48	. . .
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	. . .
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	. . .
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	. . .
4	SFA-5.5	E(X)XX15-X	. . .
4	SFA-5.5	E(X)XX16-X	. . .
4	SFA-5.5	E(X)XX18-X	. . .
4	SFA-5.5	E(X)XX18M	. . .
4	SFA-5.5	E(X)XX18M1	. . .
4	SFA-5.5	E(X)XX45	. . .
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	. . .
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	. . .
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	. . .
6	SFA-5.2	All classifications	. . .
6	SFA-5.9	All classifications	. . .
6	SFA-5.17	All classifications	. . .
6	SFA-5.18	All classifications	. . .
6	SFA-5.20	All classifications	. . .
6	SFA-5.22	All classifications	. . .
6	SFA-5.23	All classifications	. . .
6	SFA-5.25	All classifications	. . .
6	SFA-5.26	All classifications	. . .
6	SFA-5.28	All classifications	. . .
6	SFA-5.29	All classifications	. . .
6	SFA-5.30	INMs-X	. . .
6	SFA-5.30	IN5XX	. . .
6	SFA-5.30	IN3XX(X)	. . .

Practice Problem Q9: QW-432 – F-No. [SOLUTION]

What is the F-No. of SFA-5.5 classification E8018-B3L, low-alloy steel electrodes for shielded metal arc welding?

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
	Steel and Steel Alloys		
1	SFA-5.1	EXX20	...
1	SFA-5.1	EXX22	...
1	SFA-5.1	EXX24	...
1	SFA-5.1	EXX27	...
1	SFA-5.1	EXX28	...
1	SFA-5.4	EXXX(X)-26	...
1	SFA-5.5	EXX20-X	...
1	SFA-5.5	EXX27-X	...
2	SFA-5.1	EXX12	...
2	SFA-5.1	EXX13	...
2	SFA-5.1	EXX14	...
2	SFA-5.1	EXX19	...
2	SFA-5.5	E(X)XX13-X	...
3	SFA-5.1	EXX10	...
3	SFA-5.1	EXX11	...
3	SFA-5.5	E(X)XX10-X	...
3	SFA-5.5	E(X)XX11-X	...
4	SFA-5.1	EXX15	...
4	SFA-5.1	EXX16	...
4	SFA-5.1	EXX18	...
4	SFA-5.1	EXX18M	...
4	SFA-5.1	EXX48	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	...
4	SFA-5.5	E(X)XX15-X	...
4	SFA-5.5	E(X)XX16-X	...
4	SFA-5.5	E(X)XX18-X	...
4	SFA-5.5	E(X)XX18M	...
4	SFA-5.5	E(X)XX18M1	...
4	SFA-5.5	E(X)XX45	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	...
6	SFA-5.2	All classifications	...
6	SFA-5.9	All classifications	...
6	SFA-5.17	All classifications	...
6	SFA-5.18	All classifications	...
6	SFA-5.20	All classifications	...
6	SFA-5.22	All classifications	...
6	SFA-5.23	All classifications	...
6	SFA-5.25	All classifications	...
6	SFA-5.26	All classifications	...
6	SFA-5.28	All classifications	...
6	SFA-5.29	All classifications	...
6	SFA-5.30	INMs-X	...
6	SFA-5.30	IN5XX	...
6	SFA-5.30	IN3XX(X)	...

Practice Problem Q10: QW-432 – F-No. [SOLUTION]

What is the F-No. of SFA-5.17 classification F43A2-EM12K, carbon steel electrodes and fluxes for submerged arc welding?

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Steel and Steel Alloys	
1	SFA-5.1	EXX20	. . .
1	SFA-5.1	EXX22	. . .
1	SFA-5.1	EXX24	. . .
1	SFA-5.1	EXX27	. . .
1	SFA-5.1	EXX28	. . .
1	SFA-5.4	EXXX(X)-26	. . .
1	SFA-5.5	EXX20-X	. . .
1	SFA-5.5	EXX27-X	. . .
2	SFA-5.1	EXX12	. . .
2	SFA-5.1	EXX13	. . .
2	SFA-5.1	EXX14	. . .
2	SFA-5.1	EXX19	. . .
2	SFA-5.5	E(X)XX13-X	. . .
3	SFA-5.1	EXX10	. . .
3	SFA-5.1	EXX11	. . .
3	SFA-5.5	E(X)XX10-X	. . .
3	SFA-5.5	E(X)XX11-X	. . .
4	SFA-5.1	EXX15	. . .
4	SFA-5.1	EXX16	. . .
4	SFA-5.1	EXX18	. . .
4	SFA-5.1	EXX18M	. . .
4	SFA-5.1	EXX48	. . .
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	. . .
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	. . .
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	. . .
4	SFA-5.5	E(X)XX15-X	. . .
4	SFA-5.5	E(X)XX16-X	. . .
4	SFA-5.5	E(X)XX18-X	. . .
4	SFA-5.5	E(X)XX18M	. . .
4	SFA-5.5	E(X)XX18M1	. . .
4	SFA-5.5	E(X)XX45	. . .
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	. . .
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	. . .
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	. . .
6	SFA-5.2	All classifications	. . .
6	SFA-5.9	All classifications	. . .
6	SFA-5.17	All classifications	. . .
6	SFA-5.18	All classifications	. . .
6	SFA-5.20	All classifications	. . .
6	SFA-5.22	All classifications	. . .
6	SFA-5.23	All classifications	. . .
6	SFA-5.25	All classifications	. . .
6	SFA-5.26	All classifications	. . .
6	SFA-5.28	All classifications	. . .
6	SFA-5.29	All classifications	. . .
6	SFA-5.30	INMs-X	. . .
6	SFA-5.30	IN5XX	. . .
6	SFA-5.30	IN3XX(X)	. . .

Practice Problem Q11: QW-432 – F-No. [SOLUTION]

What is the F-No. of SFA-5.18 classification ER70S-4, carbon steel electrodes and rods for gas shielded arc welding?

QW-432
F-NUMBERS
Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification	UNS No.
		Steel and Steel Alloys	
1	SFA-5.1	EXX20	...
1	SFA-5.1	EXX22	...
1	SFA-5.1	EXX24	...
1	SFA-5.1	EXX27	...
1	SFA-5.1	EXX28	...
1	SFA-5.4	EXXX(X)-26	...
1	SFA-5.5	EXX20-X	...
1	SFA-5.5	EXX27-X	...
2	SFA-5.1	EXX12	...
2	SFA-5.1	EXX13	...
2	SFA-5.1	EXX14	...
2	SFA-5.1	EXX19	...
2	SFA-5.5	E(X)XX13-X	...
3	SFA-5.1	EXX10	...
3	SFA-5.1	EXX11	...
3	SFA-5.5	E(X)XX10-X	...
3	SFA-5.5	E(X)XX11-X	...
4	SFA-5.1	EXX15	...
4	SFA-5.1	EXX16	...
4	SFA-5.1	EXX18	...
4	SFA-5.1	EXX18M	...
4	SFA-5.1	EXX48	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	...
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	...
4	SFA-5.5	E(X)XX15-X	...
4	SFA-5.5	E(X)XX16-X	...
4	SFA-5.5	E(X)XX18-X	...
4	SFA-5.5	E(X)XX18M	...
4	SFA-5.5	E(X)XX18M1	...
4	SFA-5.5	E(X)XX45	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-15	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-16	...
5	SFA-5.4 austenitic and duplex	EXXX(X)-17	...
6	SFA-5.2	All classifications	...
6	SFA-5.9	All classifications	...
6	SFA-5.17	All classifications	...
6	SFA-5.18	All classifications	...
6	SFA-5.20	All classifications	...
6	SFA-5.22	All classifications	...
6	SFA-5.23	All classifications	...
6	SFA-5.25	All classifications	...
6	SFA-5.26	All classifications	...
6	SFA-5.28	All classifications	...
6	SFA-5.29	All classifications	...
6	SFA-5.30	INMs-X	...
6	SFA-5.30	IN5XX	...
6	SFA-5.30	IN3XX(X)	...

Practice Problem Q14: QW-442 – A-No. [SOLUTION]

What is the A-No. when welding SA-240 grade 304L using SFA-5.4 classification E309L (austenitic stainless steel 18Cr-8Ni) filler metal?

QW-442
A-NUMBERS
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)] C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	. . .	. . .	. .	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40-0.65	. . .	1.60	1.00
3	Chrome (0.4% to 2%)-Molybdenum	0.15	0.40-2.00	0.40-0.65	. . .	1.60	1.00
4	Chrome (2% to 6%)-Molybdenum	0.15	2.00-6.00	0.40-1.50	. . .	1.60	2.00
5	Chrome (6% to 10.5%)-Molybdenum	0.15	6.00-10.50	0.40-1.50	. . .	1.20	2.00
6	Chrome-Martensitic	0.15	11.00-15.00	0.70	. . .	2.00	1.00
7	Chrome-Ferritic	0.15	11.00-30.00	1.00	. . .	1.00	3.00
8	Chromium-Nickel	0.15	14.50-30.00	4.00	7.50-15.00	2.50	1.00
9	Chromium-Nickel	0.30	19.00-30.00	6.00	15.00-37.00	2.50	1.00
10	Nickel to 4%	0.15	. . .	0.55	0.80-4.00	1.70	1.00
11	Manganese-Molybdenum	0.17	. . .	0.25-0.75	0.85	1.25-2.25	1.00
12	Nickel-Chromium-Molybdenum	0.15	1.50	0.25-0.80	1.25-2.80	0.75-2.25	1.00

NOTE:
(1) Single values shown above are maximum.

Practice Problem Q15: QW-422 – A-No. [SOLUTION]

What would be the A-No. when welding an ASME SA-105 flange to SA-106 Grade B pipe, using an AWS A 5.1 E7018 electrode?

ASME SA-105 can be found in Table QW/QB-422.

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS
Grouping of Base Metals for Qualification

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-36	...	K02600	58 (400)	1	1	101	11.1	C–Mn–Si	Plate, bar & shapes
SA-53	Type F	...	48 (330)	1	1	101	11.1	C	Furnace welded pipe
SA-53	Type S, Gr. A	K02504	48 (330)	1	1	101	11.1	C	Smls. pipe
SA-53	Type E, Gr. A	K02504	48 (330)	1	1	101	11.1	C	Resistance welded pipe
SA-53	Type E, Gr. B	K03005	60 (415)	1	1	101	11.1	C–Mn	Resistance welded pipe
SA-53	Type S, Gr. B	K03005	60 (415)	1	1	101	11.1	C–Mn	Smls. pipe
SA-105	...	K03504	70 (485)	1	2	101	11.1	C	Flanges & fittings
SA-106	A	K02501	48 (330)	1	1	101	1.1	C–Si	Smls. pipe
SA-106	B	K03006	60 (415)	1	1	101	11.1	C–Mn–Si	Smls. pipe
SA-106	C	K03501	70 (485)	1	2	101	11.1	C–Mn–Si	Smls. pipe

The A-No. can be found in Table QW-442.

QW-442
A-NUMBERS
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)] C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	...	...	...	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40–0.65	...	1.60	1.00
3	Chrome (0.4% to 2%)–Molybdenum	0.15	0.40–2.00	0.40–0.65	...	1.60	1.00
4	Chrome (2% to 4%)–Molybdenum	0.15	2.00–4.00	0.40–1.50	...	1.60	2.00
5	Chrome (4% to 10.5%)–Molybdenum	0.15	4.00–10.50	0.40–1.50	...	1.20	2.00
6	Chrome-Martensitic	0.15	11.00–15.00	0.70	...	2.00	1.00
7	Chrome-Ferritic	0.15	11.00–30.00	1.00	...	1.00	3.00
8	Chromium–Nickel	0.15	14.50–30.00	4.00	7.50–15.00	2.50	1.00
9	Chromium–Nickel	0.30	19.00–30.00	6.00	15.00–37.00	2.50	1.00
10	Nickel to 4%	0.15	...	0.55	0.80–4.00	1.70	1.00
11	Manganese–Molybdenum	0.17	...	0.25–0.75	0.85	1.25–2.25	1.00
12	Nickel–Chrome—Molybdenum	0.15	1.50	0.25–0.80	1.25–2.80	0.75–2.25	1.00

NOTE:
(1) Single values shown above are maximum.

Practice Problem Q16: QW-422 – A-No. [SOLUTION]

What would be the A-No. when welding ASME SA-312 Type TP316 pipe using an AWS A 5.4 E316 electrode?

ASME SA-312 Type TP316 can be found in Table QW/QB-422.

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS (CONT'D)
Grouping of Base Metals for Qualification

Ferrous (CONT'D)

Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	Welding P-No.	Welding Group No.	Brazing P-No.	ISO 15608 Group	Nominal Composition	Product Form
SA-302	A	K12021	75 (515)	3	2	101	1.1	Mn–0.5Mo	Plate
SA-302	B	K12022	80 (550)	3	3	101	1.2	Mn–0.5Mo	Plate
SA-302	C	K12039	80 (550)	3	3	101	...	Mn–0.5Mo–0.5Ni	Plate
SA-302	D	K12054	80 (550)	3	3	101	...	Mn–0.5Mo–0.75Ni	Plate
SA-312	TPXM–19	S20910	100 (690)	8	3	102	8.3	22Cr–13Ni–5Mn	Smls. & welded pipe
SA-312	TPXM–11	S21904	90 (620)	8	3	102	8.3	21Cr–6Ni–9Mn	Smls. & welded pipe
SA-312	TPXM–29	S24000	100 (690)	8	3	102	8.3	18Cr–3Ni–12Mn	Smls. & welded pipe
SA-312	TP304	S30400	75 (515)	8	1	102	8.1	18Cr–8Ni	Smls. & welded pipe
SA-312	TP304L	S30403	70 (485)	8	1	102	8.1	18Cr–8Ni	Smls. & welded pipe
SA-312	TP304H	S30409	75 (515)	8	1	102	8.1	18Cr–8Ni	Smls. & welded pipe
SA-312	TP304N	S30451	80 (550)	8	1	102	8.1	18Cr–8Ni–N	Smls. & welded pipe
SA-312	TP304LN	S30453	75 (515)	8	1	102	8.1	18Cr–8Ni–N	Smls. & welded pipe
SA-312	S30600	S30600	78 (540)	8	1	102	8.1	18Cr–15Ni–4Si	Smls. & welded pipe
SA-312	S30815	S30815	87 (600)	8	2	102	8.2	21Cr–11Ni–N	Smls. & welded pipe
SA-312	S32615	S32615	80 (550)	8	1	102	8.1	18Cr–20Ni–5.5Si	Smls. & welded pipe
SA-312	TP309S	S30908	75 (515)	8	2	102	8.2	23Cr–12Ni	Smls. & welded pipe
SA-312	TP309H	S30909	75 (515)	8	2	102	8.2	23Cr–12Ni	Smls. & welded pipe
SA-312	TP309Cb	S30940	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Smls. & welded pipe
SA-312	TP309HCb	S30941	75 (515)	8	2	102	8.2	23Cr–12Ni–Cb	Smls. & welded pipe
SA-312	TP310S	S31008	75 (515)	8	2	102	8.2	25Cr–20Ni	Smls. & welded pipe
SA-312	TP310H	S31009	75 (515)	8	2	102	8.2	25Cr–20Ni	Smls. & welded pipe
SA-312	TP310Cb	S31040	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Smls. & welded pipe
SA-312	TP310HCb	S31041	75 (515)	8	2	102	8.2	25Cr–20Ni–Cb	Smls. & welded pipe
SA-312	TP310MoLN	S31050	78 (540)	8	2	102	8.2	25Cr–22Ni–2Mo–N	Smls. & welded pipe, $t > \frac{1}{4}$ in. (6 mm)
SA-312	TP310MoLN	S31050	84 (580)	8	2	102	8.2	25Cr–22Ni–2Mo–N	Smls. & welded pipe, $t \leq \frac{1}{4}$ in. (6 mm)
SA-312	S31254	S31254	95 (655)	8	4	102	8.2	20Cr–18Ni–6Mo	Smls. & welded pipe, $t > \frac{3}{16}$ in. (5 mm)
SA-312	S31254	S31254	98 (675)	8	4	102	8.2	20Cr–18Ni–6Mo	Smls. & welded pipe, $t \leq \frac{3}{16}$ in. (5 mm)
SA-312	TP316	S31600	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. & welded pipe
SA-312	TP316L	S31603	70 (485)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. & welded pipe
SA-312	TP316H	S31609	75 (515)	8	1	102	8.1	16Cr–12Ni–2Mo	Smls. & welded pipe

The A-No. can be found in Table QW-442.

QW-442
A-NUMBERS
Classification of Ferrous Weld Metal Analysis for Procedure Qualification

A-No.	Types of Weld Deposit	Analysis, % [Note (1)] C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.20	...	...	...	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40–0.65	...	1.60	1.00
3	Chrome (0.4% to 2%)–Molybdenum	0.15	0.40–2.00	0.40–0.65	...	1.60	1.00
4	Chrome (2% to 4%)–Molybdenum	0.15	2.00–4.00	0.40–1.50	...	1.60	2.00
5	Chrome (4% to 10.5%)–Molybdenum	0.15	4.00–10.50	0.40–1.50	...	1.20	2.00
6	Chrome-Martensitic	0.15	11.00–15.00	0.70	...	2.00	1.00
7	Chrome-Ferritic	0.15	11.00–30.00	1.00	...	1.00	3.00
8	Chromium–Nickel	0.15	14.50–30.00	4.00	7.50–15.00	2.50	1.00
9	Chromium–Nickel	0.30	19.00–30.00	6.00	15.00–37.00	2.50	1.00
10	Nickel to 4%	0.15	...	0.55	0.80–4.00	1.70	1.00
11	Manganese–Molybdenum	0.17	...	0.25–0.75	0.85	1.25–2.25	1.00
12	Nickel–Chrome—Molybdenum	0.15	1.50	0.25–0.80	1.25–2.80	0.75–2.25	1.00

NOTE:
(1) Single values shown above are maximum.

WPS/PQR Review # CS-2
Practice Problems

QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATION (WPS)
(See QW-200.1, Section IX, ASME Boiler & Pressure Vessel Code)

Company Name: Company Inc. **By:** Pea Green
Welding Procedure Spec. No.: *CS-2* **Date:** 09-10-13 **Supporting PQR No. (s):** CS-2, Rev. 0
WPS Revision No.: Rev. 0 **Rev. Date:** 09-10-13
Welding Process(s): SMAW **Type(s):** Manual
(Automatic, Manual, Machine, or Semi-Auto)

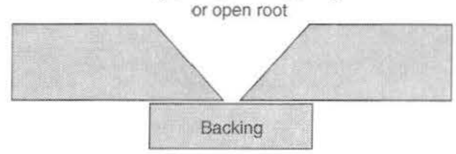
JOINTS (QW-402)

Joint Design: ______
Backing: (Yes) X **(No)** X
Backing Material: (Type): SA-516 – Gr. 70
(Refer to both backing & retainers)

X **Metal** ___ **Nonfusing Metal**
___ **Nonmetallic** ___ **Other**
No nonmetallic retainers permitted.

Joint Design

Single "V"
may be used with backing
or open root



Root spacing for open root: $\frac{3}{32}$" ± $\frac{1}{32}$"
Root spacing with backing: $\frac{1}{8}$" ± $\frac{1}{8}$"

*BASE METALS (QW-403)

P-No. 1 **Group No.** 1, 2 and 3 **to P-No.** 1 **Group No.** 1, 2 and 3
OR
Specification type and grade ______
to Specification type and grade ______
OR
Chem. Analysis and Mech. Prop. ______
to Chem. Analysis and Mech. Prop. ______

Thickness range:

Base Metal:	**Groove:**	0.188 in. to 1.5 in.	**Fillet:**	All
Pipe Dia. Range:	**Groove:**	All	**Fillet:**	All

* FILLER METALS (QW-404)

Spec. No. (SFA):	5.1		
AWS No. (Class):	E7018		
Filler Metal F-No.:	F-No. 4		
Chem. Comp. - A No.:	A-No. 1		
Size of Filler Metals:	3/32 in., 1/8 in., 5/32 in.		

Weld Metal
Thickness range: **Note: single pass thickness 0.500 in. maximum.**

Groove:	1.5 in. maximum		
Fillet:	all sizes		
Electrode-Flux (Class):			
Flux Trade Name:			
Consumable Insert:			
Other:			

* Each base metal-filler metal combination should be recorded individually.

QW-482 (Back)

WPS No.: CS-2 Rev. No.: 0

POSITIONS (QW-405)

Position(s) of Groove: ALL
Welding Progression: Up X Down X
Positions(s) of Fillet: ALL

POSTWELD HEAT TREATMENT (QW-407)

Temperature Range: No PWHT
Time Range: No PWHT

PREHEAT (QW-406)

Preheat Temp. Min.: 175°F
Interpass Temp. Max.:
Preheat Maint.: None

(Continuous or special heating where applicable should be recorded.)

GAS ((QW-408)

Percent Composition:

	Gas(es)	(Mixture)	Flow Rate
Shielding:			
Trailing:			
Backing:			

ELECTRICAL CHARACTERISTICS (QW-409)

Current AC or DC: DC Polarity: Reverse
Amps Range: 75 to 200 Volts (Range): 18 to 30

(Amps and volts range should be recorded for each electrode size, position, and thickness, etc. This information may be listed in a tabular form similar to that shown below.)

Tungsten Electrode Size and Type
(Pure Tungsten, 2% Thoriated, etc.)

Mode of metal Transfer for GMAW
(Spray arc, short circuiting arc, etc.)

Electrode Wire feed speed range

TECHNIQUE (QW-410)

String or Weave Bead: String or Weave; with weave not greater than 3 times electrode diameter
Orifice or Gas Cup Size:
Initial and Interpass Cleaning (Brushing, Grinding, etc.): Brush, grind, file as required
Note: weld preparation must be cleaned at least 1 in. back from weld surfaces
Method of Back Gouging: grinding or arc gouging allowed
Oscillation:
Contact Tube to Work Distance:
Multiple or Single Pass (per side): Multiple
Multiple or Single Electrodes: Single
Travel Speed (Range):
Peening: Strictly no peening allowed
Other:

Weld Layer(s)	Process	Class	Filler Metal		Current		Travel Speed Range	Other (e.g., Remarks, Comments, Hot Wire, Technique, Torch Angle, etc.)
			Dia.	Type Polar.	Amp Range	Volt Range		
ALL	SMAW	E-7018	3/32 in.	DC - RP	75 to 115	18 - 21		
ALL	SMAW	E-7018	1/8 in.	DC - RP	100 to 150	20 - 25		
ALL	SMAW	E-7018	5/32 in.	DC - RP	150 to 200	20 - 28		

QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORDS (PQR)
(See QW-200.2, Section IX, ASME Boiler and Pressure vessel Code)
Record Actual Conditions Used to Weld Test Coupon

Company Name: Company Inc.
Procedure Qualification Record No.: CS-2, Rev. 0 **Date:** 09-10-13
WPS No.: CS-2 Rev. 0
Welding Process(s): SMAW
Types (Manual, Automatic, Semi-Auto.): MANUAL

JOINTS (QW-402)

Groove Design of Test Coupon
(For combination qualifications, the deposited weld metal thickness shall be recorded for each filler metal or process used.)

BASE METALS (QW-403)
Material Spec.: SA-516
Type or Grade: Grade 70
P-No.: 1 **to P-No.:** 1
Thickness of Test Coupon: 0.750 in.
Diameter of Test Coupon: Plate
Other:

FILLER METALS (QW-404)
SFA Specification: 5.1
AWS Classification: E6010
Filler Metal F No.: 4
Weld metal Analysis No.: 1
Size of Filler metal: 1/8 in. and 5/32 in. diameter
Other:

Weld Metal Thickness: 0.750 in.
Note: No single pass > 3/8 in.

POSITION (QW-405)
Position of Groove: 1G
Weld Progression (Uphill, Downhill): N/A
Other:

PREHEAT (QW-406)
Preheat Temp.: 200°F minimum
Interpass temp.:
Other:

POSTWELD HEAT TREATMENT (QW-407)
Temperature: None performed
Time:
Other:

GAS (QW-408)

	Gas(es)	Percent Composition (Mixture)	Flow Rate
Shielding:			
Trailing:			
Backing:			

ELECTRICAL CHARACTERISTICS (QW-409)
Current: not recorded
Polarity: not recorded
Amps.: not recorded **Volts:** not recorded
Tungsten Electrode Size:
Other:

TECHNIQUE (QW-410)
Travel Speed: not recorded
String or Weave Bead: string root pass (see Other)
Oscillation:
Multipass or Single Pass (per side):
Single or Multiple Electrodes:
Other: weave limited to 3 times electrode diameter
no peening done.

QW-483 (Back)

PQR No.: CS-2 Rev. 0

Tensile Test (QW-150)

Specimen No.	Width	Thickness	Area	Ultimate Total Load Lb.	Ultimate Unit Stress psi	Type of Failure & Location
1	0.755	0.749	0.565	40,555	71,779	Weld Metal
2	0.752	0.748	0.562	37,173	66,575	*Base Metal

*Specimen 2 fractured in the base metal outside the weld and weld interface.

Guided Bend Tests (QW-160)

Type and Figure No.	Result
Side Bend per QW-462.2	5/32 in. open discontinuity on one corner of specimen, no sign of internal discontinuity
Side Bend per QW-462.2	No discontinuity
Side Bend per QW-462.2	3/32 in. discontinuity in the heat affected zone
Side Bend per QW-462.2	No discontinuity

Toughness Tests (QW-170)

Specimen No.	Notch Location	Specimen Size	Test Temp.	Impact Values			Drop Weight Break (Y/N)
				Ft. Lbs.	% Shear	Mils	

Comments: no impact testing performed

Fillet Weld Test (QW-180)

Result --- Satisfactory: Yes: ______ **No:** ______ **Penetration Into Parent Metal: Yes:** ______ **No:** ______

Macro --- Results: ______

Other Tests

Type of Test: ______

Deposit Analysis: ______

Other: ______

Welder's Name: Pierrine Nau **Clock No.:** 00ZE **Stamp No.:** PN

Tests conducted by: Pea Green **Laboratory Test No.:** 091013

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Code.

Organization: Company Inc.

Date: 09-10-13 **By:** Bill Smith

Practice Problem 1: WPS # CS-2 – Joint Design QW-402

Are the joint design variables (QW-402) properly addressed on the WPS and PQR to meet ASME Sec. IX?

a) No, must also list the welding pass sequence for each electrode size.
b) No, angle of V-groove is not specified.
c) No, backing size is not specified.
d) Yes.

Practice Problem 2: WPS # CS-2 – Base Metal P-No. QW-403, QW-420, and QW/QB-422

Does the PQR support the WPS with the base metal P-No. qualified?

a) No, the Group Number is not listed in the PQR.
b) No, the Group Number 4 is not listed in the WPS.
c) No, SA-516 grade 70 is not a P-No. 1 material.
d) Yes.

Practice Problem 3: WPS # CS-2 – Weld Metal F-No. QW-404, QW-430, QW-432

Does the PQR support the WPS with the weld metal F-No. qualified?

a) No, the SFA number is incorrect on the PQR.
b) No, the electrode AWS classification is incorrect on the PQR.
c) No, the A-No is incorrect.
d) No, since SFA 5.1 classification E6010 is not a F-No. 4.

Practice Problem 4: WPS # CS-2 – Weld Metal A-No. QW-442

Does the PQR support the WPS with the A-No. qualified?

a) No, the WPS specifies an A-No. of 4
b) No, the WPS specifies an A-No. of 1
c) No, an A-No. is not given in the PQR
d) Yes, the A-No. is correct.

Practice Problem 5: WPS # CS-2 – Base Metal Thickness (T) QW-403 and QW-451.1

Does the PQR support the WPS with the base metal thickness range qualified?

a) No, it should be 1/16 in. to 1.5 in.
b) No, it should be 3/16 in. to 0.750 in.
c) No, it should be 0.750 in maximum only.
d) Yes.

Practice Problem 6: WPS # CS-2 – Individual Weld Metal Pass QW-403.9

Does the PQR support the WPS with the individual weld pass thickness requirement?

a) No, the minimum value of 3/16 in. is not supported.
b) No, the maximum thickness of 1.5 in. is not supported.
c) No, the thickness range is not supported.
d) Yes.

Practice Problem 7: WPS # CS-2 – Weld Metal Thickness (t) QW-404 and QW-451.1

Does the PQR support the WPS with the weld metal thickness range qualified?

a) No, the WPS minimum value was exceed.
b) No, the PQR value was too low.
c) No, both the WPS and PQR values must be identical.
d) Yes.

Practice Problem 8: WPS # CS-2 – Fillet Weld Size QW-403 and QW-451.4

Does the PQR support the WPS for fillet weld sizes qualified?

a) No, since a fillet weld coupon was not used in the PQR.
b) No, fillet weld size should be limited to 1/16 in. to 1.5 in.
c) No, fillet weld size should be limited to 3/16 in. to 1.5 in.
d) Yes.

Practice Problem 9: WPS # CS-2 – Welding Position QW-405 and QW-461.3

Does the PQR support the WPS with the welding position qualified?

a) No, since the 1G position in the PQR does not support all positions listed in the WPS.
b) No, since only the 6G position can qualify all positions.
c) No, since only the 2G, 3G, and 4G positions together can qualify all positions.
d) Yes, since position is not an essential variable for WPS qualification.

Practice Problem 10: WPS # CS-2 – Welding Preheat QW-406

Does the PQR support the WPS with the preheat qualified?

a) No, since the PQR preheat was higher than allowed in the WPS.
b) No, since the WPS and PQR preheats need to be identical.
c) No, since the interpass temperature was not recorded on the PQR.
d) Yes, since the PQR preheat temperature was above the minimum required in the WPS.

Practice Problem 11: WPS # CS-2 – PWHT QW-407.1

Does the PQR support the WPS with the PWHT?

a) No, PWHT is required.
b) No, PWHT is required for thickness above 0.750 in.
c) No, PWHT is required for thickness above 1.0 in.
d) Yes.

Practice Problem 12: WPS # CS-2 – Electrical Characteristics QW-409

Does the PQR support the WPS with the electrical characteristics variables qualified?

a) No, since amperage was not recorded.
b) No, since voltage was not recorded.
c) No, since both amperage and voltage were not recorded.
d) Yes, since electrical characteristics are nonessential variables for SMAW.

Practice Problem 13: WPS # CS-2 – Technique QW-410

Does the PQR support the WPS with the technique variables qualified?

a) No, since the travel speed was not recorded.
b) No, since oscillation was not recorded.
c) No, since the PQR weave technique did not meet the WPS requirements.
d) Yes, since technique variables are nonessential variables for SMAW, although the weave requirement was met.

Practice Problem 14: WPS # CS-2 – Tensile Test QW-153.1(d) and QW-451.1

Does the PQR support the WPS with the tensile test results?

a) No, specimen number 1 failed in the weld metal.
b) No, specimen number 2 was below the minimum specified tensile strength (70,000 psi).
c) Yes, the tensile tests are acceptable.
d) No, specimen number 2 was below the 5% tolerance of the minimum specified tensile strength (66,500 psi).

Practice Problem 15: WPS # CS-2 – Guided Bend Tests QW-163 and QW-451.1

Does the PQR support the WPS with the guided bend test results?

a) No, 2 face and two root bend should have been tested.
b) No, since the 3/32 in. defect in the heat affected zone is unacceptable.
c) No, since the 5/32 in. defect on the corner is unacceptable.
d) Yes.