
Pressure Vessel Newsletter

Volume 2016, January Issue



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From The Editor's Desk:



New Year symbolically marks a new beginning for some; for others, it is a time to reflect on the accomplishments of the previous years. To me, 2016 is a special year, a year to celebrate, as it marks the tenth year of the Pressure Vessel Newsletter. Granted that it is not a newsletter in a traditional sense; there is no print publication, for example. And although, I have tried to release the newsletter issues on a regular timetable, there have been times when this has not been possible. But overall, it has been a very satisfying journey and it has given me immense joy in bringing these articles to you through these newsletters. The resulting interactions I have had with the pressure vessel community worldwide have been priceless.

The readership of the newsletter now exceeds 5,000, working at over 2,000 organizations, and spread over more than 50 countries across Africa, Americas, Asia, Europe and Middle East. To those who want to showcase their pressure vessel qualifications, experience and knowledge – this newsletter is an excellent platform. I would encourage you to contribute with articles that will benefit our tribe.

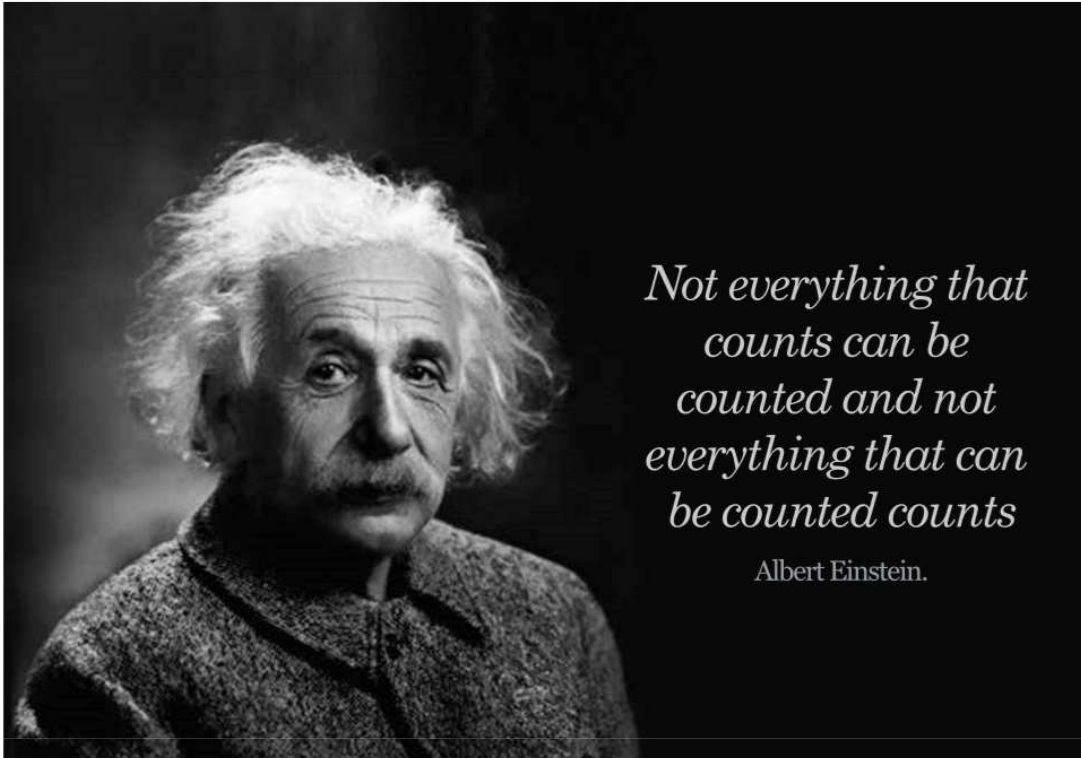
The articles in the newsletter are primarily ASME Code related – only because my own personal experience has been mostly limited to the ASME Code. Therefore, I would like to mark the tenth year of the newsletter with a series of articles illustrating the history of the ASME Boiler and Pressure Vessel Code. The material for the articles that I would have access to will come from those available in public domain; hence I would welcome contributions from individuals who have more in-depth knowledge of the history of the Code.

I have tried but have had only limited success in making the newsletter an interactive effort. Perhaps, the current format doesn't permit such an effort. I would love to hear about ideas to not only solicit articles from across the readership but also to create a Question and Answer column, for example. In any case, I would like to take this opportunity to express a big thank you to everyone for your support – especially to those who have provided me encouragements since the early years.

Best wishes to everyone for a very happy and productive New Year.



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Not everything that counts can be counted and not everything that can be counted counts

Albert Einstein.

Math of real world seldom adds up due to intangible variables that cannot be easily captured. For final tally, we know we don't just have to win contracts, we must earn customer confidence too. Our main focus is customer delight achieved due to & through positive interactions, quality alertness, proactive involvement and personalized service for varying situations & requirements.

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INTRODUCTION TO CARBON STEEL

Steels and cast irons are basically alloys of iron and various other elements in the periodic table. The vast majority of steels and all cast irons contain carbon as the principal alloying element. As a general definition, steel is an alloy of iron, carbon (under 2% C), and other alloying elements that is capable of being hot and/or cold formed into various shapes. Cast iron, on the other hand, is an alloy of iron, carbon (over 2% C), and other elements and is not normally capable of being hot and/or cold formed. Steels and cast irons are the most widely used and least expensive metallic materials on earth. This article introduces the reader to the various types of steels, and explains how they are classified and defined.

Steels

Generally, the carbon and low-alloy steels come under a classification system based on composition. The higher alloy steels (stainless, heat resistant, wear resistant etc.) can be classified according to many different systems, including composition, microstructure, application or specification. The flow diagram in Figure 1 shows very generally how steels are classified. On the left, they are classified by commercial name or application, and on the right, by microstructure.

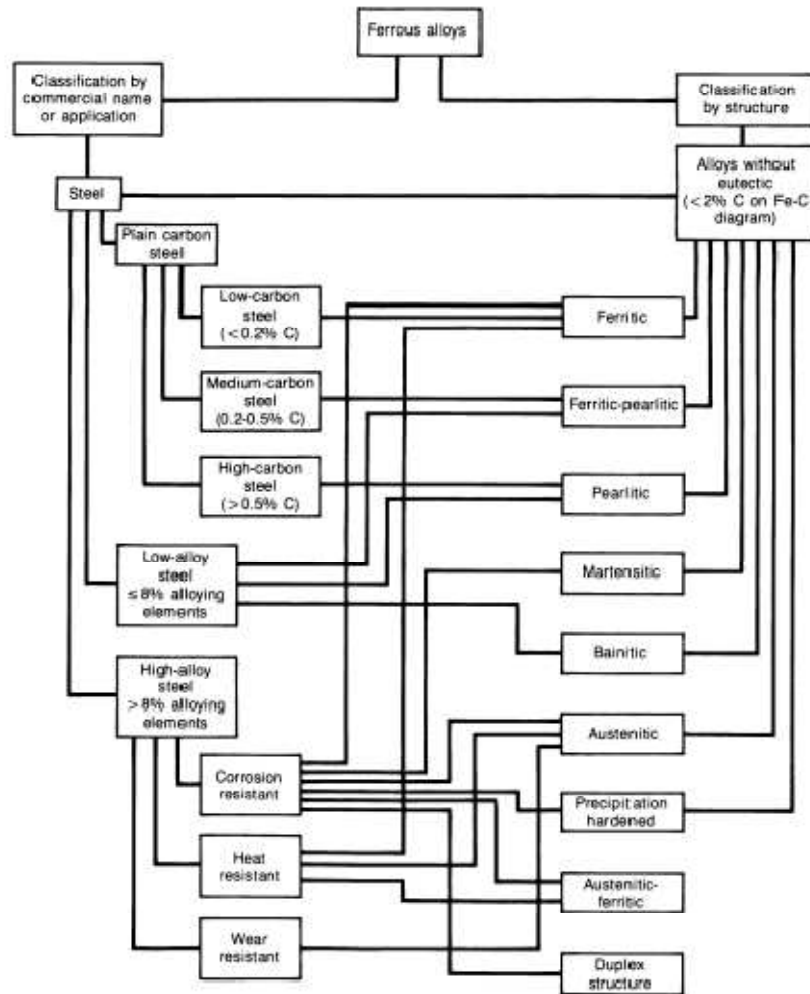


Figure 1: Classification Chart for Steels

The easiest way to classify steels is by their chemical composition. Various alloying elements are added to iron for the purpose of attaining certain specific properties and characteristics. These elements include, but are not limited to, carbon, manganese, silicon, nickel, chromium, molybdenum, vanadium, columbium (niobium), copper, aluminum, titanium, tungsten and cobalt. Most steels contain several of these elements, particularly, carbon, manganese and silicon.

Formal Classification Systems

Many nations have their own classification systems for steels and cast irons. Only those that are used in US are described in this article.

The American Iron and Steel Institute (AISI) and Society of Automotive Engineers (SAE)

For many decades, plain carbon, low-alloy steels have been classified by composition using a system devised by SAE and eventually by AISI. The system is based solely on composition. In the four- or five-digit code designation, the last two or three digits represent the carbon content (three digits for steel with carbon content of 1.00% and above), and first two digits represent the compositional class. Thus, in the designation AISI/SAE 1040, the "10" represents the class of plain carbon steels, and the "40" represents the carbon content of 0.40%C.

The American Society for Testing and Materials (ASTM)

This system is not based on composition but on the steel product and application, for example, railroad rails, boiler tubes, plate and bolts. ASTM has devised a system of specifications that contain composition, mechanical properties, and other required characteristics of steels and cast irons. The ASTM system reaches far beyond ferrous materials and includes other materials as well.

The Unified Numbering System (UNS)

Because of the confusion of different systems, a number of technical societies and governmental agencies devised what is known as the Unified Numbering System. There is a UNS designation for each steel composition, and it consists of a letter followed by five digits. The system fully incorporated the AISI/SAE system. For example, the UNS designation for AISI 1040 is G10400. The letter "G" represents plain carbon and low alloy steels. Other ferrous alloys have different letters, such as "F" for cast irons and cast steels (cast steels can also have the letter "J"), "D" for steels with specific mechanical properties, "S" for heat- and corrosion-resistant steels, "T" for tool steels, and "H" for steels with enhanced hardenability.

Carbon and Low Alloy Steels

The general category of carbon and low alloy steels encompasses plain carbon steels, alloy steels, high strength low alloy steels, and a variety of other low alloy steels. Each of these subcategories is described below:

Plain Carbon Steels

Plain carbon steels include the following subclasses:

Subclass	Carbon Content (a), %
Low carbon steels	Under 0.2
Medium carbon steels	0.2 – 0.5
High carbon steels	Above 0.5

AISI/SAE Classification System

The microstructures of typical low-carbon, medium-carbon and high-carbon steels are shown in Figures 2, 3, and 4 respectively. The low carbon steel is represented by AISI/SAE 1010 steel, the medium carbon steel by

AISI/SAE 1040 steel, and the high carbon by AISI/SAE 1095 steels. As carbon content increases, the amount of pearlite (the dark etching constituent) increases. Actually, the amount of pearlite increases to a maximum of 100% at a carbon content near 0.8%. Below 0.8%C, the other constituent in the microstructure is ferrite. Above 0.8%C, the other constituent is cementite.

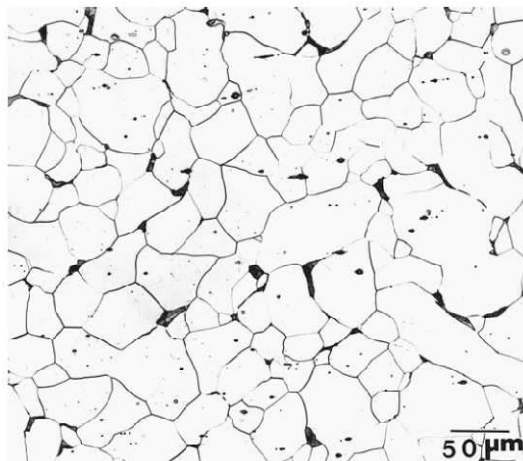


Figure 2: Low Carbon AISI 1010 Steel showing a mixture of ferrite grains and pearlite

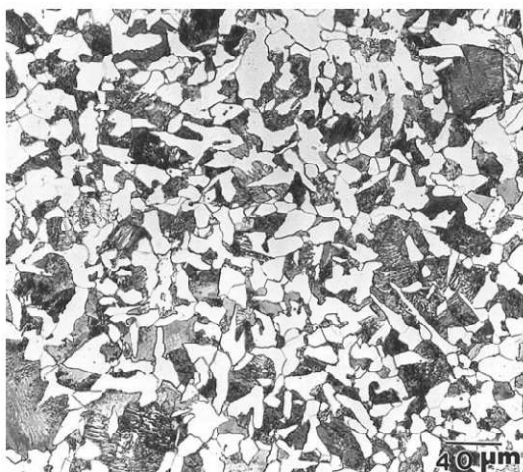


Figure 3: Medium Carbon AISI 1040 Steel showing ferrite grains (white etching) and pearlite (dark etching)

Within the AISI/SAE plain carbon steel designations, there are five subclasses – 10xx, 11xx, 12xx, 13xx, and 15xx. These are broadly based on the following categories of steel composition:

AISI/SAE Designation	Type of Steel
10xx	Plain carbon: Mn 1.00% max
15xx	Plain carbon: Mn 1.00 – 1.60%
13xx	Plain carbon: Mn 1.60 – 1.90%
11xx	Plain carbon: resulfurized
12xx	Plain carbon: resulfurized and rephosphorized

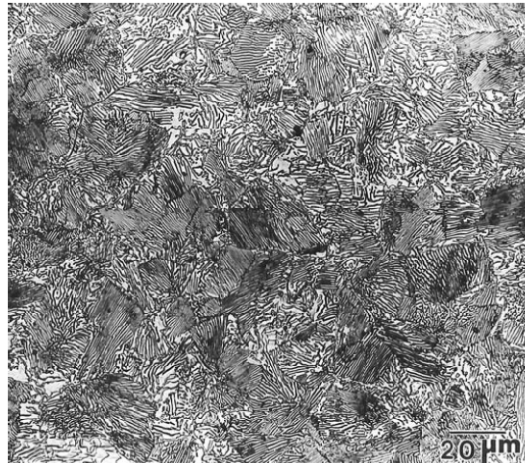


Figure 4: High Carbon AISI 1095 showing a matrix of pearlite and some cementite

The AISI/SAE 15xx and 13xx series represent high manganese, plain carbon steels. The higher manganese levels impart higher hardness and strength to the steels. The 11xx series of plain carbon, resulfurized steels contains intentionally added sulfur. The sulfur does not actually alloy with the iron but combines with manganese to form manganese sulfide inclusions. The sulfur level is much higher in the 11xx series than the 10xx series of plain carbon steels where sulfur is generally considered as an impurity. The higher sulfide level in the resulfurized steels imparts improved machinability to the steel because of the chip-breaking effect of the manganese sulfides.

The AISI/SAE 12xx series represents resulfurized and rephosphorized, plain carbon steels that are also free-machining steels with both sulfur and phosphorus as alloy additions. The phosphorus addition increases the strength of the steel and promotes chip breaking during machining operations. In order to limit the strength of the steel, the carbon content is restricted to a level under 0.15%.

ASTM Specifications

ASTM has very elaborate specifications for steels that include the type of product (sheet, plate, bar, wire, rail etc.), the composition limits, and the mechanical properties. The specification code consists of letter “A” followed by a number. A partial list of the plain carbon steels according to the ASTM specification is given subsequently:

ASTM Designation	Type of Steel
A 1	Carbon steel, tee rails
A 36	Structural steels
A 131	Structural steel for ships
A 228	Steel wire, music spring quality
A 307	Carbon steel, bolts and studs, 420 MPa (60 ksi) tensile strength
A 510	Carbon steel wire rods
A 529	Structural steel with 290 MPa (42 ksi) minimum yield point
A 570	Steel, sheet and strip, carbon, hot rolled, structural quality
A 709	Structural steel for bridges

Alloy Steels

The alloy steels are generally divided into two classes: the low-alloy steels and the high alloy steels. They are divided according to composition as follows:

Type	Alloying elements, %
Low-alloy steels	< 8
High-alloy steels	>8

AISI/SAE Classification System

As with plain carbon steels, there is an established classification system of AISI/SAE designations for the low-alloy steels. The classification is based on the principal alloying element(s) in the steel. These principal elements include carbon, manganese, silicon, nickel, chromium, molybdenum, and vanadium. Each element, either singly or in combination with other elements, imparts certain properties and characteristics to the steel. The subsequent list gives the breakdown of the AISI/SAE classification for the low-alloy steels:

AISI/SAE Designation	Type of steel
13xx	1.75% Mn steels
40xx	0.25% Mo steels
41xx	0.50 and 0.95% Cr-0.12 and 0.25% Mo steels
43xx	1.80% Ni-0.50 and 0.80% Cr-0.25 and 0.40% Mo steels
44xx	0.40% Mo steels
46xx	0.85 and 1.80% Ni-0.20 and 0.25% Mo steels
47xx	1.05% Ni-0.45% Cr-0.20 and 0.35% Mo steels
48xx	3.5% Ni-0.25% Mo steels
50xx	0.28 and 0.50% Cr steels
51xx	0.80, 0.88, 0.95 and 1.00% Cr steels
50xxx	1.05-1.45% Cr steels
51xxx	1.03% Cr steels
61xx	0.60 and 0.95% Cr-0.13 and 0.15% (min) V steels
81xx	0.30% Ni-0.40% Cr-0.12% Mo steels
86xx	0.55% Ni-0.50% Cr-0.20% Mo steels
87xx	0.55% Ni-0.50% Cr-0.25% Mo steels
88xx	0.55% Ni-0.50% Cr-0.35% Mo steels
92xx	1.40 and 2.00% Si-0.00 and 0.7% Cr steels
93xx	3.25% Ni-1.20% Cr-0.12% Mo steels
94xx	0.50% Ni-0.40% Cr-0.98% Mo steels
xxBxx	Boron steels ("B" denotes boron)
xxLxx	Leaded steels ("L" denotes lead)

ASTM Specification System

As with the plain carbon steels, ASTM specifications also cover many of the low-alloy steels. The ASTM system is driven by the application for the particular steel. The system for low-alloy steels is quite large; for example, a fairly common low-alloy steel is 2¼ Cr-1Mo steel. In the ASTM system there are 13 separate specifications covering this steel, depending on the product form that is manufactured, as shown subsequently:

Product Form	ASTM Designations
Forgins	A 182, A 336, and A 541
Tubes	A 199, A 220, and A 213
Pipe	A 335, A 369, and A 462
Castings	A 217 and A 356
Plate	A 387 and A 542

As an example, ASTM A 213 has the title “Seamless Ferritic and Austenitic Alloy Steel for Boiler, Superheater, and Heat Exchanger Tubes”. The standard actually cover 14 different grades of ferritic steels and 14 different grades of austenitic steels. The 2¼ Cr-1Mo steel is grade T22. Because the grade is used in tubing for boilers and heat exchangers, it is also part of the specification system of ASME. The ASME adopts the ASTM code and places an “S” before it as, for example, ASME SA 213 type T22.

The microstructure of a typical ASTM A 213 grade T22 steel is shown in Figure 5. It is interesting to note that if the same steel was used for a forging or plate, it may have a different microstructure because of the different specified heat treatment. Even for tubes (ASTM A 213), it can be furnished in the full-annealed, isothermal annealed, or normalized and tempered condition. Each condition would have a different microstructure.

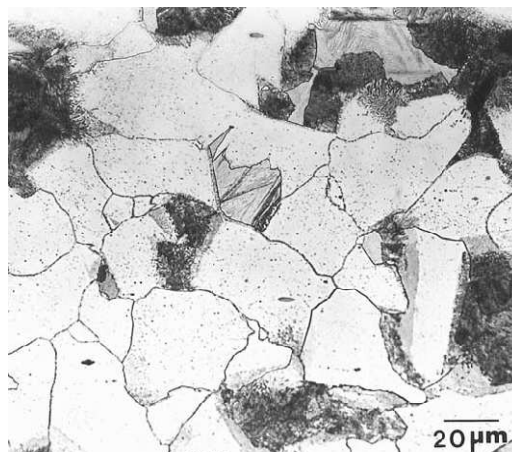


Figure 5: Micrograph of ASTM A 213 Grade T22 Boiler Tube

High-Strength, Low-Alloy Steels

Although many of the previously mentioned AISI/SAE low-alloy steels also have high strength and, in some cases, ultrahigh strength (a yield strength above 1380 MPa, or 200 ksi), there is a rather loose class of steels called HSLA steels that do not fit the previously mentioned AISI/SAE classification. These HSLA steels are a group of low- and medium-carbon steels that generally use small amounts of alloying elements to attain yield strengths usually above about 345 MPa (50 ksi) in the hot-rolled, cold-rolled, annealed, stress-relieved, accelerated cooled, direct-quenched, or normalized condition. In some cases, they are called microalloyedsteels

because of the small amounts of vanadium, columbium (niobium), and/or titanium that are added for grain refinement and precipitation strengthening. The microstructure of a typical microalloyed steel is shown in Figure 6.

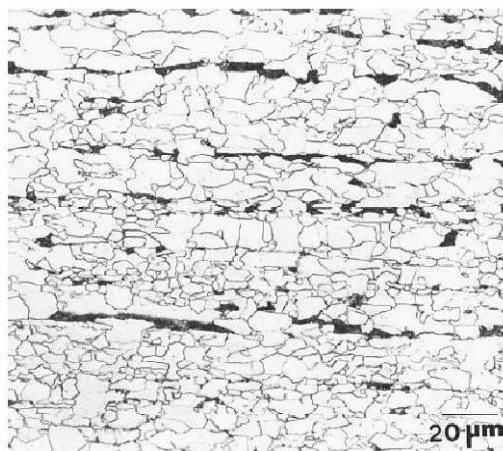


Figure 6: Micrograph of a Microalloyed 450 MPa (65 ksi) Yield Strength Linepipe Steel

ASTM Specification System

A partial list of ASTM specifications for various HSLA steels is shown below:

ASTM Designation	Type of Steel
A 242	HSLA structural steel
A 572	HSLA columbium (niobium)-vanadium structural steel
A 588	HSLA structural steel with 345 MPa (50 ksi) minimum yield point
A 656	HSLA hot-rolled structural steel V-Al-N and titanium-aluminum steels
A 714	HSLA welded and seamless steel pipe
A 715	HSLA hot-rolled sheet and strip, and sheet steel, cold-rolled, high strength, low alloy, with improved formability
A 808	HSLA with improved notch toughness
A 871	HSLA steel with atmospheric corrosion resistance

SAE Classification System

The Society of Automotive Engineers has developed a classification for HSLA steels used in automotive applications. The steels are classified according to minimum yield strength level. The latest SAE classification system for HSLA steels consists of three-digit code representing the minimum yield strength in ksi. Thus, a code of 080 would represent a 80 ksi (552 MPa) minimum yield strength. In the SAE system, there are usually one or more letters following the three-digit number to describe the chemical composition, carbon level, or deoxidation practice.

Source: Article by Denis Oakley written in September 2014, Oakley Steel website

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Feature Article

THE MAKING OF THE FIRST ASME BOILER AND PRESSURE VESSEL CODE

Shortly after the founding of American Society of Mechanical Engineers (ASME) in 1880, other societies and associations came into being that were to make a marked impact on the evolution of boiler codes and standards. One of these was American Boiler Manufacturers' Association (ABMA) which was chartered in 1889. Its stated objective was to raise the standards of boiler design and manufacture, and prevent the production and sale of boilers unfit for safe operation. Initially committees were formed on materials, recommended tests and inspections, riveting, tubes, the attachment of valves and fittings, and setting. Three years later, ABMA appointed its first committee on Uniform Specification Laws. By the turn of century, the association was heavily involved in detail work and the presentation of papers on subjects such as riveting, factors of safety, caulking, dished heads, flanging, tubes, bending and forming, staybolts, braces, drums, and hydrostatic pressure tests.

Colonel Edward Meier, who was to figure prominently in the birth of the ASME Boiler Code, was the Chairman of the ABMA Uniform Specification Committee. He was quoted as being dissatisfied with one direction that the committee work was taking. Too many members were looking at specifications in light of bidding for boilers and components, and not for the adoption of standards and codes by the states and municipalities. This outlook, he felt, was way off balance. The concepts he adhered to during this period in his career reflect the ideas he would later bring to the creation and development of the first ASME code.

During the 18th and 19th centuries, steam had become the chief source of power and spurred the industrial revolution. This period also witnessed several steam boiler explosions that were occurring at the rate of one per day and claiming about two lives per day by the early 20th century. Between 1880 and 1890, there were over 2,000 boiler explosions in the US. However, there was no legal code for safe stationary boilers in any of the US states. Massachusetts had considered the enactment of laws and regulations because of the prevalence of steam boilers in hundreds of factories throughout the state, but the legislators had become complacent for two reasons: The first was the positive influence of Hartford Steam Boiler Inspection and Insurance Company throughout New England whose agents had done an excellent job of policing equipment which the firm insured. The second was that between 1898 and 1902, there had been no serious boiler explosion reported in any of the industrial regions of the state, a dramatic contrast to the nation's total of more than 1,600 during the same period. This was attributed in part to the fact that Massachusetts had passed a law in 1850 requiring fusible plugs on all stationary high-pressure boilers.

This complacency was shattered quite abruptly on March 10, 1905 when an old boiler that had been temporarily put back into service in Brockton, Massachusetts shoe factory exploded. The boiler flew through three floors and the roof, knocked over a water tower and its full tank smashed through the roof, causing the building to collapse. The disaster resulted in 58 deaths, 117 injuries and damages of one quarter of a million dollars. During the investigation, C.E. Roberts, a manager of Hartford Steam Boiler stated, "So far as I have been able to learn there appears to have been no carelessness in handling of the boiler, and the explosion, in my opinion, was caused by a defect that was impossible to discover." Since the factory boilers were not insured and the cause was never officially determined, it was evident that the state laws were not as effective as had been claimed.

On December 6, 1906, another serious explosion took place in the state at yet another shoe factory – this time in Lynn. Although only one person was reportedly killed, this incident motivated the Governor of Massachusetts to include in his inaugural address a month later a demand for prompt action. The wheels were set in motion; a 5-man "Board of Boiler Rules" was authorized that spring, and by late summer of 1907, the first Massachusetts Rules were approved. The document was short and simple, consisting of only 3 pages. The first was devoted to a facsimile of the standard format of the certificate of insurance. The second page covered fusible plugs and their performance characteristics, based on the earlier state requirements for these safety devices. The third

page provided specific rules, which included among others, limiting cast iron boilers to a pressure of 25 psi, limiting boilers with cast iron headers to 160 psi, and data governing the shearing strength of rivets.

There were objections, coming mostly from manufacturers who viewed these regulations as prime example of needless government intervention. Some denounced the state for imposing commercial hardships that would put small boiler makers out of business. The hue and cry, along with legislative lobbying, forced a public hearing in 1909 to listen to complaints and recommendations for revisions. Attending this hearing was Dr. David Jacobus, who had arrived from New York representing the Babcock & Wilcox Company. Jacobus was later recognized for his fine work on the ASME Boiler Code; but in this instance, he was branded an “outsider” and criticized for coming all the way to make proposals that would be injurious to the welfare of manufacturers in Massachusetts. He responded by stating that it was his personal policy, as well as that of his company “to act in the broadest way possible to endorse a movement for the protection of human life and property”. Following his statement and leadership, others at the hearing spoke out in favor of the Rules.

The result was that “An Act Relating to the Operation and Inspection of Steam Boilers” was passed in 1909. The rules were divided into three parts. The first applied to boilers installed prior to January 1, 1909, fixing the maximum allowable pressures for boilers made from steel and wrought iron. It also specified the sizes of non-spring-loaded safety valves and bottom blow-off valves. The second part referred to boilers installed “now and in the future” defining maximum pressures for cast iron boilers, for boilers with cast- or malleable-iron headers or with cast-iron mud drums. The third part covered boilers of the future, anticipating requirements of materials to be employed in the fabrication of various components. It also described the procedures for stamping boilers that met the requirements of the rules and provided guidelines for every kind of component, as well as non-standard boilers and portable boilers. The document concluded with an appendix devoted to structural recommendations and the care and operation of boilers in service.

The success of Massachusetts law, along with public pressure to do something about continuing boiler explosions, motivated another state, Ohio, to take similar action. In October 1911, the Governor approved the Rules that had been formulated during the previous 5 months by the Ohio Board of Boiler Rules, which had been appointed for that purpose. The Ohio board adopted with few modifications the Rules of the Massachusetts Board in most cases, changing only the dates to refer to boilers constructed prior to, and after, the passage of the bill.

The ASME Boiler Code was conceived in 1911 out of a need to protect the public. Creation and maintenance of the Boiler Code was proposed that year by the then ASME President Colonel Edward Meier after several less successful attempts. Meier requested the ASME Council to appoint a Committee to formulate standard specifications for the construction of steam boilers and other pressure vessels and their components. However, while in midst of trying to achieve his goal of industry-wide standardization, Meier became ill and barely survived long enough to see the final version of the Code approved for publication.

Fortunately, there was a fellow engineer who was an equally strong influence in creating the Code – John Steven, of Massachusetts, a consultant whose career had been devoted largely to power generation. He had already amassed a wealth of experience in the area of Codes and Standards, having served on the Massachusetts Board of Boiler Rules. The Massachusetts Board was not simply a state regulatory body - it was composed of individuals representing boiler manufacturers, operators, inspectors and owners. This varied structure tied in with a basic objective of the first ASME Code: to assure complete and well balanced representation on the part of those who were concerned with consistency, efficiency and safety.

The Council of ASME appointed a committee, chaired by Stevens, to formulate standard specifications for the construction of steam boilers and other pressure vessels, and for their care in service. The first committee consisted of seven members and was assisted by an 18-member advisory committee. The committee members represented all facets of design, construction, installation, and operation of steam boilers. One key advisor was William Kent, with long and varied experience as a mechanical engineer including positions as editor of Iron World and American Manufacturer, manager of the Pittsburgh office of Babcock & Wilcox, and president of the

American Society of Heating and Ventilating Engineers. Greatly concerned about the diversity of standards and the absence of coordination in testing of the steam boilers, he set up demonstrations, however, each person viewing the demonstration was probably using methods that differed from those applied by others in the audience. The point was well taken, particularly when another engineer, complained to all those who would listen that there was not even a common language with which engineers could communicate many of the differences.

The Preliminary Report of the Committee was prepared in 1913 and sent to ASME's list of some 2,000 interested professionals. The report was essentially the Code itself, requiring 230 pages and including charts, tables, laws, rules and appendices. Following the receipt of suggestions, the Committee eventually completed revisions for a second printing in February of 2014. Comparison of the two editions show relatively few changes of significance which would seem to indicate that few of the recipients had been dissatisfied with the initial effort. The copies of the new printing were again sent to the ASME list which by now had swelled to some 2,500.

Unlike the first mailing, the second one brought about a "storm of protests" by some members of ASME who were opposed to rules and restrictions governing their business. In the proposed Boiler Code, they saw a threat to their economy and even to the whole free enterprise system. A compromise was worked out whereby the ASME Committee broadly agreed to make every effort to review the proposed Code with representatives of all factions involved and make suitable revisions before publishing the official First Edition. To that end, a Society resolution was passed, calling for a public hearing to be held on September 15, 1914, at which time a review would be made of all suggestions, criticisms, and reports submitted in writing on or before August 15.

The public hearings were held at the ASME building in New York City on September 15 as scheduled. The 150 individuals who attended represented every facet of the industry, from consulting engineers, educators and editors, to manufacturers, insurers, inspectors, government officials, agriculturists, railroaders, designers, heating and energy specialists, and researchers. The list of associations read like a blue book of the industry. At the hearing, the nature and the wording of the Code were discussed item by item so that everyone attending could express opinions whenever changes had to be undertaken. The accomplishments were notable. For the first time in their history, all of the makers of safety valves agreed upon a uniform specification for their products. And representatives of railroad industry presented "a most splendid criticism of the Preliminary Report which helped greatly in bringing about the actual success of the hearing."

The third draft of the Code was mailed out to the ASME list on November 5, 1914. The responses to the draft started pouring in and the seven-member committee and the eighteen-member advisory committee worked long hours for seven weeks straight to incorporate the changes and additions that had been presented to them. By the time of next Council meeting, on March 12, 1915, the Code had become an official, approved document of ASME. The first BoilerCode went on record as the 1914 edition which thus became the official "birth date" of the Code; it was the first comprehensive standard for the design, construction, and inspection and testing of boilers and pressure vessels. The code consisted of one book with 148 pages, including a detailed 30 page index, which measured five inches by eight inches. It was published as a hardcover book 6 inches by 9 inches in size, and bound in olive drab cloth. It was entitled "REPORT OF THE BOILER CODE COMMITTEE OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS"; the expenses were borne by Babcock & Wilcox.

The first Code book was divided into two parts, PART I on new installations and PART II on existing installations. Eighty pages were devoted to new installations and only five to those already existing. The remainder of the First Edition was allocated to an Appendix, with suitable diagrams, formulae and charts, and a detailed index. Power boilers and heating boilers were both covered in the main body of the text, with particular attention given to such topics as the selection of materials, manufacture, the thickness of the components, workmanship, inspection and testing, safety valves, water and steam gauges, fittings and appliances, and official ASME Stamps for uniform standards.

It also included the very first Code formula:

$$P = \frac{T_s \times t \times E}{R \times F_s}$$

P stood for the maximum allowable working pressure in psi; T_s the ultimate tensile strength in psi; t the minimum thickness of the steel plate; E the efficiency of longitudinal joints or ligaments between tube holes; R the inside radius; and F_s the factor of safety.

Six additional sections followed during the next eleven years. The first rules for pressure vessels was issued on January 15, 1925 as Section VIII of the Code. This publication was entitled "Rules for the Construction of Unfired Pressure Vessels". A chronological listing of the year of publication and the title of initial eight sections of the Boiler and Pressure Vessel Code (BPVC) are given below:

Section I	Boiler Construction Code, 1914
Section III	Locomotive Boilers, 1921
Section V	Miniature Boilers, 1922
Section IV	Low Pressure Heating Boilers, 1923
Section II	Material Specifications, 1924
Section VI	Rules for Inspection, 1924
Section VIII	Unfired Pressure Vessels, 1925
Section VII	Care and Use of Boilers, 1926

Today, there are 28 books spanning over 16,000 pages each of which measures 8½ inches by 11 inches, including 12 books dedicated to the construction and inspection of nuclear power plant components, and two Code Case books. The 28 books are either standards that provide the rules for fabrication for a component, or support documents such as Materials (Section II), Non-destructive Examination (Section V), and Welding (Section IX). Code Cases provide rules that permit the use of materials and alternative methods of construction that are not covered by the existing BPVC rules.

The ASME Boiler and Pressure Vessel Code is an American National Standard which has historically influenced public safety, product reliability, industrial efficiency and development of boiler and pressure vessel technology. Through the years, the Code has been expanded in scope and geographical application. All provinces of Canada and 49 of the 50 US States have adopted by law, Sections of the current edition of BPVC. Over 25% of companies accredited by the ASME to manufacture pressure parts in accordance with BPVC are located outside of the US and Canada. Since 1972, BPVC has been a de facto international standard and the basis for international accreditation program. BPVC affects such industries as public utilities, construction, material engineering, chemical and food production, nuclear power generation, petroleum processing, and industrial manufacturing.

Source: The Birth of a Code: ASME Boiler and Pressure Vessel Code by Leong Yee Hong (Chair, Pressure Systems Interest Group, ASME Singapore Section)

REQUIRED MARKING ON PRESSURE VESSELS FOR RADIOGRAPHIC EXAMINATION

When a pressure vessel is subjected to radiographic or ultrasonic examination, marking is applied under the ASME certification mark on the nameplate as follows:

RT1 When all the pressure retaining butt welds satisfy full radiography requirements of UW-11(a) for their full length.

Exceptions are: Category B&C butt welds on nozzles and communicating chambers that neither exceed NPS 10 (DN 250) nor 1-1/8 in (29 mm) wall thickness. This exception does not apply to UHT materials where radiographic examination for the complete length of weld is required for all welded joints of Type No. (1).

When full radiography of the above exempted category B and C butt welds are performed, it must be recorded on the Manufacturer's Data Report.

RT 2 When the complete vessel satisfies the requirement of UW-11(a)(5) and when the spot radiography requirements of UW-11(a)(5)(b) have been applied.

RT 3 When the complete vessel satisfies the spot radiography requirement of UW-11(b).

RT 4 When only part of the complete vessel has satisfied the radiographic requirements of UW-11(a) or where none of the markings "RT1", "RT2", or "RT3" are applicable.

The extent of radiography and the applicable joint efficiencies are to be noted on the Manufacturer's Data Report.

What is UW-11(a)?

Para UW-11(a) specifies the welded joints that must be examined radiographically for their entire length. Following welded joints are specified:

- 1) All butt welds in the shells and heads of vessels used to contain lethal substances. Lethal substances are defined as poisonous gases or liquids of such a nature that a small amount of the gas or the vapor of the liquid mixed or unmixed with air is dangerous to life when inhaled. The determination of a substance as a lethal substance is made by the user, and not the manufacturer of the pressure vessel.
- 2) All butt welds in the shell and heads of vessels in which the nominal thickness at the welded joint exceeds 1½ in (38 mm), or exceeds the lesser thickness prescribed in UCS-57, UNF-57, UHA-33, UCL-35, or UCL-36 for the materials covered therein, or as otherwise prescribed in UHT-57, ULW-51, ULW-52(d), ULW-54, or ULT-57.
- 3) All butt welds in the shell and heads of unfired steam boilers having design pressures that
 - Exceed 50 psi (350 kPa)
 - Not exceeding 50 psi (350 kPa) but with nominal thickness at the welded joint exceeding the thickness specified in 2) above.
- 4) All butt welds in nozzles and communicating chambers where
 - Nominal thickness at the welded joint exceeds thickness in 2) above.
 - They are attached to the shell or heads that fall under 1), 2), or 3) above that are required to be fully radiographed. In such case, category B and C butt welds in nozzles and communicating chambers that neither exceed NPS 10 (DN 250) nor 1-1/8 in (29 mm) wall thickness do not require any radiographic examination.

Ultrasonic examination may be substituted for radiography for the final closure seam of a pressure vessel if the construction of the vessel does not permit interpretable radiograph. However, the absence of a suitable radiographic equipment cannot be used as a justification for such substitution.

What is UW-11(a)(5)?

Para UW-11(a)(5) specifies radiography requirement for category A and D butt welds in the shell and heads of a pressure vessel when the design of component under consideration is based on joint efficiency permitted by UW-12(a), i.e. full radiography. In such cases,

- a) Category A and B welds connecting the shell or heads of the pressure vessel shall be of Type No. (1) or (2).
- b) Category B or C butt welds which intersect the category A butt welds in the shell or heads of vessel or connect seamless vessel shell or heads shall, as a minimum, meet the requirements for spot radiography. This requirement does not apply to nozzles and communicating chambers that neither exceed NPS 10 (DN 250) nor 1-1/8 in (29 mm) wall thickness.

Spot radiograph required by this paragraph cannot be used to satisfy spot radiography rules as applied to any other weld increment.

What are Spot radiography requirements of UW-11(b)?

Butt welded joints made in accordance with Type No. (1) or (2) which are not required to be fully radiographed, may be examined by spot radiography. If spot radiography is specified for the entire vessel, radiographic examination is not required of category B or C butt welds in nozzles or communicating chambers that exceed neither NPS 10 (DN 250) nor 1-1/8 in (29 mm) wall thickness.

Example E7.1 – NDE: Establish Joint Efficiencies, RT-1 (Taken from ASME PTB 4)

An engineer is tasked with developing a design specification for a new pressure vessel that is to be constructed in accordance with ASME B&PV Code, Section VIII, Division 1. Based on the process service description, anticipated design data, materials of construction, and welding process, the engineer verifies that full radiography is required in accordance with paragraphs UW-11(a) and UW-51 for the entire vessel. A sketch of the vessel showing nozzle sizes, orientation, and weld seams is shown in Figure E7.2.

To assist with fabrication and inspection of the vessel, the engineer developed a table to summarize the NDE requirements and joint efficiencies applicable to each welded joint of the vessel based on the full radiography requirement of paragraph UW-11(a). Table E7.2 is a sub-set of the original table and only addresses the weld joint identifiers referenced on the vessel sketch in Figure E7.2.

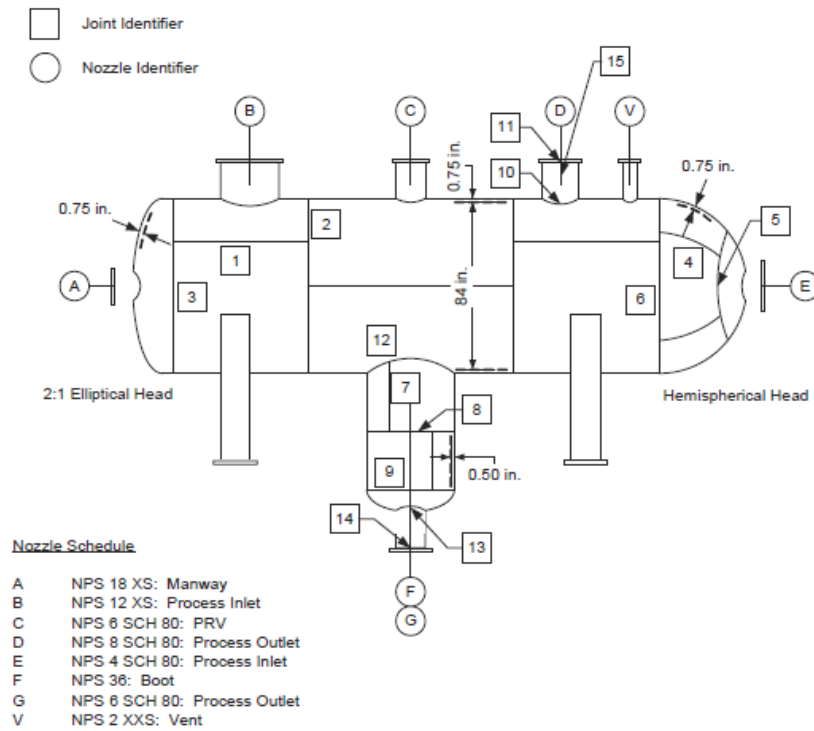


Figure E7.2: Vessel Sketch

Table F7.2 - NDF Weld Joint Requirements

Service Description		Lethal	RT Nameplate Marking		RT-1
Welding Process		SMAW	Radiographic Examination Designation		UW-11(a)
Joint Identifier	Joint Category	Joint Type	Limitations	Degree of Radiographic Examination	Joint Efficiency
1	A	1	None	Full	1.0
2	B	1	None	Full	1.0
3	B	1	None	Full	1.0
4	A	1	None	Full	1.0
5	A	1	None	Full	1.0
6	A	1	None	Full	1.0
7	A	1	None	Full	1.0
8	B	2	None	Full	0.90
9	B	2	None	Full	0.90
10	D	7	Table UW-12, Note 5	—	1.0
11	C	2	None	Exempt UW-11(a)(4)	0.65
12	D	7	Table UW-12, Note 5	—	1.0
13	D	7	Table UW-12, Note 5	—	1.0
14	C	2	None	Exempt UW-11(a)(4)	0.65
15	A	1	None	—	1.0



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