Chapter 1

INTRODUCTION TO COMPARING WORLD STEEL STANDARDS

Myth and Methodology When Comparing Steel Standards

When comparing steel standards from different national and international standard development organizations (SDOs), there is no such thing as *equivalent* steel standards. At best, one may be able to group *comparable* steel standards together based on some defined set of rules, which has been done in this handbook. For example, ASTM A 516/A 516M Grade 70 is *comparable* to JIS G 3118 symbol SGV 480 and to EN 10028-2 steel name P295GH, based on chemical compositions and mechanical properties. Yet they are not *equivalent* since there are differences in their chemical compositions and mechanical properties. Comparing steel standards is not an exact science and cannot be made into a mathematical equation where two sides of an equation are equal to one another, since there will always be differences between standards.

These differences may be significant to one user, but not significant to another user. Therefore, this handbook uses the term *comparative* to denote similar standards that have been compared to each other. Comparative is a relative word that is inevitably dependent upon the end user's requirements, who is ultimately responsible for selecting the appropriate steel for a specific application.

There are some steel standards that are shared by multiple SDOs. For example, EN ISO 4957 – Tool Steels, is a standard that is shared within the European Committee for Standardization (CEN) and the International Standards Organization (ISO) systems. Consequently, the data are equivalent in both systems, but there is only one standard.

There are also different standards that share the same grades of steel. For example, ASTM A 485 and EN ISO 683-17 share seven identical bearing steel grade chemical compositions, yet the body of each standard is different (that is, grain size, hardenability, microstructure and hardness, inspection, testing, etc.). As a result, these seven bearing steels within these two standards are not equivalent, but are comparable.

Comparative and Closest Match

There is also a difference between *comparative* and *closest match* when evaluating steel standards. While gathering the data for this handbook, it was difficult to decide whether to include data on a technically comparative basis or on a closest match basis as both have their merits and limitations (see 70 % rule in EN 10020 on page 6 for a more detailed discussion).

A technically comparative group of steels can assist the user with making a material selection based on technical merit. However, this may severely limit the number of steels that would be comparable. On the other hand, displaying the closest match data will usually increase the number of comparative steels for the user to consider, but at the risk of widening the technical comparison criteria. Likewise, a strict technical comparison will provide more accurate results, but a closest match comparison will provide more data to assist the user in searching for similar steels.

There are many instances in the handbook where it would be a disservice to the reader not to include the closest match steels, since there would be no comparisons otherwise. Since this broadens the technical comparison criteria, the user is warned that the data herein cannot substitute for education, experience, and sound engineering judgment after evaluating all of the specifications within each comparable standard.

In the end, there are no definitive rules that can be formulated to distinguish between *comparative steels* and *closest match* steels. Consequently, at the editor's discretion, both types of comparisons are used in this handbook. The following is one example of the comparison process, with technically comparative steels and closest match steels used in the table.

Table 1.1 lists the chemical compositions of nine grades of cast steels that are essentially Cr-Ni-Mo alloys, with nominally 0.30 % C. If a strict technical comparison was made based on their chemical composition, none of these alloys would be comparable since they would differ in either their carbon, manganese, chromium, nickel, or molybdenum contents. Try comparing these data yourself.

Table 1.1 List of Chemical Compositions of Cr-Ni-Mo Alloy Cast Steels Before Comparison

Standard Designation	Grade, Class, Type Symbol or Name	Steel Number	UNS Number	Weight, %, max, Unless Otherwise Specified								
				C	Mn	Si	P	S	Cr	Ni	Mo	Others
ASTM A 958-00	SC 4330	---	---	0.28-0.33	0.60-0.90	0.30-0.60	0.035	0.040	0.70-0.90	1.65-2.00	0.20-0.30	---
	SC 4340	---	---	0.38-0.43	0.60-0.90	0.30-0.60	0.035	0.040	0.70-0.90	1.65-2.00	0.20-0.30	---
JIS G 5111:1991	SCNCrM 2	---	---	0.25-0.35	0.90-1.50	0.30-0.60	0.040	0.040	0.30-0.90	1.60-2.00	0.15-0.35	---
DIN 17205:1992	GS-25 CrNiMo 4	1.6515	---	0.22-0.29	0.60-1.00	0.60	0.020	0.015	0.80-1.20	0.80-1.20	0.20-0.30	---
	GS-34 CrNiMo 6	1.6582	---	0.30-0.37	0.60-1.00	0.60	0.020	0.015	1.40-1.70	1.40-1.70	0.20-0.30	---
	GS-30 CrNiMo 8 5	1.6570	---	0.27-0.34	0.60-1.00	0.60	0.015	0.010	1.10-1.40	1.80-2.10	0.30-0.40	---
	GS-33 CrNiMo 7 4 4	1.8740	---	0.30-0.36	0.50-0.80	0.60	0.015	0.007	0.90-1.20	1.50-1.80	0.35-0.60	---
AFNOR NF A 32-053:1992	20 NCD4-M	---	---	0.17-0.23	0.80-1.20	0.60	0.025	0.020	0.30-0.50	0.80-1.20	0.40-0.80	---
AFNOR NF A 32-054:1994	G30NiCrMo8	---	---	0.33	1.00	0.60	0.030	0.020	0.80-1.20	1.70-2.30	0.30-0.60	---

Five grades of steel were eventually eliminated from Table 1.1 after technical comparison. This produced Table 1.2, which was then divided into two separate comparative groups based on the differing molybdenum contents above and below 0.30–0.35 % Mo. The thin black line in Table 1.2 is the separator between the two comparative groups.

Table 1.2 List of Chemical Compositions of Cr-Ni-Mo Cast Alloy Steels After Comparison

Standard Designation	Grade, Class, Type Symbol or Name	Steel Number	UNS Number	Weight, %, max, Unless Otherwise Specified								
				C	Mn	Si	P	S	Cr	Ni	Mo	Others
ASTM A 958-00	SC 4330	---	---	0.28-0.33	0.60-0.90	0.30-0.60	0.035	0.040	0.70-0.90	1.65-2.00	0.20-0.30	---
JIS G 5111:1991	SCNCrM 2	---	---	0.25-0.35	0.90-1.50	0.30-0.60	0.040	0.040	0.30-0.90	1.60-2.00	0.15-0.35	---
DIN 17205:1992	GS-33 CrNiMo 7 4 4	1.8740	---	0.30-0.36	0.50-0.80	0.60	0.015	0.007	0.90-1.20	1.50-1.80	0.35-0.60	---
AFNOR NF A 32-054:1994	G30NiCrMo8	---	---	0.33	1.00	0.60	0.030	0.020	0.80-1.20	1.70-2.30	0.30-0.60	---

However, if strict technical comparison rules were applied, Grade SCNCrM 2 could be rejected based on its higher manganese content when comparing it to SC 4330. In that case, SC 4330 would be rejected since it would not have a comparative steel (that is, it takes two steels to make a comparison). The same argument could be made when comparing GS-33 CrNiMo 7 4 4 and G30NiCrMo8 in the second group, where the differing nickel contents could be a basis for rejection on a stricter comparison.

A classic closest match example is shown in Table 1.3, where compared to the three other steels in this group, the four grades within EN 10085 are different; and some may argue that, on this basis, it does not belong to this comparative group. However, the Cr-Al-Mo alloys in this group are typically used as nitriding steels, and the EN 10085 steels are the closest match for this group. So excluding them would be a disservice to the user, since they belong to the same application family and its inclusion in this group will direct the user to other similar nitriding alloys.

Table 1.3 Chromium-Molybdenum-Aluminum (Cr-Mo-Al) Steels for Nitriding

Standard Designation	Grade, Class, Type, Symbol or Name	Steel Number	UNS Number	Weight, %, max, Unless Otherwise Specified								
				C	Mn	Si	P	S	Cr	Ni	Mo	Others
ASTM A 355-89 (2000)	A	---	K24065	0.38-0.43	0.50-0.70	0.15-0.35	0.035	0.040	1.40-180	---	0.30-0.40	Al 0.95-1.30
JIS G 4202:1979	SACM 645	---	---	0.40-0.50	0.60	0.15-0.50	0.030	0.030	1.30-1.70	0.25	0.15-0.30	Al 0.70-1.20, Cu 0.30
EN 10085:2001	32CrAlMo7-10	1.8505	---	0.28-0.35	0.40-0.70	0.40	0.025	0.035	1.50-1.80	---	0.20-0.40	Al 0.80-1.20
	34CrAlMo5-10	1.8507	---	0.30-0.37	0.40-0.70	0.40	0.025	0.035	1.00-1.30	---	0.15-0.25	Al 0.80-1.20
	34CrAlNi7-10	1.8550	---	0.30-0.37	0.40-0.70	0.40	0.025	0.035	1.50-1.80	0.85-1.15	0.15-0.25	Al 0.80-1.20
	41CrAlMo7-10	1.8509	---	0.38-0.45	0.40-0.70	0.40	0.025	0.035	1.50-1.80	---	0.20-0.35	Al 0.80-1.20
ISO 683-10:1987	41 CrAlMo 7 4	---	---	0.38-0.45	0.50-0.80	0.50	0.030	0.035	1.50-1.80	---	0.25-0.40	Al 0.80-1.20

There are many opportunities to make technical errors that may lead to inappropriate steel comparisons. For example, when comparing stainless steels there are many technical decisions to make since it is not common to find identical chemical compositions within standards from different countries. Table 1.4 shows a list of comparative Cr-Ni-Mo wrought austenitic stainless steels from the USA, Japan, and European Union. Note the differences in the Cr, Ni, and Mo contents among all the standards and the N limit in the EN standard. These differences will affect the corrosion resistance performance in many applications, such that the user must be very careful when selecting a comparative steel based solely on data in this handbook.

Table 1.4 List of Comparative Cr-Ni-Mo Wrought Austenitic Stainless Steels

Standard Designation	Grade, Class, Type Symbol or Name	Steel Number	UNS Number	Weight, %, max, Unless Otherwise Specified								
				C	Mn	Si	P	S	Cr	Ni	Mo	Others
ASTM A 276-03	316L	---	S31603	0.030	2.00	1.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00-3.00	---
JIS G 4303:1998	SUS316L	---	---	0.030	2.00	1.00	0.045	0.030	16.00-18.00	12.00-15.00	2.00-3.00	---
JIS G 4318:1998	SUS316L	---	---	0.030	2.00	1.00	0.045	0.030	16.00-18.00	12.00-15.00	2.00-3.00	---
EN 10088-3:1995	X2CrNiMo17-12-2	1.4404	---	0.030	2.00	1.00	0.045	0.030	16.50-18.50	10.00-13.00	2.00-2.50	N 0.11
	X2CrNiMo17-12-3	1.4432	---	0.030	2.00	1.00	0.045	0.030	16.50-18.50	10.50-13.00	2.50-3.00	N 0.11
	X2CrNiMo18-14-3	1.4435	---	0.030	2.00	1.00	0.045	0.030	17.00-19.00	12.00-15.00	2.50-3.00	N 0.11

In summary, if strict technical comparison is made to this type of data, no relationships or no associations between the various grades of steel would be established, which would serve no purpose. By widening the technical comparison criteria to find the closest match steels, the user must understand that these steels are not equivalent and cannot be indiscriminately substituted without first reviewing the complete current standards and securing competent technical advice prior to any decision-making.

To find a balance for comparison of steels by product form, use (application), mechanical properties, chemical compositions, related manufacturing processes (including heat treatment), etc., a methodology had to be put in place and rules had to be established. However, as much as methodology and rules were essential in preparing this handbook, there were many instances where they would not cover every variable and circumstance. Therefore, difficult comparison decisions as those described previously had to be made. There were literally hundreds, if not more than a thousand, such decisions made in this handbook. In these cases, the closest match comparison decisions were made at the discretion of the editor.

Organization

Two of the main variables in selecting a specific grade of steel are its intended application (use) and product form, which usually narrows the selection to a family of steels. Therefore, the remaining data chapters in this handbook were organized by product form and use, as follows:

Chapter No.	Title
2.	Carbon and Alloy Steels for General Use
3.	Structural Steel Plates
4.	Pressure Vessel Steel Plates
5.	Steel Tubes and Pipes
6.	Steel Forgings
7.	Steel Castings
8.	Wrought Stainless Steels
9.	Steels for Special Use

Although the above list at first glance looks rather straightforward, there were difficult decisions regarding the steel comparisons within each chapter. For example, ASTM has 9 definitions for *pipe* and 22 definitions for *tube*, depending on the standard's subject matter and application (see ASTM Dictionary of Engineering Science & Technology, 9th edition). In contrast, ISO 2604, Steel Products for Pressure Purposes - Quality Requirements - Part II: Wrought Seamless Tubes, notes that: "The word *tube* is synonymous with *pipe*."

Each standard is typically listed only in one chapter, but there are exceptions. For example, ASTM A 240/A 240M-04 on Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications, due to its dual role for pressure vessel and general applications (i.e., Chapter 4—Pressure Vessel Steel Plates and Chapter 8—Wrought Stainless Steels).

Definitions of Steel Terms

ASTM and CEN have established two separate standards for defining steel terms:

> ASTM A 941-03 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys (see Appendix 9) (defines the terms: carbon steel, alloy steel, low-alloy steel, and stainless steel);
>
> EN 10020:2000 Definition and Classification of Grades of Steel;(defines the terms: non-alloy steels, other alloy steels (which include alloy quality steels and alloy special steels), and stainless steels).

Note that these two standards, from the USA and EU, differ in the terms used to describe the different types of steel. The user of comparative steel standards data must take into account that each national SDO has their own set of terms and definitions for steels and related products and, in some cases, may have multiple definitions. For example, three different definitions for carbon steel can be found in ASTM standards A 941-03, A 902-03, and F 1789-04.

A summary of the chemical element limits for ASTM A 941-03 alloy steel and EN 10020:2000 non-alloy steel is shown in Table 1.5. Although the limits seem to be the same, it is important to note the 70 % rule in EN 10020, which states:

> 3.1.2 Where for elements other than manganese a maximum value only is specified in the product standard or specification for the ladle analysis, a value of 70 % of this maximum value shall be taken for classification as set out in Tables 1 and 2. For manganese see note a) of Table 1.

In some cases, this 70 % rule resulted in several steels being non-comparable. For example, EN 10028-3:2003, Flat Products Made of Steels for Pressure Purposes - Part 3: Weldable Fine Grain Steels, Normalized, contains steels with a nickel content of 0.50 % maximum (i.e., there is no minimum nickel requirement). Using the 70 % rule, this would define these steels to contain 0.35 % Ni, which is over the 0.30 % maximum limit for non-alloy steels (carbon steels), thereby making them alloy steels and becoming non-comparable with non-alloy steels.

ASTM A 941-03 and EN 10020:2000 share the same definition for stainless steel, as follows:

> 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.

In this handbook, steels have been divided into three main categories:

1. Carbon Steels (Non-Alloy Steels)
2. Alloy Steels
3. Stainless Steels

ASTM A 941-03 and EN 10020:2000 were used as guidelines in developing these categories. Where practical, these steel categories were further divided into subcategories based on their product form, intended application, service requirement, or other similar criteria.

Table 1.5 Limits for EN 10020:2000 and ASTM A 941-03
Between Carbon Steels/Non Alloy Steel and Alloy Steel[a] (% by mass)

Symbol	Name	EN 10020:2000[b]	ASTM A 941-03
Al	Aluminum	0.30	0.30
B	Boron	0.0008	0.0008
Bi	Bismuth	0.10	---
Co	Cobalt	0.30	0.30
Cr	Chromium	0.30	0.30
Cu	Copper	0.40	0.40
La	Lanthanides	0.10	---
Mn	Manganese	1.65[b]	1.65
Mo	Molybdenum	0.08	0.08
Nb	Niobium	0.06	0.06
Ni	Nickel	0.30	0.30
Pb	Lead	0.40	0.40
Se	Selenium	0.10	---
Si	Silicon	0.60	0.60
Te	Tellurium	0.10	---
Ti	Titanium	0.05	0.05
V	Vanadium	0.10	0.10
W	Tungsten	0.30	0.30
Zr	Zirconium	0.05	0.05
	Other (except C, P, S, N)	0.10	0.10

[a] Alloy steel when equal to or greater than the limit.
[b] Where manganese is specified only as a maximum the limit value is 1.80 % and the 70 % rule does not apply (see 3.1.2 of EN 10020:2000).

Cautionary Note

Many standard specifications include cautionary paragraphs that warn users about their responsibilities (e.g., see paragraph 1.5 from ASTM A 53/A 53M-02, shown below). Accordingly, it is the user's responsibility when comparing steel standards to perform an engineering review of each standard to ensure that it is suitable for their intended application.

> 1.5 The following precautionary caveat pertains only to the test method portion, Sections 9, 10, 11, 15, 16, and 17 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.

Questions Regarding the Rules of Comparison

When comparing two or more steel standards, the following questions can be asked:

Should mechanical properties or chemical composition be the main criteria? If mechanical properties are compared, which property should be the first criteria for comparison, that is, yield strength, tensile strength, elongation, impact strength, hardness, etc.? Once having selected a primary criterion, say tensile strength, should there be a secondary criterion for ranking the comparative steels within this group, for example, yield strength, hardness, etc.? When mechanical properties or chemical compositions vary with section thickness for a given steel grade, which section thickness data should be selected as the criteria for comparison? When two steels have the same minimum tensile strength values, but have different yield strength values, are they no longer similar?

Should comparisons be based on the data's minimum values, maximum values, or average values of their min/max ranges? Should alloy steels and stainless steels be compared on their mechanical properties when they are generally selected for use based on their alloying elements' abilities to provide satisfactory service in their intended applications?

Is it reasonable to compare steels based only on their chemical compositions, regardless of their product form? That is, should forging steels be compared to steel plates or tubes because they have similar chemical compositions and is this type of comparative data useful in engineering practice?

Non-Comparable Steels

Not all steels have comparative counterparts. Knowing that a steel is non-comparable can be just as important as knowing that there are comparative steels. Otherwise, valuable time could be wasted searching for something that does not exist. All steel grades within the listed standards in this handbook are either designated as comparable or non-comparable to assist the user in finding data. Non-comparable steels can be found at the end of each chapter.

Criteria for Comparing Steels

The two major criteria for comparing steels in this type of handbook are mechanical properties and chemical compositions. For each given standard steel grade, there is typically only one chemical composition, which makes it ideal as a comparison criterion. However, there are several mechanical properties that can be used to compare standard steel grades and, to be consistent throughout a handbook of this type, only one property can be chosen. The decision was to use a steel's tensile strength as the second comparison criterion.

Having settled on chemical composition and tensile strength as the two main comparison criteria, the next step was to decide when to apply one or the other, or both. Since carbon steels are typically selected based on mechanical properties, it was decided that tensile strength would be the first criterion used for comparing carbon steels. Likewise, since alloys steels and stainless steels are generally selected based on their chemistry, it was decided that chemical composition would be used to compare them.

An exception to the above methodology is for the structural steels data in Chapter 3, where the tensile strength was used as the main comparison criterion for carbon and alloy steels. This exception was made because structural steels are generally selected based on their mechanical properties. Also in this same chapter, high-strength low-alloy steels are treated as a subcategory to alloy steels, although ASTM A 941 defines them separately.

Since there was insufficient space on a page to place both the chemical composition and mechanical properties tables, they were split into two separate tables. To assist the user in keeping track of the comparison criteria used for a given steel, each table within a chapter was sequentially numbered and appended with the letter A or B. Table numbers ending in the letter A designate that it was the main criterion used for comparison, whereas table numbers ending with the letter B were "mirrored" from the A tables.

In this manner, the user must first consider the data in the A table, then see how well the data in the B table match the steels which are being compared.

This is not a foolproof methodology of comparison. For example, ASTM A 958 Grade SC 4330 has one chemical composition, but has 13 different strength classes based on heat treatment (see Chapter 7). So just because two steel grades have comparative chemical compositions does not mean that they are comparable in mechanical properties, and vice versa. Using data found in this handbook is only one step in finding suitable comparable steel for the intended application.

With this basic methodology in place, the following is a list of the comparison rules that were established to produce this handbook.

List of Comparison Rules

1. The first criterion of order for carbon (non-alloy) steels is based on tensile strength, followed by yield strength; that is, if two steels have the same tensile strength, then they are placed in ascending ordered by yield strength, and if yield strength is not required, it is placed at the top of the order.
2. Typically, comparative groups are made for every 50 MPa (50 N/mm^2 or 7.25 ksi) in tensile strength (that is, a black line divides comparative groups every 50 MPa (50 N/mm^2 or 7.25 ksi)). When an abundance of data is available, this limit may be reduced to improve the comparison accuracy.
3. Mechanical property subcategories, such as steels with impact testing below -20°C (-4°F), are used to further narrow the comparison process.
4. If a carbon steel's tensile strength varies with section thickness, the tensile strength of the lowest section thickness will be used as the governing comparison factor. There is no technical reason for choosing the lowest section thickness; it is just that one had to be chosen.
5. If a carbon steel standard does not contain mechanical properties, such as those found in Chapter 2 on Carbon and Alloy Steels for General Use, then the steels will be compared based on their carbon content.
6. The major criterion for alloy steel and stainless steel comparisons is chemical composition. Once these steels are placed in a comparative group by chemical composition, they are then arranged in ascending order within these groups by their tensile strength. Where possible, subcategories of alloy and stainless steel groups are made to further narrow the comparison process.
7. Chemical compositions listed are the heat analysis requirements in the standards (also called ladle or cast analysis). Product analyses are not listed.
8. The chemical composition and mechanical properties data for the same steel grades are not listed on the same page due to space limitations. Consequently, as a means of keeping the data consistent between these two sets of tables, each table is numbered, and each table number ends with either the letter A or B.
9. Each set of steel data in the tables is divided by two types of horizontal lines: black and grey. Black lines separate groups of steels that are more closely comparable to each other, whereas grey lines separate steel data within a comparative group. This does not mean that steels outside of these groups cannot be compared, since these horizontal lines are dependent upon all of the comparison rules in this list and can be subjective at times. Caution: do not confuse the thinner dividing black line within a table with the thicker black rule that borders the table. To assist in this regard, the pages were formatted to keep comparative groups together as much as practicable. However, when a group of comparative steels appears on more than one page, a note is placed at the bottom of the page to indicate that the comparative group continues on the following page, that is, "NOTE: this section continues on the next page."
10. Steel data in standards are not always mandatory. Some data are listed as typical values or informative values, or are found in supplementary requirements. This type of data is still very useful, and has been included in this handbook whenever possible. This type of data is identified with an explanatory note that appears in the list of standards at the beginning of the related chapter.

11. Some standards included multiple requirements for impact testing, for example, differing test temperatures or requirements for subsize specimens.
12. Where space permitted, as much data as possible were included. However, there are occasions when the phrase "see standard for impact test data" was used to indicate that more data could be found in the standard.
13. The phrase "see standard for impact test data" was also used when the standard did not specify a test temperature but did specify an absorbed energy value.
14. Impact testing values listed in the tables are typically for full-size specimens and for the minimum average result at the testing temperature, but do not include the minimum individual test piece requirement, if any.
15. For the purpose of this handbook, phrases found in standards like: "may be applied if necessary" or "may be applied by agreement between the purchaser and supplier" or "the manufacturer may find it necessary to" or "when specified" or " may be added if necessary" are not a part of the comparison process.
16. Data from footnotes in the chemical composition and mechanical properties tables of steel standards were considered during the comparison process, but were not always reported in the handbook due to lack of space in the tables or because they represented technical issues that were too complex to be represented in a tabular format. In these cases, the note "see standard" was used.
17. The same heat treatment terms used in each standard are listed them at the beginning of each chapter. Abbreviations in the tables were made based on the terms used in the standards. A concerted effort was made to make the abbreviations consistent from chapter to chapter, although there are exceptions, because each heat treatment abbreviation must be referred to in the list of heat treatment terms at the beginning of each chapter. There are many instances when the heat treatment requirements within a standard became very cumbersome to include in a small cell within a table. Consequently, the phrase "see standard" is used to direct the user to the standard to read all of the heat treatment details involved.
18. A determined effort was made to enter the data in this handbook in a manner identical to that listed in the related standard, including the use of Nb (niobium) or Cb (columbium). It should be noted that even within the same SDO, data were not always entered in the same manner from standard to standard; for example, TP304 versus TP 304, where a space between the letter P and the number 3 is listed in the data. This becomes significant when using the search engine on the accompanying e-book’s CD-ROM.
19. When a steel grade was found to be non-comparable, it was included at the end of the chapter in the non-comparable list. Therefore, if a particular steel was found to be unique and did not have a comparable steel, the user would not have to search any further.

Brief Introduction to Steel Standards and Designation Systems

In the world of standardization, metals were at the forefront at the turn of the twentieth century. In 1895, the French government assigned a commission to formulate standard methods of testing materials of construction. Later that year, the European member countries of the International Association for Testing Materials (IATM) held their first conference in Zurich and the standardization of metals began.

By reviewing some examples of the more prominent metals designation systems, a direction is offered to assist those who use metal standards as a part of their work or study. This section is not all inclusive. The amount of information on this topic could easily make up a complete book.

ASTM Designation System

ASTM's designation system for metals consists of a letter (A for ferrous materials) followed by an arbitrary sequentially assigned number. These designations often apply to specific products, for example A 548 is applicable to cold-heading quality carbon steel wire for tapping or sheet metal screws. Metric ASTM standards have a suffix letter M.

Examples of the ASTM ferrous metal designation system, describing its use of specification numbers and letters, are as follows.

> ASTM A 582/A 582M-95b (2000), Grade 303Se - Free-Machining Stainless Steel Bars:

- *A* describes a ferrous metal, but does not subclassify it as cast iron, carbon steel, alloy steel, tool steel, or stainless steel.
- *582* is a sequential number without any relationship to the metal's properties.
- M indicates that the standard A 582M is written in rationalized SI units (the "M" comes from the word "Metric"), hence together A 582/A 582M includes both inch-pound and SI units.
- 95 indicates the year of adoption or last revision and a letter *b* following the year indicates the third revision of the standard in 1995.
- *(2000),* a number in parentheses, indicates the year of last reapproval.
- Grade 303Se indicates the grade of the steel, and in this case, it has a Se (selenium) addition.

In the steel industry, the terms *Grade*, *Type*, and *Class* are generally defined as follows: *Grade* is used to describe chemical composition; *Type* is used to define deoxidation practice; and *Class* is used to indicate other characteristics such as strength level or surface finish. However, within ASTM standards, these terms were adapted for use to identify a particular metal within a metal standard and are used without any "strict" definition, but essentially mean the same thing, although some loose rules do exist, as follows.

ASTM A 106-02a Grade A, Grade B, Grade C – Seamless Carbon Steel Pipe for High-Temperature Service:

- Typically an increase in alphabet (such as the letters A, B, C) results in higher tensile or yield strength steels, and if it is an unalloyed carbon steel, an increase in carbon content.
- In this case:
  Grade A: 0.25 % C (max.), 48 ksi tensile strength (min.);
  Grade B: 0.30 % C (min.), 60 ksi tensile strength (min.); and
  Grade C: 0.35 % C, 70 ksi tensile strength (min.).

ASTM A 276-03, Type 304, 316, 410 – Stainless and Heat-Resisting Steel Bars and Shapes:

- Types 304, 316, 410 and others are based on the SAE designation system for stainless steels (see SAE and former AISI description that follows).

Another use of ASTM grade designators is found in pipe, tube, and forging products, where the first letter "P" refers to pipe, "T" refers to tube, "TP" may refer to tube or pipe, and "F" refers to forging. Examples are found in the following ASTM specifications:

- ASTM A 335/A 335M-03, Grade P22; Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service.
- ASTM A 213/A 213M-03a, Grade T22; Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes.
- ASTM A 312/A 312M-03, Grade TP304; Seamless and Welded Austenitic Stainless Steel Pipes.
- ASTM A 336/A 336M-03a, Class F22 - Steel Forgings, Alloy, for Pressure and High-Temperature Parts.

ASTM Referenced Standards and Supplementary Requirements

ASTM standards contain a "Referenced Documents" section that lists other ASTM standards which are referenced in the text that either become a part of the original standard or its supplementary requirements. Supplementary requirements are listed at the end of the ASTM standards and do not apply unless specified in the purchase order, that is, they are optional.

SAE Designation System and Related AISI Designation System

Carbon and Alloy Steels

For many years, certain grades of carbon and alloy steels have been designated by a four-digit AISI/SAE numbering system that identified the grades according to standard chemical compositions. Since the American Iron and Steel Institute (AISI) does not write material specifications, the relationship between AISI and grade designations has been discontinued. Beginning with the 1995 edition of the Iron and Steel Society (ISS) Strip Steel Manual, the four-digit designations are referred to solely as SAE designations.

The SAE system uses a basic four-digit system to designate the chemical composition of carbon and alloy steels. Throughout the system, the last two digits give the carbon content in hundredths of a percent. Carbon steels are designated 10XX. For example, a carbon steel containing 0.45 % carbon is designated 1045 in this system.

Resulfurized carbon steels are designated within the series 11XX, resulfurized and rephosphorized carbon steels 12XX and steels having manganese contents between 0.9 and 1.5 %, but no other alloying elements are designated 15XX. Composition ranges for manganese and silicon and maximum percentages for sulfur and phosphorus are also specified.

For alloy steels, the first two digits of the SAE system describe the major alloying elements present in the material, the first digit giving the alloy group. For example the 43XX series steels contain 1.65–2.00 % Ni, 0.50–0.80 % Cr and 0.20–0.30 % Mo, along with composition ranges for manganese and silicon and maximums for sulfur and phosphorus.

Additional letters added between the second and third digits include "B" when boron is added (between 0.0005 and 0.003 %) for enhanced hardenability, and "L" when lead is added (between 0.15 and 0.35 %) for enhanced machinability. The prefix "M" is used to designate merchant quality steel (the least restrictive quality descriptor for hot-rolled steel bars used in noncritical parts of structures and machinery). The prefix "E" (electric-furnace steel) and the suffix "H" (hardenability requirements) are mainly applicable to alloy steels. The full series of classification groups is shown in Table 1.6.

Table 1.6 Types and Identifying Elements in Standard SAE Carbon and Alloy Steels

Carbon Steels	Description
10XX	non-resulfurized, 1.00 manganese maximum
11XX	resulfurized
12XX	rephosphorized and resulfurized
15XX	non-resulfurized, over 1.00 manganese maximum

Alloy Steels	Description
13XX	1.75 manganese
40XX	0.20 or 0.25 molybdenum or 0.25 molybdenum and 0.042 sulfur
41XX	0.50, 0.80, or 0.95 chromium and 0.12, 0.20, or 0.30 molybdenum
43XX	1.83 nickel, 0.50 to 0.80 chromium, and 0.25 molybdenum
46XX	0.85 or 1.83 nickel and 0.20 or 0.25 molybdenum
47XX	1.05 nickel, 0.45 chromium, 0.20 or 0.35 molybdenum
48XX	3.50 nickel and 0.25 molybdenum
51XX	0.80, 0.88, 0.93, 0.95, or 1.00 chromium
51XXX	1.03 chromium
52XXX	1.45 chromium
61XX	0.60 or 0.95 chromium and 0.13 or 0.15 vanadium minimum
86XX	0.55 nickel, 0.50 chromium, and 0.20 molybdenum
87XX	0.55 nickel, 0.50 chromium, and 0.25 molybdenum
88XX	0.55 nickel, 0.50 chromium, and 0.35 molybdenum
92XX	2.00 silicon or 1.40 silicon and 0.70 chromium
50BXX	0.28 or 0.50 chromium
51BXX	0.80 chromium
81BXX	0.30 nickel, 0.45 chromium, and 0.12 molybdenum
94BXX	0.45 nickel, 0.40 chromium, and 0.12 molybdenum

UNS Designation System

The Unified Numbering System (UNS) is an alphanumeric designation system consisting of a letter followed by five numbers. This system represents only the chemical composition for an individual metal or alloy and is not a metal standard or specification. For the most part, existing systems such as the SAE designations, were incorporated into the UNS so that some familiarity was given to the system where possible.

For example, the UNS prefix letter for carbon and alloy steels is "G," and the first four digits are the SAE designation, for example, SAE 1040 is UNS G10400. The intermediate letters "B" and "L" of the SAE system are replaced by making the fifth digit of the UNS designation 1 and 4, respectively, while the prefix letter "E" for electric furnace steels is designated in UNS system by making the fifth digit "6." The SAE steels, which have a hardenability requirement indicated by the suffix letter "H," are designated by the Hxxxxx series in the UNS system. Carbon and alloy steels not referred to in the SAE system are categorized under the prefix letter "K."

Where possible, the first letter in the system denotes the metal group, for instance "S" designates stainless steels. Of the five digits of the UNS designation for stainless steels, the first three are the SAE alloy classification, for example, S304XX. The final two digits are equivalent to the various modifications represented by suffix letters in the SAE system as given in the list of suffixes in Table 1.6. The UNS designations for ferrous metals and alloys are described in Table 1.7.

Table 1.7 UNS Designations for Ferrous Metals and Alloys

UNS Descriptor	**Ferrous Metals**
Dxxxxx	Specified mechanical properties steels
Fxxxxx	Cast irons
Gxxxxx	SAE and Former AISI carbon and alloy steels (except tool steels)
Hxxxxx	AISI H-steels
Jxxxxx	Cast steels
Kxxxxx	Miscellaneous steels and ferrous alloys
Sxxxxx	Heat and corrosion-resistant (stainless) steels
Txxxxx	Tool steels
UNS Descriptor	**Welding Filler Metals**
Wxxxxx	Welding filler metals, covered and tubular electrodes classified by weld deposit composition

Canadian Standards Association (CSA)

The Canadian Standards Association (CSA) has established metal standards for structural steels (CSA G40.20/40.21), pipeline steels (CSA Z245.1), corrugated steel pipe (G401), wire products (CSA G4, G12, G30.x, G279.2, G387), sprayed metal coatings (G189), and welding consumables (CSA W48.x).

Most CSA material standards use SI units, although some are available in both SI and Imperial units (for example, CSA G40.20/G40.21-04). When a CSA standard designation is followed by the letter "M," it uses SI units, and if the letter "M" is not present, it may use both units or use only Imperial units. The type of measurement units adopted in CSA standards are specific industry driven, with some industries moving faster towards the exclusive use of SI units than others, and thus the reason for these differences.

As far as practicable, rationalization with relevant International Standards Organization (ISO) standards has been achieved in CSA G4, Steel Wire Rope for General Purpose and for Mine Hoisting and for Mine Haulage. Similarly, the 2002 edition of CSA Z245.1, Steel Line Pipe, references requirements for ISO 1027:1993 on radiographic image indicators for non-destructive testing: principles and identification, as well as ISO 5579:1985 on nondestructive testing – radiographic examination of metallic materials by X- and gamma rays – basic rules.

Introduction to European (EN) Standard Steel Designation System

The Comité Européen de Normalisation (CEN) (European Committee for Standardization) was founded in 1961 by the national standards bodies in the European Economic Community and EFTA countries. Now CEN is contributing to the objectives of the European Union and European Economic Area with voluntary technical standards. CEN is a system of formal processes to produce standards, shared principally between:

- 28 national members and the representative expertise they assemble from each country. These members vote for and implement European Standards (EN);
- 8 associate members and two counsellors;
- The CEN Management Centre, Brussels.

It works closely with the European Committee for Electrotechnical Standardization (CENELEC), the European Telecommunications Standards Institute (ETSI), and the International Organization for Standardization (ISO). It also has close liaisons with European trade and professional organizations.

The principal task of CEN is to prepare and issue European standards (EN), defined as a set of technical specifications established and approved in collaboration with the parties concerned in the various member countries of CEN. They are established on the principle of consensus and adopted by the votes of weighted majority. Adopted standards must be implemented in their entirety as national standards by each member country, regardless of the way in which the national member voted, and any conflicting national standards must be withdrawn.

The identification of European standards in each member country begins with the reference letters of the country's national standards body, for example, BS for BSI in the United Kingdom, DIN for DIN in Germany, NF for AFNOR in France, etc. It is followed by the initials EN and a sequential number of up to five digits. For example, BS EN 10025, DIN EN 10025, or NF EN 10025 are all the same EN standard, which are available in English, French, and German.

An EN standard may contain one document or it may be made up of several parts. For example, EN 10028 Parts 1 through 8, where each part specifies a particular characteristic of the steel product, and may not include the word *part* in the designation, but rather replace it with a hyphen, e.g., EN 10028-1, meaning Part 1. The prefix "pr" preceding the EN designation identifies the document as a draft standard that has not yet been approved, e.g., prEN 10088-1.

EN 10027 Standard Designation System for Steels

The CEN designation system for steels is standardized in EN 10027, which is published in two parts:

- Part 1 - Steel Names
- Part 2 - Steel Numbers

The steel name is a combination of letters and numbers as described by EN 10027-1. Within this system, steel names are classified into two groups. The system is similar in some respects to, but not identical with, that outlined in an ISO technical report (ISO TR 4949:1989 (E) "Steel names based on letter symbols").

Steel Names

Steel Names Group 1 within EN 10027-1 refers to steels that are designated according to their application and mechanical or physical properties. These have names that are comprised of one or more letters, related to the application, followed by a number related to properties. For example, the name for structural steels begins with the letter S, line pipe steels begin with the letter L, rail steels begin with the letter R, and steels for pressure purposes begin with the letter P, such as EN 10028-3 Steel Name P275N.

Steel Names Group 2 is used for steels that are designated according to their chemical composition, and are further divided into four subgroups depending on alloy content. Examples of these Group 2 steel names are:

- EN 10222-2 Steel Name 13CrMo4-5
- EN 10250-4 Steel Name X2CrNi18-9

Steel Numbers

EN 10027-2 describes the system used for assigning steel numbers, which are complementary to the steel names described above. The number consists of a fixed number of digits and is hence more suitable than the name for data processing purposes. The number is in the form 1.XXXX, where the 1. refers to steel. The first two digits following the "1" represent the steel group number. Examples of steel numbers are as follows:

- EN 10222-2 Steel Name 13CrMo4-5, Steel Number 1.7335
- EN 10250-4 Steel Name X2CrNi18-9, Steel Number 1.4307

Former National Standards Superseded by CEN Standards

An increasing number of national European and UK standards are being withdrawn and superseded by EN standards. This transition, from old to new standards, has made it increasingly more difficult to compare the superseded national standards with current standards from other nations outside of Europe and the UK, let alone comparing them to the new EN standards. Appendix 6 lists the EN standards with the superseded national standards and Appendix 7 lists the national standards that were superseded by the current EN standards (that is, the reverse of Appendix 6).

For example, if you are looking up a former national standard such as DIN 17441, Appendix 7 shows that it has been superseded by EN 10028-7:2000. Appendix 6 shows this information in reverse order, so that no matter which standard designation you are interested in, that is, the superseded or current standard, you can find it in this handbook.

Superseded national standards may be replaced by more than one new EN standard and some may have been partially replaced. So, a superseded national standard could be replaced by 2, 3, 4, or more new EN standards, or it may be only partially replaced by these new EN standards. These details can be found in Appendixes 6 and 7.

Indexes in this Handbook

One of the easiest ways of using this handbook is to refer to one of the four indexes. If a user is looking for a comparable steel, then the information can be found in at least one of the indexes. The indexes are built around the steel designation systems described previously, namely:

- Steel Grade/Name Index
- UNS Number Index
- Steel Number Index
- Specification Designation