STEEL CASTINGS HANDBOOK

SUPPLEMENT 2

2017
SUMMARY OF STANDARD
SPECIFICATIONS FOR
STEEL CASTINGS

STEEL FOUNDERS' SOCIETY
OF AMERICA

Steel Castings Handbook
Supplement 2

Summary of Standard Specifications
For Steel Castings - 2017

PREFACE

Supplement 2 will be revised at regular intervals. Supplement 2 is only a summary that is useful in comparing the general requirements in different types of specifications. When ordering, an up-to-date original specification should be used.

CONTENTS

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ORDERING STEEL CASTINGS

Overview

When making inquiries or ordering parts, all pertinent information must be stated on both the inquiry and order. This information should include all of the following components.

1. Casting shape – either by drawing or pattern. Drawings should include dimensional tolerances, indications of surfaces to be machined, and datum points for locating. If only a pattern is provided, then the dimensions of the casting are as predicted by the pattern.
2. Material specification and grade (e.g. ASTM A 27/A 27M – 95 Grade 60-30 Class 1).
3. Number of parts.
4. Supplementary requirements (e.g. ASTM A 781/A 781M – 95 S2 Radiographic Examination).
   A. Test methods (e.g. ASTM E 94)
   B. Acceptance criteria (e.g. ASTM E 186 severity level 2, or MSS SP-54-1995).
5. Any other information that might contribute to the production and use of the part.

To produce a part by any manufacturing process it is necessary to know the design of the part, the material to be used and the testing required. These three elements are discussed in detail in the following sections.

Design

Background

To obtain the highest quality product, the part should be designed to take advantage of the flexibility of the casting process. The foundry must have either the part drawing or pattern equipment and know the number of parts to be made. To take advantage of the casting process, the foundry should also know which surfaces are to be machined and where datum points are located. Reasonable dimensional tolerances must be indicated where a drawing is provided. Tolerances are normally decided by agreement between the foundry and customer. SFSA Supplement 3 represents a common starting point for such agreements. Supplement 3 is not a specification and care should be taken to reach agreement on what tolerances are required. Close cooperation between the customers' design engineers and the foundry's casting engineers is essential, to optimize the casting design, in terms of cost and performance. Additional guidelines for casting design are given in "Steel Castings Handbook" and Supplement 1,3, and 4 of the "Steel Castings Handbook".

Minimum Section Thickness

The rigidity of a section often governs the minimum thickness to which a section can be designed. There are cases however when a very thin section will suffice, depending upon strength and rigidity calculations, and when castability becomes the governing factor. In these cases, it is necessary that a limit of minimum section thickness per length be adopted in order for the molten steel to completely fill the mold cavity.

Molten steel cools rapidly as it enters a mold. In a thin section close to the gate, which delivers the hot metal, the mold will fill readily. At a distance from the gate, the metal may be too cold to fill the same thin section. A minimum thickness of 0.25" (6 mm) is suggested for design use when conventional steel casting techniques are employed. Wall thicknesses of 0.060" (1.5 mm) and sections tapering down to 0.030" (0.76 mm) are common for investment castings.

Draft

Draft is the amount of taper or the angle, which must be allowed on all vertical faces of a pattern to permit its removal from the sand mold without tearing the mold walls. Draft should be added to the design dimensions but metal thickness must be maintained.

Regardless of the type of pattern equipment used, draft must be considered in all casting designs. Draft can be eliminated by the use of cores; however, this adds significant costs. In cases where the amount of draft may affect the subsequent use of the casting, the drawing should specify whether this draft is to be added to or subtracted from the casting dimensions as given.

The necessary amount of draft depends upon the size of the casting, the method of production, and whether molding is by hand or machine. Machine molding will require a minimum amount of draft. Interior surfaces in green sand molding usually require more draft than exterior surfaces. The amount of draft recommended under normal conditions is about 3/16 inch per foot (approximately 1.5 degrees), and this allowance would normally be added to design dimensions.

Parting Line

Parting parallel to one plane facilitates the production of the pattern as well as the production of the mold. Patterns with straight parting lines, parting lines parallel to a single plane, can be produced more easily and at lower cost than patterns with irregular parting lines.

Casting shapes that are symmetrical about one centerline or plane readily suggest the parting line. Such casting design simplifies molding and coring, and should be used wherever possible. They should always be made as "split patterns" which require a minimum of handwork in the mold, improve casting finish, and reduce costs.

Cores

A core is a separate unit from the mold and is used to create openings and cavities that cannot be made by the pattern alone. Every attempt should be made by the designer to eliminate or reduce the number of cores needed for a particular design to reduce the final cost of the casting. The minimum diameter of a core that can be successfully used in steel castings is dependent upon three factors; the thickness of the metal section surrounding the core, the length of the core, and the special precautions and procedures used by the foundry.

The adverse thermal conditions to which the core is subjected increase in severity as the metal thickness surrounding the core increases and the core diameter decreases. These increasing amounts of heat from the heavy section must be dissipated through the core. As the severity of the thermal condition increases, the cleaning of the castings and core removal becomes much more difficult and expensive.

The thickness of the metal section surrounding the core and the length of the core affect the bending stresses induced in the core by buoyancy forces and therefore the ability of the foundry to obtain the tolerances required. If the size of the core is large enough, rods can often be used to strengthen the core. Naturally, as the metal thickness and the core length increase, the amount of reinforcement required to resist the bending stresses also increases. Therefore, the minimum diameter core must also increase to accommodate the extra reinforcing required.

The cost of removing cores from casting cavities may become prohibitive when the areas to be cleaned are inaccessible. The casting design should provide for openings sufficiently large enough to permit ready access for the removal of the core.

Internal Soundness/Directional Solidification

Steel castings begin to solidify at the mold wall, forming a continuously thickening envelope as heat is dissipated through the mold-metal interface. The volumetric contraction which occurs within a cross section of a solidifying cast member must be compensated by liquid feed metal from an adjoining heavier section, or from a riser which serves as a feed metal reservoir and which is placed adjacent to, or on top of, the heavier section.

The lack of sufficient feed metal to compensate for volumetric contraction at the time of solidification is the cause of shrinkage cavities. They are found in sections which, owing to design, must be fed through thinner sections. The thinner sections solidify too quickly to permit liquid feed metal to pass from the riser to the thicker sections.

Machining

In the final analysis, the foundry's casting engineer is responsible for giving the designer a cast product that is capable of being transformed by machining to meet the specific requirements intended for the function of the part. To accomplish this goal a close relationship must be maintained between the customer's engineering and purchasing staff and the casting producer. Jointly, and with a cooperative approach, the following points must be considered.

1. The molding process, its advantages and its limitations.
2. Machining stock allowance to assure clean up on all machined surfaces.
3. Design in relation to clamping and fixturing devices to be used during machining.

4. Selection of material specification and heat treatment.
5. Quality of parts to be produced.

Layout

It is imperative that every casting design when first produced be checked to determine whether all machining requirements called for on the drawings may be attained. This may be best accomplished by having a complete layout of the sample casting to make sure that adequate stock allowance for machining exists on all surfaces requiring machining. For many designs of simple configuration that can be measured with a simple rule, a complete layout of the casting may not be necessary. In other cases, where the machining dimensions are more complicated, it may be advisable that the casting be checked more completely, calling for target points and the scribing of lines to indicate all machined surfaces.

Material

The material to be used to produce the part must be identified in the order. Material for steel castings is generally ordered to ASTM requirements, although other specifications may be used. This supplement contains a summary of the scope, chemical composition requirements and mechanical property requirements of these material or product specifications. Many requirements are common to several specifications and are given in ASTM A 781/A 781M, ASTM A 703/A 703M, ASTM A 957, ASTM A 985, and ISO 4990.

ASTM A 781/A 781M – 16 CASTINGS, STEEL AND ALLOY, COMMON REQUIREMENTS, FOR GENERAL INDUSTRIAL USE

This specification covers a group of requirements that are mandatory requirements of the following steel casting specifications issued by American Society of Testing and Materials (ASTM). If the product specification specifies different requirements, the product specification shall prevail. ASTM Designations: A 27/A 27M, A 128/A 128M, A 148/A 148M, A 297/A 297M, A 447/A 447M, A 494/A 494M, A 560/A 560M, A 743/A 743M, A 744/A 744M, A 747/A 747M, A 890/A 890M, A 915/A 915M, A 958, and A 1002.

ASTM A 703/A 703M – 15 STEEL CASTINGS, GENERAL REQUIREMENTS, FOR PRESSURE CONTAINING PARTS

This specification covers a group of common requirements that, unless otherwise specified in an individual specification, shall apply to steel castings for pressure-containing parts under each of the following ASTM specifications. ASTM Designations: A 216/A 216M, A 217/A 217M, A 351/A 351M, A 352/A 352M, A 389/A 389M, A 487/A 487M, A 990, and A 995/A 995M.

ASTM A 957/A 957M – 15a INVESTMENT CASTINGS, STEEL AND ALLOY, COMMON REQUIREMENTS, FOR GENERAL INDUSTRIAL USE

This specification covers a group of requirements that are mandatory for castings produced by the investment casting process to meet the metallurgical requirements of the following steel casting specifications issued by ASTM. ASTM Designations: A 27/A 27M, A 128/A 128M, A 148/A 148M, A 297/A 297M, A 447/A 447M, A 494/A 494M, A 560/A 560M, A 732/A 732M, A 743/A 743M, A 744/A 744M, A 747/A 747M, A 890/A 890M, A 915/A 915M, A 958, and A 1002.

ASTM A 985/A 985M – 16 STEEL INVESTMENT CASTINGS GENERAL REQUIREMENTS, FOR PRESSURE-CONTAINING PARTS

This specification covers a group of common requirements, which are mandatory for steel castings produced by the investment casting process for pressure-containing parts under each of the following ASTM specifications. ASTM Designations: A 216/A 216M, A 217/A 217M, A 351/A 351M, A 352/A 352M, A 389/A 389M, A 487/A 487M, A 990/A 990M, and A 995/A 995M.

ISO 4990:2015 STEEL CASTINGS – GENERAL TECHNICAL DELIVERY REQUIREMENTS

Tests

Testing ensures that the material meets the requirements of the specification; consequently, testing is mandatory. More frequent testing or other tests may be imposed by use of supplementary requirements of product specifications or general requirement specifications. The least testing done consistent with the goals allows for the most economical product.

In addition to specifying test methods, acceptance criteria must be agreed on. The more testing and tighter the acceptance criteria, the more expensive the steel casting produced, without necessarily increasing the quality or serviceability of the steel casting. Hence, the extent of testing and acceptance criteria should be based on the design and service requirements.

The mechanical properties required are obtained from test bars cast separately from or attached to the castings to which they refer. The mechanical properties obtained represent the quality of steel, but do not necessarily represent the properties of the castings themselves. Solidification conditions and rate, if cooling during heat treatment, affect the properties of the casting, which in turn are influenced by casting thickness, size, and shape. In particular, the hardenability of some grades may restrict the maximum size at which the required mechanical properties are obtainable.

SUMMARY OF MATERIAL SPECIFICATIONS FOR CARBON AND ALLOY CAST STEELS

The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code makes extensive use of the ASTM specifications with slight modifications. For the sake of comparison, the ASME specifications use the preface SA so that SA 216 is related to ASTM A 216/A 216M. However, while ASTM A 216/A 216M could be used for the sake of comparison of grades, ASME SA 216 contained in Section II, must be used when complying with the code.

The American Iron and Steel Institute (AISI) and the Society of Automotive Engineers (SAE) developed a four number wrought alloy designation system, which is used extensively. These steels have been identified in the AISI classification by a numerical index system that is partially descriptive of the composition. The first digit indicates the type to which the steel belongs. A "1" indicates a carbon steel, a "2" indicates a nickel steel, and a digit greater than "2" indicates alloys other than nickel or alloy combinations. For low alloy steels, the second digit indicates the approximate percentage of the predominant alloy element. Usually the last two or three digits indicate the average carbon content in "points", or hundredths of a percent. Thus, "2340" indicates a nickel steel of approximately 3% nickel (3.25 to 3.75) and 0.40% carbon (0.38 to 0.43). The basic numerals for the various types of AISI steels (including plain-carbon steels) are listed in the table below. The basic numbering system adopted by the Society of Automotive Engineers is quite similar, differing only in minor details. The SAE Handbook should be consulted for comparison.

AISI Classification System

Series Designation	**Type**
10xx	Nonresulphurized carbon steel grades
11xx	Resulphurized carbon steel grades
12xx	Rephosphorized and resulphurized carbon steel grades
13xx	Manganese 1.75%
15xx	Manganese over 1.00 to 1.65%
23xx	Nickel 3.50%
25xx	Nickel 5.00%
31xx	Nickel 1.25% - Chromium 0.65%
33xx	Nickel 3.50% - Chromium 1.55%
40xx	Molybdenum 0.25%
41xx	Chromium 0.50 or 0.95% - Molybdenum 0.12 or 0.20%
43xx	Nickel 1.80% - Chromium 0.50 to 0.80% - Molybdenum 0.25%
44xx	Molybdenum 0.40 or 0.53%
46xx	Nickel 1.55 or 1.80% - Molybdenum 0.20 or 0.25%
47xx	Nickel 1.05% - Chromium 0.45% - Molybdenum 0.20%
48xx	Nickel 3.50% - Molybdenum 0.25%
50xx	Chromium 0.28 or 0.40%
51xx	Chromium 0.80, 0.90, 0.95, 1.00 or 1.05%
5xxx	Carbon 1.00% - Chromium 0.50, 1.00 or 1.45%
61xx	Chromium 0.80 or 0.95% - Vanadium 0.10% or 0.15% min.
81xx	Nickel 0.30 – Chromium 0.40 - Molybdenum 0.12
86xx	Nickel 0.55% - Chromium 0.50 or 0.65% - Molybdenum 0.20%
87xx	Nickel 0.55% - Chromium 0.50% - Molybdenum 0.25%
88xx	Nickel 0.55% - Chromium 0.50% - Molybdenum 0.35%
92xx	Manganese 0.85% - Silicon 2.00%
93xx	Nickel 3.25% - Chromium 1.20% - Molybdenum 0.12%
B	Denotes boron steel (e.g. 51B60)
BV	Denotes boron-vanadium steel (e.g. TS 43BV12 or TS 43BV14)
L	Denotes leaded steel (e.g. 10L18)

Needless to say, this list representing as it does, a standardization and simplification of thousands of alloy-steel compositions, is a very valuable aid to the specification and choice of alloy steels for various applications. Many of

these steels were developed for specific applications, and their continual satisfactory performance has resulted in a considerable degree of standardization of application among these compositions. These designations can be ordered in castings through the use of ASTM A 148/A 148M, A 915/A 915M, or A 958 but care must be used to select a grade with compatible mechanical properties. Also the wrought composition must be modified, especially the silicon and manganese content to allow for casting.

Below is a list of carbon and alloy cast steel specifications, with summary details on the following pages. Note that the values given in the summary of the specifications are stated with either U.S. Conventional Units (USCS) or Metric (SI) units, and are to be regarded separately. Units given in brackets are SI units. The values stated in each system are not exact equivalents (soft conversion); therefore, each system must be used independently of the other. Combining values from the two systems, by using conversion equations (hard conversion), may result in nonconformance with the specification. Also note that the values in the table are given in a minimum over maximum format. This means that if the value is a minimum it will be listed in the upper portion of the specification's table row and in the lower portion of the row if it is a maximum value. Finally, note that tables and their footnotes may be split across two or more pages.

AAR M-201 – 16	Steel Castings
ABS 2/1.5 – 17	Part 2, Chapter 1, Section 5: Hull Steel Castings
ABS 2/3.9 – 17	Part 2, Chapter 3, Section 9: Steel Castings for Machinery, Boilers, and Pressure Vessels
ASTM A 27/A 27M – 16	Steel Castings, Carbon, for General Application
ASTM A 148/A 148M – 15a	Steel Castings, High Strength, for Structural Purposes
ASTM A 216/A 216M – 16	Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
ASTM A 217/A 217M – 14	Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service
ASTM A 352/A 352M – 12	Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service
ASTM A 356/A 356M – 16	Steel Castings, Carbon, Low Alloy and Stainless Steel, Heavy Walled for Steam Turbines
ASTM A 389/A 389M – 13	Steel Castings, Alloy, Specially Heat-treated, for Pressure-Containing Parts, Suitable for High-Temperature Service
ASTM A 487/A 487M – 14	Steel Castings, Suitable for Pressure Service
ASTM A 597/A 597M – 14	Cast Tool Steel
ASTM A 732/A 732M – 14	Castings, Investment, Carbon and Low Alloy, for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures
ASTM A 757/A 757M – 15	Steel Castings, Ferritic and Martensitic for Pressure-Containing and Other Applications, for Low-Temperature Service
ASTM A 915/A 915M – 13	Steel Castings, Carbon, and Alloy, Chemical Requirements Similar to Standard Wrought Grades
ASTM A 958/A 958M – 15	Steel Castings, Carbon, and Alloy, with Tensile Requirements, Chemical Requirements Similar to Standard Wrought Grades
FEDERAL QQ-S-681F	Steel Castings
ISO 3755:1991	Cast Carbon Steels for General Engineering
ISO 4991:2015	Steel Castings for Pressure Purposes
ISO 9477:2015	High Strength Cast Steels for General Engineering and Structural Purposes
ISO 13521:2015	Austenitic Manganese Steel Castings
ISO 14737:2015	Cast Carbon and Low Alloy Steels for General Applications
Lloyd's Register Rule 2.4.1 – 16	Steel Castings Part 2, Chapter 4, Section 1: General Requirements
Lloyd's Register Rule 2.4.2 – 16	Steel Castings Part 2, Chapter 4, Section 2: Castings for Ship and Other Structural Applications
Lloyd's Register Rule 2.4.3 – 16	Steel Castings Part 2, Chapter 4, Section 3: Castings for Machinery Construction
Lloyd's Register Rule 2.4.4 – 16	Steel Castings Part 2, Chapter 4, Section 4: Castings for Crankshafts
Lloyd's Register Rule 2.4.5 – 16	Steel Castings Part 2, Chapter 4, Section 5: Castings for Propellers
Lloyd's Register Rule 2.4.6 – 16	Steel Castings Part 2, Chapter 4, Section 6: Castings for Boilers, Pressure Vessels and Piping Systems
Lloyd's Register Rule 2.4.7 – 16	Steel Castings Part 2, Chapter 4, Section 7: Ferritic Steel Castings for Low Temperature Service
Lloyd's Register Rule 2.4.9 – 16	Steel Castings Part 2, Chapter 4, Section 9: Steel Castings for Container Corner Fittings
MIL-C-24707/1 – 89	Castings, Ferrous, for Machinery and Structural Applications
MIL-C-24707/2 – 89	Castings, for Pressure Containing Parts Suitable for High Temperature Service
MIL-S-870B – 89	Steel Castings, Molybdenum Alloy
MIL-S-15083B(NAVY) – 89	Steel Castings
MIL-S-15464B(SHIPS) – 89	Steel Alloy, Chromium-Molybdenum; Castings
MIL-S-23008D(SH) – 03	Steel Castings, Alloy, High Yield Strength (HY-80 and HY-100)
MIL-S-46052A(MR) – 83	Steel Castings, High Strength, Low Alloy
SAE J435 – 07	Automotive Steel Castings
NAVSEA TP 0300 – 15	Base Materials for Critical Applications: Requirements for Low Alloy Steel Plate, Forgings, Castings, Shapes, Bars, and Heads of HY-80/100/130 and HSLA-80/100

AAR M-201 – 16 STEEL CASTINGS

This specification cover carbon and alloy steel castings for locomotive and car equipment and for miscellaneous use graded as A, B, B+, C, D, and E. This specification provides for all castings unless another AAR Specification for a particular product provides for a variation.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)							CHEMICAL COMPOSITION, % (maximum percent unless range given)				
Grade	Heat Treatment	Tensile Strength ksi	Yield Strength ksi	Elong %	Red A %	Other Tests[A,B] Hardness BHN	Impact Test ft-lb	Impact Test °F	C	Mn	P	S	Si
A	Unannealed	60	30	22	30	108 160	-	-	0.32[C]	0.90[C]	0.04	0.04	1.50
A	A or N	60	30	26	38	108 160	-	-	0.32[C]	0.90[C]	0.04	0.04	1.50
B	N or NT	70	38	24	36	137 228	15	20	0.32[C]	0.90[C]	0.04	0.04	1.50
B+	N or NT	80	50	24	36	137 228	15	20	0.32[C]	0.90[C]	0.04	0.04	1.50
C	NT or QT	90	60	22	45	179 241	0 (NT) 20 (QT)	15 (NT) -40 (QT)	0.32	1.85	0.04	0.04	1.50
D	QT	105	85	17	35	211 285	20	-40	0.32	1.85	0.04	0.04	1.50
E	QT	120	100	14	30	241 311	20	-40	0.32	1.85	0.04	0.04	1.50

[A] Grades D and E steel - composition of the steel, except for coupler locks, shall produce in the standard Jominy test the minimum hardness at 7/16 in. from the quenched end for the carbon composition as follows, based on the initial composition: up to 0.25% carbon = 30 HRC minimum, 0.25-0.30% carbon = 33 HRC minimum, and 0.31-0.32% carbon = 35 HRC minimum.
[B] Dynamic tear and nil ductility test temperature (alternate impact property test): Grade B and B+ 60°F, Grade C (NT) 60°F, Grade C (QT) -60°F, Grade D -60°F, and Grade E -60°F (see original specification for full details).
[C] Grades A, B, and B+ steel – for each reduction of 0.01% carbon below the maximum specified, an increase of 0.04% manganese above the maximum specified will be permitted to a maximum of 1.2%.

ABS 2/1.5 – 17 HULL STEEL CASTINGS

Requirements cover carbon-steel castings intended to be used in hull construction and equipment as distinguished from high-temperature applications.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, %[B] (maximum percent unless range given)										
Grade	Heat Treatment[A]	Tensile Strength MPa	Yield Strength MPa	Elong %	Red A %	Other Tests Impact Test[A] ft-lbs [J]	Impact Test[A] °F [°C]	C[C]	Si	Mn	S	P	Residual Elements[D] Cu	Cr	Ni	Mo	Al	Total
Ordinary	A, N, or NT	415	205	25	40			0.23	0.60	0.70 1.60	0.040	0.040	0.30	0.30	0.40	0.15		0.80
Special	A, N, or NT	415	205	25	40	20 [27]	32 [0]	0.23	0.60	0.70 1.60	0.035	0.035					[E]	0.80

[A] See original specification for full details.
[B] For special grade steel castings, a ladle and product analysis is to be made.

[C] For non-welded castings, the maximum carbon content is to be 0.40%.
[D] Grain refining elements such as aluminum may be used at the discretion of the manufacturer. The content of such elements is to be reported.
[E] Aluminum (acid soluble) = 0.015-0.080%; aluminum total = 0.020-0.10%

ABS 2/3.9 – 17 STEEL CASTINGS FOR MACHINERY, BOILERS, AND PRESSURE VESSELS

Requirements cover carbon-steel castings intended to be used in machinery, boiler, and pressure-vessel construction, such as crankshafts, turbine casings and bedplates.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)				
ABS Grade ASTM Designation	Heat Treatment[A]	Tensile Strength		Yield Strength		Elong %	Red A %	C[B]	Mn	P	S	Si
		ksi	MPa	ksi	MPa							
1 A27, Grade 60-30	A, N, or NT	60	415	30	205	24	35			0.040	0.040	0.60
2 A27, Grade 70-36	A, N, or NT	70	485	36	250	22	30			0.040	0.040	0.60
3 A216, Grade WCA	A, N, or NT	60	415	30	205	24	35			0.040	0.040	0.60
4 A216, Grade WCB	A, N, or NT	70	485	36	250	22	35			0.040	0.040	0.60

[A] See original specification for full details.
[B] For welded construction, the maximum carbon content is to be 0.23%.

ASTM A 27/A 27M – 16 STEEL CASTINGS, CARBON, FOR GENERAL APPLICATION

This specification covers carbon steel castings for general applications that require up to 70 ksi (485 MPa) minimum tensile strength.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)									
Grade[A] and UNS	Heat Treatment	Tensile Strength		Yield Strength		Elong %[B]	Red A %	C[C]	Mn[C]	P	S	Si	Specified Residual Elements[D]				
		ksi	MPa	ksi	MPa								Ni	Cr	Mo	Cu	Total max%
N-1 J02500								0.25	0.75	0.035	0.035	0.80	0.50	0.50	0.25	0.50	1.00
N-2 J03500	A, N, NT, or QT							0.35	0.60	0.035	0.035	0.80	0.50	0.50	0.25	0.50	1.00
U-60-30 [415-205] J02500		60	415	30	205	22	30	0.25	0.75	0.035	0.035	0.80	0.50	0.50	0.25	0.50	1.00
60-30 [415-205] J03000	A, N, NT, or QT	60	415	30	205	24	35	0.30	0.60	0.035	0.035	0.80	0.50	0.50	0.25	0.50	1.00
65-35 [450-240] J03001	A, N, NT, or QT	65	450	35	240	24	35	0.30	0.70	0.035	0.035	0.80	0.50	0.50	0.25	0.50	1.00

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)									
Grade[A] and UNS	Heat Treatment	Tensile Strength		Yield Strength		Elong %[B]	Red A %	C[C]	Mn[C]	P	S	Si	Specified Residual Elements[D]				
		ksi	MPa	ksi	MPa								Ni	Cr	Mo	Cu	Total max%
70-36 [485-250] J03501	A, N, NT, or QT	70	485	36	250	22	30	0.35	0.70	0.035	0.035	0.80	0.50	0.50	0.25	0.50	1.00
70-40 [485-275] J02501[E]	A, N, NT, or QT	70	485	40	275	22	30	0.25	1.20	0.035	0.035	0.80	0.50	0.50	0.25	0.50	1.00

[A] Specify Class 1 (post weld heat treatment required) or Class 2 (no PWHT needed) in addition to grade designation.
[B] When ICI test bars are used in tensile testing as provided for in this specification, the gage length to reduced section diameter ratio shall be 4 to 1.
[C] For each reduction of 0.01% carbon below the maximum specified, an increase of 0.04% manganese above the maximum specified will be permitted to a maximum of 1.40% for grades 70-40 [485-275] and 1.00% for the other grades.
[D] Supplementary requirement not required unless stipulated by customer - maximum content of unspecified elements; total maximum content of unspecified elements is 1.00%.
[E] Grade 70-40 [485-275] may be used to meet the requirement of Grade 70-36 [485-250], when agreed upon between the manufacturer and the purchaser.

ASTM A 148/A 148M – 15a STEEL CASTINGS, HIGH STRENGTH, FOR STRUCTURAL PURPOSES

This specification covers carbon steel and alloy steel castings that are to be subjected to higher mechanical stresses than those covered in Specification A 27/A 27M.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)								CHEMICAL COMPOSITION, % (maximum percent unless range given)	
Grade and UNS	Heat Treatment	Tensile Strength		Yield Strength		Elong %	Red A %	Impact Test ft-lb [J]		P	S
		ksi	MPa	ksi	MPa			Average	Single		
80-40 [550-275] D50400	A, N, NT, or QT	80	550	40	275	18	30			0.05	0.06
80-50 [550-345] D50500	A, N, NT, or QT	80	550	50	345	22	35			0.05	0.06
90-60 [620-415] D50600	A, N, NT, or QT	90	620	60	415	20	40			0.05	0.06
105-85 [725-585] D50850	A, N, NT, or QT	105	725	85	585	17	35			0.05	0.06
115-95 [795-655] D50950	A, N, NT, or QT	115	795	95	655	14	30			0.05	0.06
130-115 [895-795] D51150	A, N, NT, or QT	130	895	115	795	11	25			0.05	0.06
135-125 [930-860] D51250	A, N, NT, or QT	135	930	125	860	9	22			0.05	0.06

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)								CHEMICAL COMPOSITION, % (maximum percent unless range given)	
Grade and UNS	Heat Treatment	Tensile Strength		Yield Strength		Elong %	Red A %	Impact Test ft-lb [J]		P	S
		ksi	MPa	ksi	MPa			Average	Single		
150-135 [1035-930] D51350	A, N, NT, or QT	150	1035	135	930	7	18			0.05	0.06
160-145 [1105-1000] D51450	A, N, NT, or QT	160	1105	145	1000	6	12			0.05	0.06
165-150 [1140-1035] D51500	A, N, NT, or QT	165	1140	150	1035	5	20			0.020	0.020
165-150L [1140-1035L] D51501	A, N, NT, or QT	165	1140	150	1035	5	20	20 [27]	16 [22]	0.020	0.020
210-180 [1450-1240] D51800	A, N, NT, or QT	210	1450	180	1240	4	15			0.020	0.020
210-180L [1450-1240L] D51801	A, N, NT, or QT	210	1450	180	1240	4	15	15 [20]	12 [16]	0.020	0.020
260-210 [1795-1450] D52100	A, N, NT, or QT	260	1795	210	1450	3	6			0.020	0.020
260-210L [1795-1450L] D52101	A, N, NT, or QT	260	1795	210	1450	3	6	6 [8]	4 [5]	0.020	0.020

ASTM A 216/A 216M – 16 STEEL CASTINGS, CARBON, SUITABLE FOR FUSION WELDING, FOR HIGH TEMPERATURE SERVICE

This specification covers carbon steel castings for valves, flanges, fittings, or other pressure-containing parts for high-temperature service and of quality suitable for assembly with other castings or wrought-steel parts by fusion welding.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)									
Grade and UNS	Heat Treatment[A]	Tensile Strength		Yield Strength[B]		Elong %[C]	Red A %	C	Mn	P	S	Si	Specified Residual Elements[D]				
		ksi	MPa	ksi[B]	MPa[C]								Ni	Cr	Mo	Cu	V	Total Content max %
WCA J02502	A, N, NT	60 85	415 585	30	205	24	35	0.25[E]	0.70[E]	0.035	0.035[H]	0.60	0.50	0.50	0.20	0.30	0.03	1.00
WCB J03002	A, N, NT	70 95	485 655	36	250	22	35	0.30[F]	1.00[F]	0.035	0.035[H]	0.60	0.50	0.50	0.20	0.30	0.03	1.00
WCC J02503	A, N, NT	70 95	485 655	40	275	22	35	0.25[G]	1.20[G]	0.035	0.035[H]	0.60	0.50	0.50	0.20	0.30	0.03	1.00

[A] Quench and temper may only be applied if supplemental requirement S15 is specified.

[B] Determine by either 0.2% offset method or 0.5% extension-under-load-method.
[C] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.
[D] Not applicable when Supplementary Requirement S11 is specified.
[E] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted up to a maximum of 1.10%.
[F] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted up to a maximum of 1.28%.
[G] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted up to a maximum of 1.40%.
[H] For lower maximum sulfur content, see Supplementary Requirement S52.

ASTM A 217/A 217M – 14 STEEL CASTINGS, MARTENSITIC STAINLESS AND ALLOY, FOR PRESSURE-CONTAINING PARTS, SUITABLE FOR HIGH-TEMPERATURE SERVICE

This specification covers martensitic stainless steel and alloy steel castings for values, flanges, fittings, and other pressure-containing parts intended primarily for high-temperature and corrosive service.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, %[C] (maximum percent unless range given)																				
Grade and UNS	Heat Treatment	Tensile Strength		Yield Strength[A]		Elong %[B]	Red A %	C	Mn	P	S	Si	Ni	Cr	Mo	Cb	N	V	Specified Residual Elements								
		ksi	MPa	ksi	MPa														Al	Cu	Ni	Cr	Ti	W	V	Zr	Total Content max.
WC1 J12524	NT	65 90	450 620	35	240	24	35	0.25	0.50 0.80	0.04	0.045	0.60	…	…	0.45 0.65	…	…	…	…	0.50	0.50	0.35	…	0.10	…	…	1.00
WC4 J12082	NT	70 95	485 655	40	275	20	35	0.05 0.20	0.50 0.80	0.04	0.045	0.60	0.70 1.10	0.50 0.80	0.45 0.65	…	…	…	…	0.50	…	…	…	0.10	…	…	0.60
WC5 J22000	NT	70 95	485 655	40	275	20	35	0.05 0.20	0.40 0.70	0.04	0.045	0.60	0.60 1.00	0.50 0.90	0.90 1.20	…	…	…	…	0.50	…	…	…	0.10	…	…	0.60
WC6 J12072	NT	70 95	485 655	40	275	20	35	0.05 0.20	0.50 0.80	0.035[D]	0.035[D]	0.60	…	1.00 1.50	0.45 0.65	…	…	…	…	0.50	0.50	…	…	0.10	…	…	1.00
WC9 J21890	NT	70 95	485 655	40	275	20	35	0.05 0.18	0.40 0.70	0.035	0.035[D]	0.60	…	2.00 2.75	0.90 1.20	…	…	…	…	0.50	0.50	…	…	0.10	…	…	1.00
WC11 J11872	NT	80 105	550 725	50	345	18	45	0.15 0.21	0.50 0.80	0.020	0.015	0.30 0.60	…	1.00 1.50	0.45 0.65	…	…	…	0.01	0.50	0.50	…	…	…	0.03	…	1.00
C5 J42045	NT	90 115	620 795	60	415	18	35	0.20	0.40 0.70	0.04[D]	0.045[D]	0.75	…	4.00 6.50	0.45 0.65	…	…	…	…	0.50	0.50	…	…	0.10	…	…	1.00
C12 J82090	NT	90 115	620 795	60	415	18	35	0.20	0.35 0.65	0.035[D]	0.035[D]	1.00	…	8.00 10.00	0.90 1.20	0.03	…	0.06	…	0.50	0.50	…	…	0.10	…	…	1.00
C12A J84090	NT or QT	85 110	585 760	60	415	18	45	0.08 0.12	0.30 0.60	0.025	0.010	0.20 0.50	0.40	8.0 9.5	0.85 1.05	0.060 0.10	0.030 0.070	0.18 0.25	0.02	…	…	…	0.01	…	…	0.01	
CA15 J91150	NT	90 115	620 795	65	450	18	30	0.15	1.00	0.040[D]	0.025[D]	1.50	1.00	11.5 14.0	0.50	…	…	…	…	…	…	…	…	…	…	…	

[A] Determine by either 0.2% offset method or 0.5% extension-under-load method.
[B] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.
[C] Where ellipses (…) appear in this table, there is no requirement, and the element need not be analyzed for or reported.
[D] For lower maximum phosphorus or sulfur contents, see Supplementary Requirement S52.

ASTM A 352/A 352M – 12 STEEL CASTINGS, FERRITIC AND MARTENSITIC, FOR PRESSURE-CONTAINING PARTS, SUITABLE FOR LOW-TEMPERATURE SERVICE

This specification covers steel castings for valves, flanges, fittings, and other pressure-containing parts intended primarily for low-temperature service.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)									CHEMICAL COMPOSITION, % (maximum percent unless range given)																	
Grade and UNS	Heat Treatment	Tensile Strength[A]		Yield Strength[B]		Elong %[C]	Red A %	OTHER TESTS Impact Test[A,D]			C	Si	Mn	P	S	Ni	Cr	Mo	Cu	V	Specified Residual Elements[E]					
		ksi	MPa	ksi	MPa			Average ft-lb [J]	Single ft-lb [J]	°F [°C]											Ni	Cr	Mo	Cu	V	Total Content Max
LCA J02504	NT or QT	60 85	415 585	30	205	24	35	13 [18]	10 [14]	-25 [-32]	0.25[F]	0.60	0.70[F]	0.04	0.045			0.20	0.30		0.50	0.50			0.03	1.00
LCB[F] J03003	NT or QT	65 90	450 620	35	240	24	35	13 [18]	10 [14]	-50 [-46]	0.30	0.60	1.00	0.04	0.045						0.50	0.50	0.20	0.30	0.03	1.00
LCC J02505	NT or QT	70 95	485 655	40	275	22	35	15 [20]	12 [16]	-50 [-46]	0.25[F]	0.60	1.20[F]	0.04	0.045						0.50	0.50	0.20	0.30	0.03	1.00
LC1 J12522	NT or QT	65 90	450 620	35	240	24	35	13 [18]	10 [14]	-75 [-59]	0.25	0.60	0.50 0.80	0.04	0.045	…	…	0.45 0.65	…	…						
LC2 J22500	NT or QT	70 95	485 655	40	275	24	35	15 [20]	12 [16]	-100 [-73]	0.25	0.60	0.50 0.80	0.04	0.045	2.00 3.00	…	…	…	…						
LC2-1 J42215	NT or QT	105 130	725 895	80	550	18	30	30 [41]	25 [34]	-100 [-73]	0.22	0.50	0.55 0.75	0.04	0.045	2.50 3.50	1.35 1.85	0.30 0.60	…	…						
LC3 J31550	NT or QT	70 95	485 655	40	275	24	35	15 [20]	12 [16]	-150 [-101]	0.15	0.60	0.50 0.80	0.04	0.045	3.00 4.00	…	…	…	…						
LC4 J41500	NT or QT	70 95	485 655	40	275	24	35	15 [20]	12 [16]	-175 [-115]	0.15	0.60	0.50 0.80	0.04	0.045	4.00 5.00	…	…	…	…						
LC9 J31300	QT	85	585	75	515	20	30	20 [27]	15 [20]	-320[-196]	0.13	0.45	0.90	0.04	0.045	8.50 10.0	0.50	0.20	0.30	0.03						
CA6NM J91540	NT	110 135	760 930	80	550	15	35	20 [27]	15 [20]	-100 [-73]	0.06	1.00	1.00	0.04	0.03	3.5 4.5	11.5 14.0	0.4 1.0	…	…						

[A] See 1.2 (original specification).
[B] Determine by either 0.2% offset method or 0.5% extension-under-load method.
[C] When ICI test bars are used in tensile testing as provided for in Specification A 703/ A 703M, the gage length to reduced section diameter ration shall be 4 to 1.
[D] See Appendix X1 (original specification).
[E] Specified residual elements – the total content of these elements is 1.00% maximum.
[F] For each reduction of 0.01% below the maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted up to a maximum of 1.10% for LCA, 1.28% for LCB, and 1.40% LCC.

ASTM A 356/A 356M – 16 STEEL CASTINGS, CARBON, LOW ALLOY AND STAINLESS STEEL, HEAVY WALLED FOR STEAM TURBINES

This specification covers one grade of martensitic stainless steel and several grades of ferritic steel castings for cylinders (shells), value chests, throttle valves, and other heavy-walled castings for steam turbine applications.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, %[A] (maximum percent unless range given)												
Grade and UNS	Heat Treatment	Tensile Strength		Yield Strength		Elong %	Red A %	C	Mn	Si	P	S	Mo	Cr	Ni	V	Cb	N	Al	Other
		ksi	MPa	ksi	MPa															
1 J03502	NT	70	485	36	250	20.0	35.0	0.35[B]	0.70[B]	0.60	0.035	0.030	…	…	…	…	…	…	…	…
2 J12523	NT	65	450	35	240	22.0	35.0	0.25[B]	0.70[B]	0.60	0.035	0.030	0.45 0.65	…	…	…	…	…	…	…
5 J12540	NT	70	485	40	275	22.0	35.0	0.25[B]	0.70[B]	0.60	0.035	0.030	0.40 0.60	0.40 0.70	…	…	…	…	…	…
6 J12073	NT	70	485	45	310	22.0	35.0	0.20	0.50 0.80	0.60	0.035	0.030	0.45 0.65	1.00 1.50	…	…	…	…	…	…
8 J11697	NT	80	550	50	345	18.0	45.0	0.20	0.50 0.90	0.20 0.60	0.035	0.030	0.90 1.20	1.00 1.50	…	0.05 0.15	…	…	…	…
9 J21610	NT	85	585	60	415	15.0	45.0	0.20	0.50 0.90	0.20 0.60	0.035	0.030	0.90 1.20	1.00 1.50	…	0.20 0.35	…	…	…	…
10 J22090	NT	85	585	55	380	20.0	35.0	0.20	0.50 0.80	0.60	0.035	0.030	0.90 1.20	2.00 2.75	…	…	…	…	…	…
CA6NM J91540	NT	110	760	80	550	15.0	35.0	0.06	1.00	1.00	0.040	0.030	0.4 1.0	11.5 14.0	3.5 4.5	…	…	…	…	…

[A] Where ellipses appear in this table, there is no requirement and the element need not be analyzed for or reported.
[B] For each 0.01% reduction in carbon below the maximum specified, an increase of 0.04% points of manganese over the maximum specified for that element may be permitted up to 1.00%.

ASTM A 389/A 389M – 13 STEEL CASTINGS, ALLOY, SPECIALLY HEAT-TREATED, FOR PRESSURE-CONTAINING PARTS, SUITABLE FOR HIGH-TEMPERATURE SERVICE

This specification covers alloy steel castings, which have been subjected to special heat treatment, for valves, flanges, fittings, and other pressure-containing parts intended primarily for high-temperature service.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)							
Grade and UNS	Heat Treatment	Tensile Strength		Yield Strength[A]		Elong %[B]	Red A %	C	Mn	P	S	Si	Cr	Mo	V
		ksi	MPa	ksi	MPa										
C23 J12080	NT	70	483	40	276	18.0	35.0	0.20	0.30 0.80	0.035	0.035	0.60	1.00 1.50	0.45 0.65	0.15 0.25
C24 J12092	NT	80	552	50	345	15.0	35.0	0.20	0.30 0.80	0.035	0.035	0.60	0.80 1.25	0.90 1.20	0.15 0.25

[A] Determine by either 0.2% offset or 0.5% extension-under-load method.
[B] When ICI test bars are used in tensile testing as provided for in Specification A 703/ A 703M, the gage length to reduced section diameter ration shall be 4 to 1.

ASTM A 487/A 487M – 14 STEEL CASTINGS, SUITABLE FOR PRESSURE SERVICE

This specification covers low-alloy steels, and martensitic stainless steels in the normalized and tempered, or quenched and tempered condition suitable for pressure-containing parts. The weldability of the classes in the specification varies from readily weldable to weldable only with adequate precautions, and the weldability of each class should be considered prior to assembly by fusion welding.

GRADE		MECHANICAL PROPERTIES (min. unless range given)								CHEMICAL COMPOSITION, % (max. percent unless range given)																		
Grade and UNS	Class[A]	Tensile Strength		Yield Strength		Elong %	Red A %	Hardness (max) HRC [BHN]	Thickness (max) in [mm]	C	Mn	P	S	Si	Ni	Cr	Mo	V	B	Cu	Residual Elements						
		ksi	MPa	ksi	MPa																		Cu	Ni	Cr	Mo+W	W	V	Total Content
1 J13002	A	85 110	585 760	55	380	22	40			0.30	1.00	0.035	0.035	0.80	…	…	…	0.04 0.12	…	…	0.50	0.50	0.35	0.25	…	…	1.00
	B	90 115	620 795	65	450	22	45																					
	C	90	620	65	450	22	45	22 [235]																				
2 J13005	A	85 110	585 760	53	365	22	35			0.30	1.00 1.40	0.035	0.035	0.80	…	…	0.10 0.30	…	…	…	0.50	0.50	0.35	…	0.10	0.03	1.00
	B	90 115	620 795	65	450	22	40																					
	C	90	620	65	450	22	40	22 [235]																				
4 J13047	A	90 115	620 795	60	415	18	40			0.30	1.00	0.035	0.035	0.80	0.40 0.80	0.40 0.80	0.15 0.30	…	…	…	0.50	…	…	…	0.10	0.03	0.60
	B	105 130	725 895	85	585	17	35																					
	C	90	620	60	415	18	35	22 [235]																				
	D	100	690	75	515	17	35	22 [235]																				
	E	115	795	95	655	15	35																					
6 J13855	A	115	795	80	550	18	30			0.05 0.38	1.30 1.70	0.035	0.035	0.80	0.40 0.80	0.40 0.80	0.30 0.40	…	…	…	0.50	…	…	…	0.10	0.03	0.60
	B	120	825	95	655	12	25																					
7[B] J12084	A	115	795	100	690	15	30		2.5 [63.5]	0.05 0.20	0.60 1.00	0.035	0.035	0.80	0.70 1.00	0.40 0.80	0.40 0.60	0.03 0.10	0.002 0.006	0.15 0.50	0.50	…	…	…	0.10	…	0.60
8 J22091	A	85 110	585 760	55	380	20	35			0.05 0.20	0.50 0.90	0.035	0.035	0.80	…	2.00 2.75	0.90 1.10	…	…	…	0.50	…	…	…	0.10	0.03	0.60
	B	105	725	85	585	17	30																					
	C	100	690	75	515	17	35	22 [235]																				
9 J13345	A	90	620	60	415	18	35			0.05 0.33	0.60 1.00	0.035	0.035	0.80	…	0.75 1.10	0.15 0.30	…	…	…	0.50	0.50	…	…	0.10	0.03	1.00
	B	105	725	85	585	16	35																					
	C	90	620	60	415	18	35	22 [235]																				
	D	100	690	75	515	17	35	22 [235]																				
	E	115	795	95	655	15	35																					
10 J23015	A	100	690	70	485	18	35			0.30	0.60 1.00	0.035	0.035	0.80	1.40 2.00	0.55 0.90	0.20 0.40	…	…	…	0.50	…	…	…	0.10	0.03	0.60

GRADE		MECHANICAL PROPERTIES (min. unless range given)								CHEMICAL COMPOSITION, % (max. percent unless range given)																		
Grade and UNS	Class[A]	Tensile Strength		Yield Strength		Elong %	Red A %	Hardness (max) HRC [BHN]	Thickness (max) in [mm]	C	Mn	P	S	Si	Ni	Cr	Mo	V	B	Cu	Residual Elements						
		ksi	MPa	ksi	MPa																Cu	Ni	Cr	Mo+W	W	V	Total Content
	B	125	860	100	690	15	35																					
11 J12082	A	70 95	484 655	40	275	20	35			0.05 0.20	0.50 0.80	0.035	0.035	0.60	0.70 1.10	0.50 0.80	0.45 0.65	…	…	…	0.50	…	…	…	0.10	0.03	0.50
	B	105 130	725 895	85	585	17	35																					
12 J22000	A	70 95	485 655	40	275	20	35			0.05 0.20	0.40 0.70	0.035	0.035	0.60	0.60 1.00	0.50 0.90	0.90 1.20	…	…	…	0.50	…	…	…	0.10	0.03	0.50
	B	105 130	725 895	85	585	17	35																					
13 J13080	A	90 115	620 795	60	415	18	35			0.30	0.80 1.10	0.035	0.035	0.60	1.40 1.75	…	0.20 0.30	…	…	…	0.50	…	0.40	…	0.10	0.03	0.75
	B	105 130	725 895	85	585	17	35																					
14 J15580	A	120 145	825 1000	95	655	14	30			0.55	0.80 1.10	0.035	0.035	0.60	1.40 1.75	…	0.20 0.30	…	…	…	0.50	…	0.40	…	0.10	0.03	0.75
16 J31200	A	70 95	485 655	40	275	22	35			0.12[C]	2.10[C]	0.02	0.02	0.50	1.00 1.40	…	…	…	…	…	0.20	…	0.20	0.10	0.10	0.02	0.50
CA15 J91150	A	140 170	965 1170	110 130	760 895	10	25			0.15	1.00	0.035	0.035	1.50	1.00	11.5 14.0	0.50	…	…	…	0.50	…	…	…	0.10	0.05	0.50
	B	90 115	620 795	65	450	18	30																					
	C	90	620	60	415	18	35	22 [235]																				
	D	100	690	75	515	17	35	22 [235]																				
CA15M J91151	A	90 115	620 795	65	450	18	30			0.15	1.00	0.035	0.035	0.65	1.00	11.5 14.0	0.15 1.0	…	…	…	0.50	…	…	…	0.10	0.05	0.50
CA6NM J91540	A	110 135	760 930	80	550	15	35			0.06	1.00	0.035	0.03	1.00	3.5 4.5	11.5 14.0	0.4 1.0	…	…	…	0.50	…	…	…	0.10	0.05	0.50
	B	100	690	75	515	17	35	22 [235][D]																				

[A] See original specification for additional information on heat treatment requirements.
[B] Proprietary steel composition.
[C] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.40% manganese above the specified maximum will be permitted up to a maximum of 2.30%.
[D] Test Methods and Definitions A 370, Table 3a does not apply to CA6NM. The conversion given is based on CA6NM test coupons. (For example, see ASTM STP 756.8).

ASTM A 597/A 597M – 14 CAST TOOL STEEL

This specification covers tool steel compositions for usable shapes cast by pouring directly into suitable molds and for master heats for remelting and casting.

GRADE and UNS	CHEMICAL COMPOSITION, % (maximum percent unless range given)[A]										
	C	Mn	Si	S	P	Cr	Mo	V	Co	W	Ni
CA-2 T90102	0.95 1.05	0.75	1.50	0.03	0.03	4.75 5.50	0.90 1.40	0.20 0.50[B]	…	…	…
CD-2 T90402	1.40 1.60	1.00	1.50	0.03	0.03	11.00 13.00	0.70 1.20	0.40 1.00[B]	0.70 1.00[B]	…	…
CD-5 T90405	1.35 1.60	0.75	1.50	0.03	0.03	11.00 13.00	0.70 1.20	0.35 0.55	2.50 3.50	…	0.40 0.60[B]
CS-5 T91905	0.50 0.65	0.60 1.00	1.75 2.25	0.03	0.03	0.35	0.20 0.80	0.35	…	…	…
CM-2 T11302	0.78 0.88	0.75	1.00	0.03	0.03	3.75 4.50	4.50 5.50	1.25 2.20	0.25	5.50 6.75	0.25
CS-7 T91907	0.45 0.55	0.40 0.80	0.60 1.00	0.03	0.03	3.00 3.50	1.20 1.60	…	…	…	…
CH-12	0.30 0.40	0.75	1.50	0.03	0.03	4.75 5.75	1.25 1.75	0.20 0.50	…	1.00 1.70	…
CH-13	0.30 0.42	0.75	1.50	0.03	0.03	4.75 5.75	1.25 1.75	0.75 1.20	…	…	…
CD-51	0.85 1.00	1.00 3.00	1.50	0.03	0.03	0.40 1.00	…	0.30	…	0.40 0.60	…

[A] Where ellipses (…) appear in this table there is no requirement, and the element need not be analyzed or reported.
[B] Optional element. Tool steels have found satisfactory application either with or without the element present. If desired, it should be specified on the order.

ASTM A 732/A 732M – 14 CASTINGS, INVESTMENT, CARBON AND LOW ALLOY, FOR GENERAL APPLICATION, AND COBALT ALLOY FOR HIGH STRENGTH AT ELEVATED TEMPERATURES

This specification covers carbon and low-alloy steel castings made by the investment casting process.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)																		
Grade and UNS	Heat Treatment	Tensile Strength		Yield Strength		Elong %	Other Tests	C	Mn	P	S	Si	Ni	Cr	Mo	V	Co	W	Fe	B	Specified Residual Elements					
		ksi	MPa	ksi	MPa		Stress Rupture[A] ksi [MPa]														Cu	Ni	Cr	Mo+W	W	Total Content
1A J02002	A	60	414	40	276	24		0.15 0.25	0.20 0.60	0.04	0.045	0.20 1.00									0.50	0.50	0.35	0.25		1.00
2A J03011	A	65	448	45	310	25		0.25 0.35	0.70 1.00	0.04	0.045	0.20 1.00									0.50	0.50	0.35		0.10	1.00
2Q J03011	QT	85	586	60	414	10		0.25 0.35	0.70 1.00	0.04	0.045	0.20 1.00									0.50	0.50	0.35		0.10	1.00
3A J04002	A	75	517	48	331	25		0.35 0.45	0.70 1.00	0.04	0.045	0.20 1.00									0.50	0.50	0.35		0.10	1.00
3Q J04002	QT	100	689	90	621	10		0.35 0.45	0.70 1.00	0.04	0.045	0.20 1.00									0.50	0.50	0.35		0.10	1.00
4A	A	90	621	50	345	20		0.45 0.55	0.70 1.00	0.04	0.045	0.20 1.00									0.50				0.10	0.60

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)																		
Grade and UNS	Heat Treatment	Tensile Strength		Yield Strength		Elong %	Other Tests	C	Mn	P	S	Si	Ni	Cr	Mo	V	Co	W	Fe	B	Specified Residual Elements					
		ksi	MPa	ksi	MPa		Stress Rupture[A] ksi [MPa]														Cu	Ni	Cr	Mo+W	W	Total Content
4Q	QT	125	862	100	689	5		0.45 0.55	0.70 1.00	0.04	0.045	0.20 1.00									0.50				0.10	0.60
5N J13052	NT	85	586	55	379	22		0.30	0.70 1.00	0.04	0.045	0.20 0.80				0.05 0.15					0.50	0.50	0.35	0.25		1.00
6N J13512	NT	90	621	60	414	20		0.35	1.35 1.75	0.04	0.045	0.20 0.80			0.25 0.55						0.50	0.50	0.35		0.25	1.00
7Q J13045	QT	150	1030	115	793	7		0.25 0.35	0.40 0.70	0.04	0.045	0.20 0.80		0.80 1.10	0.15 0.25						0.50				0.10	0.60
8Q J14049	QT	180	1241	145	1000	5		0.35 0.45	0.70 1.00	0.04	0.045	0.20 0.80		0.80 1.10	0.15 0.25						0.50	0.50			0.10	1.00
9Q J23055	QT	150	1030	115	793	7		0.25 0.35	0.40 0.70	0.04	0.045	0.20 0.80	1.65 2.00	0.70 0.90	0.20 0.30						0.50				0.10	0.60
10Q J24054	QT	180	1241	145	1000	5		0.35 0.45	0.70 1.00	0.04	0.045	0.20 0.80	1.65 2.00	0.70 0.90	0.20 0.30						0.50				0.10	1.00
11Q J12094	QT	120	827	100	689	10		0.15 0.25	0.40 0.70	0.04	0.045	0.20 0.80	1.65 2.00		0.20 0.30						0.50		0.35		0.10	1.00
12Q J15048	QT	190	1310	170	1172	4		0.45 0.55	0.65 0.95	0.04	0.045	0.20 0.80		0.80 1.10		0.15 min					0.50	0.50		0.10		1.00
13Q J12048	QT	105	724	85	586	10		0.15 0.25	0.65 0.95	0.04	0.045	0.20 0.80	0.40 0.70	0.40 0.70	0.15 0.25						0.50				0.10	1.00
14Q J13051	QT	150	1030	115	793	7		0.25 0.35	0.65 0.95	0.04	0.045	0.20 0.80	0.40 0.70	0.40 0.70	0.15 0.25						0.50				0.10	1.00
15A[B] J19966	A	…	…	…	…	…		0.95 1.10	0.25 0.55	0.04	0.045	0.20 0.80		1.30 1.60							0.50	0.50			0.10	0.60
21 R30021	as cast	52.0[C]	360[C]			10	23.0 [160]	0.20 0.30	1.00	0.040	0.040	1.00	1.7 3.8	25.0 29.0	5.0 6.0		remainder	…	3.00	0.007						
31	as cast	55.0[C]	380[C]			10	30.0 [205]	0.45 0.55	1.00	0.040	0.040	1.00	9.5 11.5	24.5 26.5	…		remainder	7.0 8.0	2.00	0.005 0.015						

[A] Stress rupture test at 1500°F [820°C], the minimum rupture life is 15 hours with a minimum elongation in 4D of 5%.
[B] Hardness Rockwell B, 100 max.
[C] Test at elevated temperature, 1500°F [820°C].

ASTM A 757/A 757M – 15 STEEL CASTINGS, FERRITIC AND MARTENISTIC FOR PRESSURE-CONTAINING AND OTHER APPLICATIONS, FOR LOW-TEMPERATURE SERVICE

This specification covers carbon and low-alloy steel castings for pressure-containing and other applications intended primarily for petroleum and gas pipelines in areas subject to low-ambient temperatures. Castings shall be heat treated by normalizing and tempering or liquid quenching and tempering. All classes are weldable under proper conditions. Hardenability of some grades may limit useable section size.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)									CHEMICAL COMPOSITION, % (maximum percent unless range given)														
Grade and UNS	Heat Treatment	Tensile Strength		Yield Strength		Elong %	Red A %	Other Tests[A]			C	Mn	P	S	Si	Ni	Cr	Mo	Specified Residual Elements						
								Impact Test												V	Cu	Ni	Cr	Mo	W	Total Content[C]
		ksi	MPa	ksi	MPa			Average ft-lb [J]	Single ft-lb [J]	°F [°C]																
A1Q J03002	QT	65	450	35	240	24	35	13 [17]	10 [14]	-50 [-46]	0.30	1.00	0.025	0.025	0.60				0.03	0.50	0.50	0.40	0.25		1.00
A2Q J02503	QT	70	485	40	275	22	35	15 [20]	12 [16]	-50 [-46]	0.25[B]	1.20[B]	0.025	0.025	0.60				0.03	0.50	0.50	0.40	0.25	1.00	
B2N, B2Q J22501	NT or QT	70	485	40	275	24	35	15 [20]	12 [16]	-100 [-73]	0.25	0.50 0.80	0.025	0.025	0.60	2.0 3.0			0.03	0.50		0.40	0.25		1.00
B3N, B3Q J31500	NT or QT	70	485	40	275	24	35	15 [20]	12 [16]	-150 [-101]	0.15	0.50 0.80	0.025	0.025	0.60	3.0 4.0			0.03	0.50		0.40	0.25		1.00
B4N, B4Q J41501	NT or QT	70	485	40	275	24	35	15 [20]	12 [16]	-175 [-115]	0.15	0.50 0.80	0.025	0.025	0.60	4.0 5.0			0.03	0.50		0.40	0.25		1.00
C1Q J12582	QT	75	515	55	380	22	35	15 [20]	12 [16]	-50 [-46]	0.25	1.20	0.025	0.025	0.60	1.5 2.0		0.15 0.30	0.03	0.50		0.40			1.00
D1N1, D1Q1 J22092	NT or QT	85 115	585 795	55	380	20	35	[D]	[D]	[D]	0.20	0.40 0.80	0.025	0.025	0.60		2.0 2.75	0.90 1.20	0.03	0.50	0.50			0.10	1.00
D1N2, D1Q2 J22092	NT or QT	95 125	655 860	75	515	18	35	[D]	[D]	[D]	0.20	0.40 0.80	0.025	0.025	0.60		2.0 2.75	0.90 1.20	0.03	0.50	0.50			0.10	1.00
D1N3, D1Q3 J22092	NT or QT	105 135	725 930	85	585	15	30	[D]	[D]	[D]	0.20	0.40 0.80	0.025	0.025	0.60		2.0 2.75	0.90 1.20	0.03	0.50	0.50			0.10	1.00
E1Q J42220	QT	90	620	65	450	22	40	30 [41]	25 [34]	-100 [-73]	0.22	0.50 0.80	0.025	0.025	0.60	2.5 3.5	1.35 1.85	0.35 0.60	0.03	0.50					0.70
E2N1, E2Q1 J42065	NT or QT	90 120	620 825	70	485	18	35	30 [41]	25 [34]	-100 [-73]	0.20	0.40 0.70	0.020	0.020	0.60	2.75 3.90	1.50 2.0	0.40 0.60	0.03	0.50				0.10	0.70
E2N2, E2Q2 J42065	NT or QT	105 135	725 930	85	585	15	30	20 [27]	15 [20]	-100 [-73]	0.20	0.40 0.70	0.020	0.020	0.60	2.75 3.90	1.50 2.0	0.40 0.60	0.03	0.50				0.10	0.70
E2N3, E2Q3 J42065	NT or QT	115 145	795 1000	100	690	13	30	15 [20]	12 [16]	-100 [-73]	0.20	0.40 0.70	0.020	0.020	0.60	2.75 3.90	1.50 2.0	0.40 0.60	0.03	0.50				0.10	0.70
E3N J91550	NT	110	760	80	550	15	35	20 [27]	15 [20]	-100 [-73]	0.06	1.00	0.030	0.030	1.00	3.5 4.5	11.5 14.0	0.40 1.0		0.50				0.10	0.50

[A] Refer to the original specification for additional information on toughness requirement and effective size information.
[B] For each 0.01% reduction in carbon below the maximum specified, an increase of 0.04% manganese over the maximum specified will be permitted up to 1.40%.
[C] Total residuals includes phosphorus and sulfur.
[D] Requirements shall be subject to agreement between the manufacturer and the purchaser.

ASTM A 915/A 915M – 13 STEEL CASTINGS, CARBON, AND ALLOY, CHEMICAL REQUIREMENTS SIMILAR TO STANDARD WROUGHT GRADES

This specification covers carbon and low-alloy steel castings having chemical analyses similar to that of the standard wrought grades.

GRADE & HEAT TREATMENT		CHEMICAL COMPOSITION, % (maximum percent unless range given)							
Grade and UNS	**Heat Treatment**	**C**	**Mn**	**P**	**S**	**Si**	**Ni**	**Cr**	**Mo**
SC 1020 J02003	as cast, A, N, NT, or QT	0.18 0.23	0.40 0.80	0.040	0.040	0.30 0.60	…	…	…
SC 1025 J02508	as cast, A, N, NT, or QT	0.22 0.28	0.40 0.80	0.040	0.040	0.30 0.60	…	…	…
SC 1030 J03012	A, N, NT, or QT	0.28 0.34	0.50 0.90	0.040	0.040	0.30 0.60	…	…	…
SC 1040 J04003	A, N, NT, or QT	0.37 0.44	0.50 0.90	0.040	0.040	0.30 0.60	…	…	…
SC 1045 J04502	A, N, NT, or QT	0.43 0.50	0.50 0.90	0.040	0.040	0.30 0.60	…	…	…
SC 4130 J13502	A, N, NT, or QT	0.28 0.33	0.40 0.80	0.040	0.040	0.30 0.60	…	0.80 1.10	0.15 0.25
SC 4140 J14045	A, N, NT, or QT	0.38 0.43	0.70 1.10	0.040	0.040	0.30 0.60	…	0.80 1.10	0.15 0.25
SC 4330 J23259	A, N, NT, or QT	0.28 0.33	0.60 0.90	0.040	0.040	0.30 0.60	1.65 2.00	0.70 0.90	0.20 0.30
SC 4340 J24053	A, N, NT, or QT	0.38 0.43	0.60 0.90	0.040	0.040	0.30 0.60	1.65 2.00	0.70 0.90	0.20 0.30
SC 8620 J12095	A, N, NT, or QT	0.18 0.23	0.60 1.00	0.040	0.040	0.30 0.60	0.40 0.70	0.40 0.60	0.15 0.25
SC 8625 J12595	A, N, NT, or QT	0.23 0.28	0.60 1.00	0.040	0.040	0.30 0.60	0.40 0.70	0.40 0.60	0.15 0.25
SC 8630 J13095	A, N, NT, or QT	0.28 0.33	0.60 1.00	0.040	0.040	0.30 0.60	0.40 0.70	0.40 0.60	0.15 0.25

ASTM A 958/A 958M – 15 STEEL CASTINGS, CARBON, AND ALLOY, WITH TENSILE REQUIREMENTS, CHEMICAL REQUIREMENTS SIMILAR TO STANDARD WROUGHT GRADES

This specification covers carbon and low-alloy steel castings having chemical analyses similar to that of the standard wrought grades.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)													CHEMICAL COMPOSITION, % (maximum percent unless range given)							
Grade and UNS	**Heat Treatment**	**Tensile Requirements/Grade Suitability[A,C]**													**C**	**Mn**	**P**	**S**	**Si**	**Ni**	**Cr**	**Mo**
		65/35	**70/36**	**80/40**	**80/50**	**90/60**	**105/85**	**115/95**	**130/115**	**135/125**	**150/135**	**160/145**	**165/150**	**210/180**								
SC 1020 J02003	A, N, NT, or QT	X	X												0.18 0.23	0.40 0.80	0.040	0.040	0.30 0.60			
SC 1025 J02508	A, N, NT, or QT	X	X												0.22 0.28	0.40 0.80	0.040	0.040	0.30 0.60			
SC 1030 J03012	A, N, NT, or QT	X	X	X	X										0.28 0.34	0.50 0.90	0.040	0.040	0.30 0.60			
SC 1040 J04003	A, N, NT, or QT	X[B]	X	X	X	X									0.37 0.44	0.50 0.90	0.040	0.040	0.30 0.60			
SC 1045 J04502	A, N, NT, or QT	X[B]	X[B]	X	X	X	X	X							0.43 0.50	0.50 0.90	0.040	0.040	0.30 0.60			

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)													CHEMICAL COMPOSITION, % (maximum percent unless range given)							
Grade and UNS	Heat Treatment	Tensile Requirements/Grade Suitability[A,C]													C	Mn	P	S	Si	Ni	Cr	Mo
		65/35	70/36	80/40	80/50	90/60	105/85	115/95	130/115	135/125	150/135	160/145	165/150	210/180								
SC 4130 J13502	A, N, NT, or QT	X[B]	X[B]	X	X	X	X	X	X	X	X				0.28 0.33	0.40 0.80	0.035	0.040	0.30 0.60		0.80 1.10	0.15 0.25
SC 4140 J14045	A, N, NT, or QT	X[B]	X[B]	X[B]	X[B]	X	X	X	X	X	X	X	X		0.38 0.43	0.70 1.10	0.035	0.040	0.30 0.60		0.80 1.10	0.15 0.25
SC 4330 J23259	A, N, NT, or QT	X[B]	X[B]	X[B]	X[B]	X	X	X	X	X	X	X	X	X	0.28 0.33	0.60 0.90	0.035	0.040	0.30 0.60	1.65 2.00	0.70 0.90	0.20 0.30
SC 4340 J24053	A, N, NT, or QT	X[B]	X[B]	X[B]	X[B]	X[B]	X	X	X	X	X	X	X	X	0.38 0.43	0.60 0.90	0.035	0.040	0.30 0.60	1.65 2.00	0.70 0.90	0.20 0.30
SC 8620 J12095	A, N, NT, or QT	X[B]	X[B]	X	X	X	X	X							0.18 0.23	0.60 1.00	0.035	0.040	0.30 0.60	0.40 0.70	0.40 0.60	0.15 0.25
SC 8625 J12595	A, N, NT, or QT	X[B]	X[B]	X	X	X	X	X	X	X					0.23 0.28	0.60 1.00	0.035	0.040	0.30 0.60	0.40 0.70	0.40 0.60	0.15 0.25
SC 8630 J13095	A, N, NT, or QT	X[B]	X[B]	X	X	X	X	X	X	X	X				0.28 0.33	0.60 1.00	0.035	0.040	0.30 0.60	0.40 0.70	0.40 0.60	0.15 0.25

[A] X denotes that the properties may be achieved by at least one of the heat treatments referenced in 5. The effect of section thickness should be considered in making grade selections. The heat treatment requirements do not imply that all section thicknesses will be through hardened.
[B] These grades significantly exceed the minimum strength levels; therefore, they may be unsuitable for use due to weldability, and machinability issues.
[C] Tensile requirements for the different classes given in the table below.

TENSILE REQUIREMENTS													
Class	65/35	70/36	80/40	80/50	90/60	105/85	115/95	130/115	135/125	150/135	160/145	165/150	210/180
Tensile (ksi)	65	70	80	80	90	105	115	130	135	150	160	165	210
Tensile [MPa]	450	485	550	550	620	725	795	895	930	1035	1105	1140	1450
Yield (ksi)	35	36	40	50	60	85	95	115	125	135	145	150	180
Yield [MPa]	240	250	275	345	415	585	655	795	860	930	1000	1035	1240
Elong. (%)	24	22	18	22	18	17	14	11	9	7	6	5	4
Red. A (%)	35	30	30	35	35	35	30	25	22	18	12	10	8

FEDERAL QQ-S-681F STEEL CASTINGS

This specification covers mild-to-medium-strength carbon steel castings for general application as described in ASTM A 27 and high-strength steel castings for structural purposes as described in ASTM A 148.

Canceled May 20, 1985 – use ASTM A 27 and ASTM A 148

ISO 3755:1991 CAST CARBON STEELS FOR GENERAL ENGINEERING

Canceled December 09, 2015 – use ISO 14737:2015

ISO 4991:2015 STEEL CASTINGS FOR PRESSURE PURPOSES

This International Standard covers steel castings used for pressure purposes. It includes materials which are used for the manufacture of components subject to pressure vessel codes and for other pressure containing components not subject to codal requirements.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)[C]							CHEMICAL COMPOSITION, % (maximum percent unless range given)										
		AT ROOM TEMPERATURE				AT LOW TEMPERATURE													
		Tensile Test			Impact Test	Impact Test		Other Tests[D]											
Grade and UNS	Heat Treatment[A]	Yield Strength $R_{p0.2}$ MPa	Tensile Strength R_m MPa	A %	KV J	KV J	°C		C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu	Other
GP240GH	N[B]	240	420 600	22	27				0.18 0.23[E]	0.60	0.50 1.20[E]	0.030	0.020	0.30	0.12	0.40	0.03	0.30	[F]
GP240GH	QT	240	420 600	22	40				0.18 0.23[E]	0.60	0.50 1.20[E]	0.030	0.020	0.30	0.12	0.40	0.03	0.30	[F]
GP280GH	N[B]	280	480 640	22	27				0.18 0.25[E]	0.60	0.80 1.20[E]	0.030	0.020	0.30	0.12	0.40	0.03	0.30	[F]
GP280GH	QT	280	480 640	22	40				0.18 0.25[E]	0.60	0.80 1.20[E]	0.030	0.020	0.30	0.12	0.40	0.03	0.30	[F]
G17Mn5	QT	240	450 600	24		27	-40		0.15 0.20	0.60	1.00 1.60	0.020	0.025	0.30	0.12	0.40	0.03	0.30	[F]
G20Mn5	N[B]	300	480 620	20		27	-30		0.17 0.23	0.60	1.00 1.60	0.020	0.020	0.30	0.12	0.80	0.03	0.30	
G20Mn5	QT	300	500 650	22	27	27	-40		0.17 0.23	0.60	1.00 1.60	0.020	0.020	0.30	0.12	0.80	0.03	0.30	
G18Mo5	QT	240	440 590	23		27	-45		0.15 0.20	0.60	0.80 1.20	0.020	0.020	0.30	0.45 0.65	0.40	0.050	0.30	
G20Mo5	QT	245	440 690	22					0.15 0.23	0.60	0.50 1.00	0.025	0.020	0.30	0.40 0.60	0.40	0.050	0.30	
G17CrMo5-5	QT	315	490 690	20	27				0.15 0.20	0.60	0.50 1.00	0.020	0.020	1.00 1.50	0.45 0.65	0.40	0.050	0.30	
G17CrMo9-10	QT	400	590 740	18	40				0.13 0.20	0.60	0.50 0.90	0.020	0.020	2.00 2.50	0.90 1.20	0.40	0.050	0.30	
G12MoCrV5-2	QT	295	510 660	17	27				0.10 0.15	0.45	0.40 0.70	0.030	0.020	0.30 0.50	0.40 0.60	0.40	0.22 0.30	0.30	
G17CrMoV5-10	QT	440	590 780	15	27				0.15 0.20	0.60	0.50 0.90	0.020	0.015	1.20 1.50	0.90 1.10	0.40	0.20 0.30	0.30	
G25NiCrMo3	QT1	415	620 795	18	27				0.23 0.28	0.80	0.60 1.00	0.030	0.025	0.40 0.80	0.15 0.30	0.40 0.80	0.03	0.30	
G25NiCrMo3	QT2	585	725 865	17	27				0.23 0.28	0.80	0.60 1.00	0.030	0.025	0.40 0.80	0.15 0.30	0.40 0.80	0.03	0.30	
G25NiCrMo6	QT1	485	690 860	18	27				0.23 0.28	0.60	0.60 0.90	0.030	0.025	0.70 0.90	0.20 0.30	1.00 2.00	0.03	0.30	
G25NiCrMo6	QT2	690	860 1000	15	40				0.23 0.28	0.60	0.60 0.90	0.030	0.025	0.70 0.90	0.20 0.30	1.00 2.00	0.03	0.30	
G17NiCrMo13-6	QT	600	750 900	15		27	-80		0.15 0.19	0.50	0.55 0.80	0.015	0.015	1.30 1.80	0.45 0.60	3.00 3.50	0.050	0.30	

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)[C]							CHEMICAL COMPOSITION, % (maximum percent unless range given)										
Grade and UNS	Heat Treatment[A]	AT ROOM TEMPERATURE				AT LOW TEMPERATURE		Other Tests[D]	C	Sl	Mn	P	S	Cr	Mo	Ni	V	Cu	Other
		Tensile Test			Impact Test	Impact Test													
		Yield Strength $R_{p0.2}$ MPa	Tensile Strength R_m MPa	A %	KV J	KV J	°C												
G9Ni10	QT	280	480 630	24		27	-70		0.06 0.12	0.60	0.50 0.80	0.020	0.015	0.30	0.20	2.00 3.00	0.050	0.30	
G9Ni14	QT	360	500 650	20		27	-90		0.06 0.12	0.60	0.50 0.80	0.020	0.015	0.30	0.20	3.00 4.00	0.050	0.30	

[A] The type of heat treatment is mandatory. N= normalized, QT= quenched and tempered. Refer to the original specification for additional information on heat treatment requirements.
[B] Tempering is permitted.
[C] $R_{p0.2}$: 0.2% offset yield strength or 0.2% proof strength, R_m: tensile strength, A%: elongation after fracture on original gage length $L_o=5.65\sqrt{S_o}$ (where S_o is the original cross sectional area), KV: ISO V-notch impact strength
[D] Refer to the original specification for additional information on other tests at high temperatures.
[E] For each reduction of 0.01% carbon below the maximum specified, an increase of 0.04% manganese above the maximum specified will be permitted to a maximum of 1.40%.
[F] %Cr + %Mo + %Ni + %V + %Cu ≤ 1.00%

ISO 9477:2015 HIGH STRENGTH CAST STEELS FOR GENERAL ENGINEERING AND STRUCTURAL PURPOSES

This International Standard specifies requirements for four grades of heat-treated cast carbon and alloy steels for general engineering and structural purposes.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[A] (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)		
Grade and UNS	Heat Treatment[B]	Yield Strength R_{eH} MPa	Tensile Strength R_m MPa	A %	Z %	Other Tests Impact Test KV J	P	S	Si
410-620		410		16	40	20	0.030	0.025	0.60
540-720		540		14	35	20	0.030	0.025	0.60
620-820		620		11	30	18	0.030	0.025	0.60
840-1030		840		7	22	15	0.030	0.025	0.60

[A] R_{eH}: upper yield strength, if measurable, otherwise the 0.2% proof stress: R_m: tensile strength, A%: elongation after fracture on original gage length $L_o=5.65\sqrt{S_o}$ (where S_o is the original cross sectional area), Z%: reduction of area, KV: impact energy. See original specification for additional details on mechanical properties.
[B] The type of heat-treatment is left to the discretion of the manufacturer, unless specifically agreed upon at the time of ordering.

ISO 13521:2015 AUSTENITIC MANGANESE STEEL CASTINGS

This International Standard specifies austenitic manganese cast steels for wear resistant service. The grades covered by this International Standard will experience maximum service life in applications where the surface of the castings is subject to impact.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B]	Other Tests[c]	CHEMICAL COMPOSITION, % (maximum percent unless range given)							
Grade and UNS	Heat Treatment[A]			C	Si	Mn	P	S	Cr	Mo	Ni
GX120MnMo7-1	ST & WQ			1.05 1.35	0.3 0.9	6.0 8.0	0.060	0.045		0.9 1.2	
GX110MnMo13-1	ST & WQ			0.75 1.35	0.3 0.9	11.0 14.0	0.060	0.045		0.9 1.2	
GX100Mn13[D]	ST & WQ			0.90 1.05	0.3 0.9	11.0 14.0	0.060	0.045			
GX120Mn13[D]	ST & WQ			1.05 1.35	0.3 0.9	11.0 14.0	0.060	0.045			
GX120MnCr13-2	ST & WQ			1.05 1.35	0.3 0.9	11.0 14.0	0.060	0.045	1.5 2.5		
GX120MnCr13-3	ST & WQ			1.05 1.35	0.3 0.9	11.0 14.0	0.060	0.045			3.0 4.0
GX120Mn18[D]	ST & WQ			1.05 1.35	0.3 0.9	16.0 19.0	0.060	0.045			
GX90MnMo14	as-cast[E] or ST & WQ			0.70 1.00	0.3 0.6	13.0 15.0	0.070	0.045		1.0 1.8	
GX120MnCr18-2	ST & WQ			1.05 1.35	0.3 0.9	16.0 19.0	0.060	0.045	1.5 2.5		

[A] ST &WQ = solution treated and quenched in water
[B] Mechanical tests at room temperature shall be performed when agreed upon between the purchaser and manufacturer.
[C] Bend test, hardness test, and microstructure shall be performed when agreed upon between the purchaser and the manufacturer – see original specification for more details
[D] These grades are sometimes used for non-magnetic service
[E] For castings with thicknesses less than [45 mm] and containing less than 0.8% carbon, heat treatment is not required.

ISO 14737:2015 CAST CARBON AND LOW ALLOY STEELS FOR GENERAL APPLICATIONS

This International Standard specifies requirements for carbon and low alloy cast steel grades for general applications.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)									
Grade and UNS	Heat Treatment[A]	Thickness t mm	Tensile Test			Other Tests Impact Test	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu
			Yield Strength $R_{p0.2}$ MPa	Tensile Strength R_m MPa	A %	KV J										
GE200	N	≤ 300	200	380 530	25	27	-	-	-	0.035	0.030	0.30	0.12	0.40	0.03	0.30
GS200	N	≤ 100	200	380 530	25	35	0.18	0.60	1.20	0.030	0.025	0.30	0.12	0.40	0.03	0.30
GE240	N	≤ 300	240	450 600	22	27	-	-	-	0.035	0.030	0.30	0.12	0.40	0.03	0.30

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)									
			Tensile Test			Other Tests										
Grade and UNS	Heat Treatment[A]	Thickness t mm	Yield Strength $R_{p0.2}$ MPa	Tensile Strength R_m MPa	A %	Impact Test KV J	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu
GS240	N	≤ 100	240	450 600	22	31	0.23	0.60	1.20	0.030	0.025	0.30	0.12	0.40	0.03	0.30
GS270	N	≤ 100	270	480 630	18	27	0.24	0.60	1.30	0.030	0.025	0.30[D]	0.12[D]	0.40[D]	0.03[D]	0.30[D]
GS340	N	≤ 100	340	550 700	15	20	0.30	0.60	1.50	0.030	0.025	0.30[D]	0.12[D]	0.40[D]	0.03[D]	0.30[D]
G28Mn6	N	≤ 250	260	520 670	18	27	0.25 0.32	0.60	1.20 1.80	0.035	0.030	0.30	0.15	0.40	0.05	0.30
G28Mn6	QT1	≤ 100	450	600 750	14	35	0.25 0.32	0.60	1.20 1.80	0.035	0.030	0.30	0.15	0.40	0.05	0.30
G28Mn6	QT2	≤ 50	550	700 850	10	31	0.25 0.32	0.60	1.20 1.80	0.035	0.030	0.30	0.15	0.40	0.05	0.30
G28MnMo6	QT1	≤ 50	500	700 850	12	35	0.25 0.32	0.60	1.20 1.60	0.025	0.025	0.30	0.20 0.40	0.40	0.05	0.30
G28MnMo6	QT1	≤ 100	480	670 830	10	31	0.25 0.32	0.60	1.20 1.60	0.025	0.025	0.30	0.20 0.40	0.40	0.05	0.30
G28MnMo6	QT2	≤ 100	590	850 1000	8	27	0.25 0.32	0.60	1.20 1.60	0.025	0.025	0.30	0.20 0.40	0.40	0.05	0.30
G20Mo5	QT	≤ 100	245	440 590	22	27	0.15 0.23	0.60	0.50 1.00	0.025	0.020[D]	0.30	0.40 0.60	0.40	0.05	0.30
G10MnMoV6-3	QT1	≤ 50	380	500 650	22	60	0.12	0.60	1.20 1.80	0.025	0.020	0.30	0.20 0.40	0.40	0.05 0.10	0.30
G10MnMoV6-3	QT1	50 < t ≤ 100	350	480 630	22	60	0.12	0.60	1.20 1.80	0.025	0.020	0.30	0.20 0.40	0.40	0.05 0.10	0.30
G10MnMoV6-3	QT1	100 < t ≤ 150	330	480 630	20	60	0.12	0.60	1.20 1.80	0.025	0.020	0.30	0.20 0.40	0.40	0.05 0.10	0.30
G10MnMoV6-3	QT1	150 < t ≤ 250	330	450 600	18	60	0.12	0.60	1.20 1.80	0.025	0.020	0.30	0.20 0.40	0.40	0.05 0.10	0.30
G10MnMoV6-3	QT2	50 < t ≤ 100	500	600 750	18	60	0.12	0.60	1.20 1.80	0.025	0.020	0.30	0.20 0.40	0.40	0.05 0.10	0.30
G10MnMoV6-3	QT2	50 < t ≤ 100	400	550 700	18	60	0.12	0.60	1.20 1.80	0.025	0.020	0.30	0.20 0.40	0.40	0.05 0.10	0.30
G10MnMoV6-3	QT2	100 < t ≤ 150	380	500 650	18	60	0.12	0.60	1.20 1.80	0.025	0.020	0.30	0.20 0.40	0.40	0.05 0.10	0.30
G10MnMoV6-3	QT2	150 < t ≤ 250	350	460 610	18	60	0.12	0.60	1.20 1.80	0.025	0.020	0.30	0.20 0.40	0.40	0.05 0.10	0.30
G10MnMoV6-3	QT3	t ≤ 100	400	520 650	22	27[C]	0.12	0.60	1.20 1.80	0.025	0.020	0.30	0.20 0.40	0.40	0.05 0.10	0.30
G10MnMoV6-3	QT3	t ≤ 100	400	520 650	22	60	0.12	0.60	1.20 1.80	0.025	0.020	0.30	0.20 0.40	0.40	0.05 0.10	0.30
G20NiCrMo2-2	NT	t ≤ 100	200	550 700	18	10	0.18 0.23	0.60	0.60 1.00	0.035	0.030	0.40 0.60	0.15 0.25	0.40 0.70	0.05	0.30
G20NiCrMo2-2	QT1	t ≤ 100	430	700 850	15	25	0.18 0.23	0.60	0.60 1.00	0.035	0.030	0.40 0.60	0.15 0.25	0.40 0.70	0.05	0.30
G20NiCrMo2-2	QT2	t ≤ 100	540	820 970	12	25	0.18 0.23	0.60	0.60 1.00	0.035	0.030	0.40 0.60	0.15 0.25	0.40 0.70	0.05	0.30

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)									
			Tensile Test			Other Tests										
Grade and UNS	Heat Treatment[A]	Thickness t mm	Yield Strength $R_{p0.2}$ MPa	Tensile Strength R_m MPa	A %	Impact Test KV J	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu
G25NiCrMo2-2	NT	t ≤ 100	240	600 750	18	10	0.23 0.28	0.60	0.60 1.00	0.035	0.030	0.40 0.60	0.15 0.25	0.40 0.70	0.05	0.30
G25NiCrMo2-2	QT1	t ≤ 100	500	750 900	15	25	0.23 0.28	0.60	0.60 1.00	0.035	0.030	0.40 0.60	0.15 0.25	0.40 0.70	0.05	0.30
G25NiCrMo2-2	QT2	t ≤ 100	600	850 1000	12	25	0.23 0.28	0.60	0.60 1.00	0.035	0.030	0.40 0.60	0.15 0.25	0.40 0.70	0.05	0.30
G30NiCrMo2-2	NT	t ≤ 100	270	630 780	18	10	0.28 0.33	0.60	0.60 1.00	0.035	0.030	0.40 0.60	0.15 0.25	0.40 0.70	0.05	0.30
G30NiCrMo2-2	QT1	t ≤ 100	540	820 970	14	25	0.28 0.33	0.60	0.60 1.00	0.035	0.030	0.40 0.60	0.15 0.25	0.40 0.70	0.05	0.30
G30NiCrMo2-2	QT2	t ≤ 100	630	900 1050	11	25	0.28 0.33	0.60	0.60 1.00	0.035	0.030	0.40 0.60	0.15 0.25	0.40 0.70	0.05	0.30
G17CrMo5-5	QT	t ≤ 100	315	490 690	20	27	0.15 0.20	0.60	0.50 1.00	0.025	0.020[E]	1.00 1.50	0.45 0.65	0.40	0.05	0.30
G17CrMo9-10	QT	t ≤ 150	400	590 740	18	40	0.13 0.20	0.60	0.50 0.90	0.025	0.020[E]	2.00 2.50	0.90 1.20	0.40	0.05	0.30
G26CrMo4	QT1	t ≤ 100	450	600 750	16	40	0.22 0.29	0.60	0.50 0.80	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G26CrMo4	QT1	100 < t ≤ 250	300	550 700	14	27	0.22 0.29	0.60	0.50 0.80	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G26CrMo4	QT2	t ≤ 100	550	700 850	10	18	0.22 0.29	0.60	0.50 0.80	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G34CrMo4	NT	t ≤ 100	270	630 780	16	10	0.30 0.37	0.60	0.50 0.80	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G34CrMo4	QT1	t ≤ 100	540	700 850	12	35	0.30 0.37	0.60	0.50 0.80	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G34CrMo4	QT1	100 < t ≤ 150	480	620 770	10	27	0.30 0.37	0.60	0.50 0.80	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G34CrMo4	QT1	150 < t ≤ 250	330	620 770	10	16	0.30 0.37	0.60	0.50 0.80	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G34CrMo4	QT2	t ≤ 100	650	830 980	10	27	0.30 0.37	0.60	0.50 0.80	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G42CrMo4	NT	t ≤ 100	300	700 850	15	10	0.38 0.45	0.60	0.60 1.00	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G42CrMo4	QT1	t ≤ 100	600	800 950	12	31	0.38 0.45	0.60	0.60 1.00	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G42CrMo4	QT1	100 < t ≤ 150	550	700 850	10	27	0.38 0.45	0.60	0.60 1.00	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G42CrMo4	QT1	150 < t ≤ 250	350	650 800	10	16	0.38 0.45	0.60	0.60 1.00	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G42CrMo4	QT2	t ≤ 100	700	850 1000	10	27	0.38 0.45	0.60	0.60 1.00	0.025	0.020[E]	0.80 1.20	0.15 0.30	0.40	0.05	0.30
G30CrMoV6-4	QT1	t ≤ 100	700	850 1000	14	45	0.27 0.34	0.60	0.60 1.00	0.025	0.020[E]	1.30 1.70	0.30 0.50	0.40	0.05 0.15	0.30
G30CrMoV6-4	QT1	100 < t ≤ 150	550	750 900	12	27	0.27 0.34	0.60	0.60 1.00	0.025	0.020[E]	1.30 1.70	0.30 0.50	0.40	0.05 0.15	0.30

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)									
			Tensile Test			Other Tests										
Grade and UNS	Heat Treatment[A]	Thickness t mm	Yield Strength $R_{p0.2}$ MPa	Tensile Strength R_m MPa	A %	Impact Test KV J	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu
G30CrMoV6-4	QT1	150 < t ≤ 250	350	650 800	12	20	0.27 0.34	0.60	0.60 1.00	0.025	0.020[E]	1.30 1.70	0.30 0.50	0.40	0.05 0.15	0.30
G30CrMoV6-4	QT2	t ≤ 100	750	900 1100	12	31	0.27 0.34	0.60	0.60 1.00	0.025	0.020[E]	1.30 1.70	0.30 0.50	0.40	0.05 0.15	0.30
G35CrNiMo6-6	N	t ≤ 150	550	800 950	12	31	0.32 0.38	0.60	0.60 1.00	0.025	0.020[E]	1.40 1.70	0.15 0.35	1.40 1.70	0.05	0.30
G35CrNiMo6-6	N	150 < t ≤ 250	500	750 900	12	31	0.32 0.38	0.60	0.60 1.00	0.025	0.020[E]	1.40 1.70	0.15 0.35	1.40 1.70	0.05	0.30
G35CrNiMo6-6	QT1	t ≤ 100	700	850 1000	12	45	0.32 0.38	0.60	0.60 1.00	0.025	0.020[E]	1.40 1.70	0.15 0.35	1.40 1.70	0.05	0.30
G35CrNiMo6-6	QT1	100 < t ≤ 150	650	800 950	12	35	0.32 0.38	0.60	0.60 1.00	0.025	0.020[E]	1.40 1.70	0.15 0.35	1.40 1.70	0.05	0.30
G35CrNiMo6-6	QT1	150 < t ≤ 250	650	800 950	12	30	0.32 0.38	0.60	0.60 1.00	0.025	0.020[E]	1.40 1.70	0.15 0.35	1.40 1.70	0.05	0.30
G35CrNiMo6-6	QT2	t ≤ 100	800	900 1050	10	35	0.32 0.38	0.60	0.60 1.00	0.025	0.020[E]	1.40 1.70	0.15 0.35	1.40 1.70	0.05	0.30
G30NiCrMo7-3	NT	t ≤ 100	550	760 900	12	10	0.28 0.33	0.60	0.60 0.90	0.035	0.030	0.70 0.90	0.20 0.30	1.65 2.00	0.05	0.30
G30NiCrMo7-3	QT1	t ≤ 100	690	930 1100	10	25	0.28 0.33	0.60	0.60 0.90	0.035	0.030	0.70 0.90	0.20 0.30	1.65 2.00	0.05	0.30
G30NiCrMo7-3	QT2	t ≤ 100	795	1030 1200	8	25	0.28 0.33	0.60	0.60 0.90	0.035	0.030	0.70 0.90	0.20 0.30	1.65 2.00	0.05	0.30
G40NiCrMo7-3	NT	t ≤ 100	585	860 1100	10	10	0.38 0.43	0.60	0.60 0.90	0.035	0.030	0.70 0.90	0.20 0.30	1.65 2.00	0.05	0.30
G40NiCrMo7-3	QT1	t ≤ 100	760	1000 1140	8	25	0.38 0.43	0.60	0.60 0.90	0.035	0.030	0.70 0.90	0.20 0.30	1.65 2.00	0.05	0.30
G40NiCrMo7-3	QT2	t ≤ 100	795	1030 1200	8	25	0.38 0.43	0.60	0.60 0.90	0.035	0.030	0.70 0.90	0.20 0.30	1.65 2.00	0.05	0.30
G32NiCrMo8-5-4	QT1	t ≤ 100	700	850 1000	16	50	0.28 0.35	0.60	0.60 1.00	0.020	0.015	1.00 1.40	0.30 0.50	1.60 2.10	0.05	0.30
G32NiCrMo8-5-4	QT1	100 < t ≤ 250	650	820 970	14	35	0.28 0.35	0.60	0.60 1.00	0.020	0.015	1.00 1.40	0.30 0.50	1.60 2.10	0.05	0.30
G32NiCrMo8-5-4	QT2	t ≤ 100	950	1050 1200	10	35	0.28 0.35	0.60	0.60 1.00	0.020	0.015	1.00 1.40	0.30 0.50	1.60 2.10	0.05	0.30

[A] N= normalized, NT= normalized and tempered, QT= quenched and tempered. Number 1, 2, or 3 after "T" indicates a different tempering temperature. Refer to the original specification for additional information on heat treatment requirements.

[B] $R_{p0.2}$: 0.2% offset yield strength or 0.2% proof strength, R_m: tensile strength, A%: elongation after fracture on original gage length $L_o=5.65\sqrt{S_o}$ (where S_o is the original cross sectional area), KV: ISO V-notch impact strength

[C] -20C test temperature

[D] Cr + Mo + Ni + V + Cu max. 1.00%

[E] For castings of ruling thickness < 28mm, S ≤ 0.030% is permitted.

Lloyd's Register Rule 2.4.1 – 16 STEEL CASTINGS PART 2, CHAPTER 4, SECTION 1: GENERAL REQUIREMENTS

This section gives the general requirements for steel castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels, and piping systems.

Castings are to be made at foundries approved by LR. See the original specification for additional information such as general test samples, non-destructive examination, defective casting rectification, and identification of castings.

Lloyd's Register Rule 2.4.2 – 16 STEEL CASTINGS PART 2, CHAPTER 4, SECTION 2: CASTINGS FOR SHIP AND OTHER STRUCTURAL APPLICATIONS

The requirements for carbon-manganese steel castings intended for ship and other structural applications where the design and acceptance tests are related to mechanical properties at ambient temperature are given in this Section.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)[A]						CHEMICAL COMPOSITION, % (maximum percent unless range given)										
Grade	Heat Treatment	Tensile Strength MPa	Yield Strength MPa	Elong %	Red A %	Other Tests Impact Test J	Other Tests Impact Test [°C]	C	Si	Mn	S	P	Al	Residual Elements Cu	Cr	Ni	Mo	Total
Normal	A, N, NT, or QT	400	200	25	40	-	-	0.23	0.60	0.70 1.60	0.040	0.040	-	0.30	0.30	0.40	0.15	0.80
Special[B]	A, N, NT, or QT	400	200	25	40	27	0	0.23	0.60	0.70 1.60	0.035	0.035	0.015 0.080[C,D]	0.30	0.30	0.40	0.15	0.80

[A] See original specification for full details on required mechanical tests - castings used in ship construction for the stern-frame, rudder, and propeller shaft supports are to be examined by ultrasonic and magnetic particle methods.
[B] For the Special grade, the nitrogen content is to be determined.
[C] The total aluminum content may be determined instead of the acid soluble content; in which case the total aluminum content is to be 0.020 – 0.10%.
[D] Grain refining elements other than aluminum may be used subject to special agreement with LR.

Lloyd's Register Rule 2.4.3 – 16 STEEL CASTINGS PART 2, CHAPTER 4, SECTION 3: CASTINGS FOR MACHINERY CONSTRUCTION

This Section gives the material requirements for carbon-manganese steel castings intended for use in machinery construction and which are not within the scope of Chapter 4, Section 4 Castings for crankshafts.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)										
Grade	Heat Treatment[A]	Tensile Strength MPa	Yield Strength MPa	Elong %	Red A %	Other Tests[B]	C[C]	Si	Mn	S	P	Residual Elements Cu	Cr	Ni	Mo	Total
	A, N, NT, or QT	400 550	200	25	40		0.40	0.60	0.50 1.60	0.040	0.040	0.30	0.30	0.40	0.15	0.80
	A, N, NT, or QT	440 590	220	22	30		0.40	0.60	0.50 1.60	0.040	0.040	0.30	0.30	0.40	0.15	0.80
	A, N, NT, or QT	480 630	240	20	27		0.40	0.60	0.50 1.60	0.040	0.040	0.30	0.30	0.40	0.15	0.80

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)									
Grade	Heat Treatment[A]	Tensile Strength MPa	Yield Strength MPa	Elong %	Red A %	Other Tests[B]	C[C]	Si	Mn	S	P	Residual Elements				
												Cu	Cr	Ni	Mo	Total
	A, N, NT, or QT	520 670	260	18	25		0.40	0.60	0.50 1.60	0.040	0.040	0.30	0.30	0.40	0.15	0.80
	A, N, NT, or QT	560 710	300	15	20		0.40	0.60	0.50 1.60	0.040	0.040	0.30	0.30	0.40	0.15	0.80
	A, N, NT, or QT	600 750	320	13	20		0.40	0.60	0.50 1.60	0.040	0.040	0.30	0.30	0.40	0.15	0.80

[A] Stress relief may be required depending on what type of part is cast; see original specifications for additional information.
[B] Non-destructive examination varies with the type of part that is cast; see original specifications for additional information
[C] Castings which are intended for parts of a welded fabrication are to be of weldable quality with a carbon content generally not exceeding 0.23%

Lloyd's Register Rule 2.4.4 – 16 STEEL CASTINGS PART 2, CHAPTER 4, SECTION 4: CASTINGS FOR CRANKSHAFTS

This Section gives the requirements for carbon and carbon-manganese steel castings for semi-built and fully built crankshafts.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)									
Grade	Heat Treatment	Tensile Strength MPa	Yield Strength MPa	Elong %	Red A %	Other Tests[A] Impact Test[B] J	C[C]	Si	Mn	S	P	Residual Elements				
												Cu	Cr	Ni	Mo	Total
	A or NT	400 550	200	28	45	32	0.40	0.60	0.50 1.60	0.040	0.040	0.30	0.30	0.40	0.15	0.80
	A or NT	440 590	220	26	45	28	0.40	0.60	0.50 1.60	0.040	0.040	0.30	0.30	0.40	0.15	0.80
	A or NT	480 630	240	24	40	25	0.40	0.60	0.50 1.60	0.040	0.040	0.30	0.30	0.40	0.15	0.80
	A or NT	520 670	260	22	40	20	0.40	0.60	0.50 1.60	0.040	0.040	0.30	0.30	0.40	0.15	0.80
	A or NT	550 700	275	20	35	18	0.40	0.60	0.50 1.60	0.040	0.040	0.30	0.30	0.40	0.15	0.80

[A] Each casting is to be examined by ultrasonic testing, and magnetic particle or dye penetrant examination is to be carried out over all surfaces.
[B] Impact tests are to be made at ambient temperature
[C] See original specification for full details on rectification of defective castings - weld repairs are not permitted if the carbon content exceeds 0.30%

Lloyd's Register Rule 2.4.5 – 16 STEEL CASTINGS PART 2, CHAPTER 4, SECTION 5: CASTINGS FOR PROPELLERS

This Section gives the requirements for cast steel propellers and propeller blades in carbon-manganese, low alloy and stainless steels. The requirements for copper alloy propellers and blades are given in Chapter 9 Section 1 Castings for propellers.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)				
Grade	Heat Treatment[A]	Tensile Strength MPa	Yield Strength MPa	Elong %	Red A %	Other Tests[B] Impact Test[C] J	C	Mn	Cr	Mo[D]	Ni
Martensitic (12Cr 1Ni)	QT	590	440	19	20	20	0.15	2.0	11.5 17.0	0.5	2.0
Martensitic (13Cr 4Ni)	QT	750	550	19		30	0.06	2.0	11.5 17.0	1.0	3.5 5.0
Martensitic (16Cr 5Ni)	QT	760	540	35	35	30	0.06	2.0	15.0 17.5	1.5	3.5 6.0
Austenitic (19Cr 11Ni)	ST	440	180	20	35	-	0.12	1.6	16.0 21.0	4.0	8.0 13.0

[A] See original specification for full details on heat treatment.
[B] See original specification for full details such as non-destructive testing, rectification of defective castings, identification, and certification
[C] When a general service notation Ice Class 1AS, 1A, 1B, or 1C is required the tests are to be made at –10°C; however, for general service or where the notation Ice Class 1D is required the tests are to be made at 0°C.
[D] Minimum values are to be in accordance with the agreed specification or recognized National or International Standards.

Lloyd's Register Rule 2.4.6 – 16 STEEL CASTINGS PART 2, CHAPTER 4, SECTION 6: CASTINGS FOR BOILERS, PRESSURE VESSELS AND PIPING SYSTEMS

This Section gives the requirements for carbon-manganese and alloy steel castings for boilers, pressure vessels and piping systems for use at temperatures not lower than 0°C.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)												
Grade	Heat Treatment	Tensile Strength MPa	Yield Strength MPa	Elong %	Red A %	Other Tests[A]	C	Si	Mn	S	P	Cr	Mo	V	Residual Elements Cr	Mo	Cu	Ni	Total
Carbon-manganese	A, N, NT, or QT	485 655	275	22	25		0.25	0.60	0.50 1.20	0.040	0.040	-	-	-	0.30	0.15	0.30	0.40	0.80
½Mo	A, N, NT, or QT	460 590	260	18	30		0.20	0.60	0.50 1.00	0.040	0.040	-	0.45 0.65	-	0.30	-	0.30	0.40	
1Cr ½Mo	A, N, NT, or QT	480 630	280	17	20		0.20	0.60	0.50 0.80	0.040	0.040	1.00 1.50	0.45 0.65	-	-	-	0.30	0.40	
2¼Cr 1Mo	A, N, NT, or QT	540 630	325	17	20		0.18	0.60	0.40 0.70	0.040	0.040	2.00 2.75	0.90 1.20	-	-	-	0.30	0.40	
½Cr ½Mo ¼V	A, N, NT, or QT	510 660	295	17	20		0.10 0.15	0.45	0.40 0.70	0.030	0.030	0.30 0.50	0.40 0.60	0.22 0.30	-	-	0.30	0.30	

[A] See original specification for full details such as non-destructive examination and mechanical properties for design purposes.

Lloyd's Register Rule 2.4.7 – 16 STEEL CASTINGS PART 2, CHAPTER 4, SECTION 7: FERRITIC STEEL CASTINGS FOR LOW TEMPERATURE SERVICE

This Section gives the requirements for castings in carbon-manganese and nickel alloy steels intended for use in liquefied gas piping systems where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)										
Grade	Heat Treatment	Tensile Strength MPa	Yield Strength MPa	Elong %	Red A %	Other Tests[A] Impact Test J	Other Tests[A] Impact Test °C	C	Si	Mn	S	P	Ni	Residual Elements Cr	Cu	Mo	V	Total
Carbon-manganese 400	N, NT, or QT	400 550	200	25	40			0.23	0.60	0.70 1.60	0.030	0.030	0.80	0.25	0.30	0.15	0.03	0.60
Carbon-manganese 430	N, NT, or QT	430 580	215	23	35	27	-60[B]	0.23	0.60	0.70 1.60	0.030	0.030	0.80	0.25	0.30	0.15	0.03	0.60
Carbon-manganese 460	N, NT, or QT	460 610	230	22	30			0.23	0.60	0.70 1.60	0.030	0.030	0.80	0.25	0.30	0.15	0.03	0.60
2 ¼ Ni 490	N, NT, or QT	490 640	275	20	35	34	-70	0.25	0.60	0.50 0.80	0.025	0.030	2.00 3.00	0.25	0.30	0.15	0.03	0.60
3 ½ Ni 490	N, NT, or QT	490 640	275	20	35	34	-95	0.15	0.60	0.50 0.80	0.020	0.025	3.00 4.00	0.25	0.30	0.15	0.03	0.60

[A] See original specification for full details

[B] The test temperature for carbon-manganese steels may be [5 C] below the design temperature if the latter is above –55°C, with a maximum test temperature of –20°C.

Lloyd's Register Rule 2.4.9 – 16 STEEL CASTINGS PART 2, CHAPTER 4, SECTION 9: STEEL CASTINGS FOR CONTAINER CORNER FITTINGS

This Section gives the requirements for cast steel corner fittings used in the fabrication of freight and tank containers. The fittings are also to comply with the requirements of the latest edition of International Standard ISO 1161.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)					CHEMICAL COMPOSITION, %[B] (maximum percent unless range given)										
Grade	Heat Treatment	Tensile Strength MPa	Yield Strength MPa	Elong %	Red A %	Other Tests[A]	C	Mn	Si	P	S	Cr	Ni	Cu	Mo	Al	Cr+Ni+Cu+Mo
	N or QT	430 600	220	25	40		0.20	0.90 1.50	0.50	0.035	0.035	0.25	0.30	0.20	0.08	0.015[C]	0.70

[A] See original specification for full details such as ultrasonic or radiographic non-destructive examination, repair of defects, identification, and certification

[B] The carbon equivalent must not exceed 0.45%

[C] The total aluminum content may be determined instead of the acid soluble content; in such cases the total aluminum content is to be not less than 0.02% - aluminum may be replaced partly or totally by other grain refining elements as stated in the approved specification.

MIL-C-24707/1 – 89 CASTINGS, FERROUS, FOR MACHINERY AND STRUCTURAL APPLICATIONS

This specification covers steel castings for machinery and structural applications below 775 F where impact strength may be a consideration.

PREVIOUS SPECIFICATION MIL-S-15083B (grade)	REPLACEMENT SPECIFICATION MIL-C-24707/1 ASTM specification (grade)	FEDERAL GRADE QQ-S-681F ASTM specification (grade)	EQUIVALENT GRADE MIL-C-24707/1 ASTM specification (grade)
(CW)	A 757 (A1Q) or A 216 (WCA)	A 27 (N-1)	A 757 (A1Q) or A 216 (WCA) or A 217 (WC1)

PREVIOUS SPECIFICATION MIL-S-15083B (grade)	REPLACEMENT SPECIFICATION MIL-C-24707/1 ASTM specification (grade)	FEDERAL GRADE QQ-S-681F ASTM specification (grade)	EQUIVALENT GRADE MIL-C-24707/1 ASTM specification (grade)
(B)	A 757 (A1Q) or A 216 (WCA)	A 27 (N-2)	A 757 (A1Q) or A 216 (WCA) or A 217 (WC1)
(65-35)	A 757 (A1Q) or A 216 (WCB)	A 27 (U60-30)	A 757 (A1Q) or A 216 (WCB) or A 217 (WC1)
(70-36)	A 757 (A2Q) or A 216 (WCB, WCC)	A 27 (60-30)	A 757 (A1Q) or A 216 (WCB) or A 217 (WC1)
(80-40)	A 757 (A2Q) or A 487 (2 class A, B, C)	A 27 (65-35)	A 757 (A1Q) or A 216 (WCB) or A 217 (WC1)
(80-50)	A 757 (C1Q) or A 487 (2 class A, B, C)	A 27 (70-36)	A 757 (A2Q) or A 216 (WCB, WCC)
(90-60)	A 757 (E1Q) or A 487 (4 class A)	A 27 (70-40)	A 757 (A2Q) or A 216 (WCC)
(100-70)	A 757 (E2N1/E2Q1)	A 148 (80-40)	A 757 (A2Q) or A 487 (2 class A, B, C)
(105-85)	A 757 (E2N2/E2Q2) or A 487 (4 class B)	A 148 (80-50)	A 757 (C1Q) or A 487 (2 class A, B, C)
(120-95)	A 757 (E2N3/E2Q3) or A 487 (14 class A)	A 148 (90-60)	A 757 (E1Q) or A 487 (4 class A)
(150-125)	*Special application only*	A 148 (105-85)	A 757 (E2N2/E2Q2) or A 487 (4 class B)
		A 148 (120-95)	A 757 (E2N3/E2Q3) or A 487 (14 class A)

Additional notes for specification are as follows; see original military specification booklet for further information, including Quality Assurance Provisions. The specified residual elements shall be determined for carbon steels. When no impact requirement is given, there shall be a requirement of 20 ft-lbs @ 10°F; except for deck applications, which shall meet a requirement of 20 ft-lbs @ -20°F. When specified, the stress relieving temperature shall be 50°F [30°C] but not more than 100°F [60°C] below the tempering temperature; mechanical properties shall be determined after the stress relief heat treatment.

MIL-C-24707/2 – 89 CASTINGS, FOR PRESSURE CONTAINING PARTS SUITABLE FOR HIGH TEMPERATURE SERVICE

This specification covers alloy steel castings for machinery, structural, and pressure containing parts for high temperature applications.

PREVIOUS SPECIFICATION MIL specification (grade)	REPLACEMENT SPECIFICATION MIL-C-24707/2 ASTM specification (grade)
MIL-S-870B	A 217 (WC1)
MIL-S-15464B(SHIPS) (1)	A 217 (WC6)
MIL-S-15464B(SHIPS) (2)	A 217 (WC9)
MIL-S-15464B(SHIPS) (3)	A 389 (C23)

Additional notes for specification are as follows; see original military specification booklet for further information, including Quality Assurance Provisions. When specified, the stress relieving temperature shall be 50°F [30°C] but not more than 100°F [60°C] below the tempering temperature; mechanical properties shall be determined after the stress relief heat treatment.

MIL-S-870B – 89 STEEL CASTINGS, MOLYBDENUM ALLOY

Canceled January 27, 1989 – use MIL-C-24707/2, grade WC1

MIL-S-15083B(NAVY) – 89 STEEL CASTINGS

Canceled January 27, 1989 – use MIL-C-24707/1

MIL-S-15464B(SHIPS) – 89 STEEL ALLOY, CHROMIUM-MOLYBDENUM; CASTINGS

Canceled January 27, 1989 – use MIL-C-24707/2

MIL-S-23008D(SH) – 03 STEEL CASTINGS, ALLOY, HIGH YIELD STRENGTH (HY-80 AND HY-100)

Canceled June 5, 2003 – use T9074-BD-GIB-010/0300

MIL-S-46052A(MR) – 83 STEEL CASTINGS, HIGH STRENGTH, LOW ALLOY

Canceled May 31, 1983 – use ASTM A 148 as follows: for MIL class 180-150 use grade 165-150L, for MIL class 220-180 use grade 210-180L, and for MIL class 260-210 use grade 260-210L.

SAE J435 – 07 AUTOMOTIVE STEEL CASTINGS

These specifications cover steel castings used in the automotive and allied industries.

GRADE		MECHANICAL PROPERTIES (minimum unless range given)							CHEMICAL COMPOSITION, % (maximum percent unless range given)				
New Grade	Old Grade	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong %	Red A %	Other Tests Hardness (BHN)	C	Mn	Si	P	S
0000	0022							187	0.12 0.22	0.50 0.90	0.60	0.040	0.045
415	0025	60	415	30	205	22	30	187	0.25	0.75[A]	0.80	0.040	0.045
450	0030	65	450	35	240	24	35	131 187	0.30	0.70[A]	0.80	0.040	0.045
585	0050A	85	585	45	310	16	24	170 229	0.40 0.50	0.50 0.90	0.80	0.040	0.045
690	0050B	100	690	70	485	10	15	207 255	0.40 0.50	0.50 0.90	0.80	0.040	0.045
550	080	80	550	50	345	22	35	163 207				0.040	0.045
620	090	90	620	60	415	20	40	187 241				0.040	0.045
725	0105	105	725	85	585	17	35	217 248				0.040	0.045
830	0120	120	830	95	655	14	30	248 311				0.040	0.045
1035	0150	150	1035	125	860	9	22	311 363				0.040	0.045
1205	0175	175	1205	145	1000	6	21	363 415				0.040	0.045

[A] For each reduction of 0.01% carbon below the maximum specified, an increase of 0.04% manganese above the maximum specified will be permitted to a maximum of 1% manganese.

NAVSEA TP 0300 – 15

BASE MATERIALS FOR CRITICAL APPLICATIONS: REQUIREMENTS FOR LOW ALLOY STEEL PLATE, FORGINGS, CASTINGS, SHAPES, BARS, AND HEADS OF HY-80/100/130 AND HSLA-80/100

This specification covers the general requirements, quality assurance provisions, test procedures, and instructions for preparation for delivery for high-strength steel plate, shapes, bars, castings, forgings, and other products.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)																
Grade	Heat Treatment[A]	Thickness t in [mm]	Tensile Test[B] Yield Strength ksi	Yield Strength MPa	Elong %	Red A %	Other Tests Impact Test[D]	C	Mn	P	S	Si	Ni	Cr	Mo	V[E]	Ti[E]	Cu[E]	As[E]	Sn[E]	Sb[E]	Al	N
HY-80	Q&T	t ≤ 6 [152][C]	80 99.5	552 686	20	50		0.20	0.55 0.75	0.014	0.005	0.50	2.75 3.25	1.35 1.65	0.30 0.60	0.03	0.02	0.25	0.025	0.03	0.025	0.04	100 ppm[F]
HY-100	Q&T	t ≤ 6 [152][C]	100 120	690 827	18	50		0.22	0.55 0.75	0.014	0.005	0.50	3.00 3.50	1.35 1.65	0.30 0.60	0.03	0.02	0.25	0.025	0.03	0.025	0.04	100 ppm[F]

[A] See original specification for full heat treatment details.
[B] See original specification for test specimen location and mechanical properties for other thickness.
[C] Ultimate strength is reported for information only. For t up to and including 4 inches [102 mm], sample location shall be t/2. For t greater than 4 inches [102 mm], sample location shall be t/4 or 2 inches [51 mm], whichever is greater.
[D] See original specification for impact properties for various thickness.
[E] Elements shall not be intentionally added.
[F] Nitrogen content shall be determined with samples and instrumentation in accordance with ASTM E1019 or by other NAVSEA approved method. Nitrogen analysis may be performed during refining, in the ladle, or from samples removed from the final product.

SUMMARY OF MATERIAL SPECIFICATIONS FOR HIGH ALLOY CAST STEELS

The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code makes extensive use of ASTM specifications with slight modifications. For the sake of comparison, the ASME specifications use the preface SA so that SA 351 is related to ASTM A 351/A 351M. However, while ASTM A 351/A 351M could be used for comparison of grades, the ASME SA 351 contained in Section II must be used when complying with the code.

Cast stainless steels are most often specified on the basis of composition using the alloy designation system adopted by the Alloy Casting Institute (ACI). These ACI alloy designations, e.g. CF-8M, have been adopted by ASTM and are preferred for cast alloy over the corresponding wrought steel designation of the American Iron and Steel Institute (AISI). The reason for this is that the grades intentionally have different compositions than their wrought counterparts.

The ranges of iron, chromium, and nickel for the cast alloy compositions most widely used are identified with a letter which is part of the ACI grade designation. The initial letter of the grade designation, C or H, indicates whether the alloy is intended primarily for aqueous corrosion service (C) or elevated temperature, i.e. heat-resistant, service (H). The second letter of the ACI designation denotes the nominal chromium-nickel type. As the nickel content of the grade increases, the letter in the ACI designation increases from A (lowest) to Z (highest). Numerals following the letters relate to the maximum carbon content of the corrosion-resistant (C) alloys. When used with heat resistant grades (H), the numerals are the midpoint of a 0.10 carbon range. If additional alloying elements are included in the grade, they are denoted by the addition of a letter to the ACI designation. Thus, CF-8M is an alloy for corrosion resistant service of the 19% Cr and 9% Ni type with a maximum carbon content of 0.08% and which contains molybdenum.

The CF grade alloys constitute the most technologically important and highest tonnage segment of corrosion-resistant casting production. These 19Cr-9Ni alloys are the cast counterparts of the 18Cr-8Ni or AISI 300 series wrought stainless steels. In general, the cast and wrought alloys possess equivalent resistance to corrosive media and they are frequently used in conjunction with each other.

Important differences do exist, however, between the cast CF grade alloys and their wrought AISI counterparts. Most significant among these is the difference in alloy microstructure in the end-use condition. The CF grade cast alloys are duplex ferrite-in-austenite and usually contain from 5 to 40% ferrite, depending on the particular alloy, whereas their wrought counterparts are fully austenitic. The ferrite in cast stainless with duplex structures is magnetic, a point that is often confusing when cast stainless steels are compared to their wrought counterparts by checking their attraction to a magnet. This difference in microstructures is attributable to the fact that the chemical compositions of the cast and wrought alloys are different by intent. Ferrite is present by intent in cast CF grade stainless steels for three reasons: to provide strength, to improve weldability, and to maximize resistance to corrosion in specific environments.

Below is a list of high alloy cast steel specifications, with summary details on the following pages. Note that the values given in the summary of the specifications are stated with either U.S. Conventional Units (USCS) or Metric (SI) units, and are to be regarded separately. Units given in brackets are SI units. The values stated in each system are not exact equivalents (soft conversion); therefore, each system must be used independently of the other. Combining values from the two systems, by using conversion equations (hard conversion), may result in nonconformance with the specification. Also note that the values in the table are given in a minimum over maximum format. This means that if the value is a minimum it will be listed in the upper portion of the specification's table row and in the lower portion of the row if it is a maximum value. Finally, note that tables and their footnotes may be split across two or more pages.

ASTM A 128/A128M – 12	Steel Castings, Austenitic Manganese
ASTM A 297/A 297M – 14	Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application
ASTM A 351/A 351M – 16	Castings, Austenitic, Austenitic-Ferritic, For Pressure-Containing Parts
ASTM A 447/A 447M – 11	Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service
ASTM A 494/A 494M – 15	Castings, Nickel and Nickel Alloy
ASTM A 560/A 560M – 12	Castings, Chromium-Nickel Alloy
ASTM A 743/A 743M – 13a$^{\varepsilon 1}$	Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application
ASTM A 744/A 744M – 13	Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
ASTM A 747/A 747M – 16a	Steel Castings, Stainless, Precipitation Hardening
ASTM A 890/A 890M – 13	Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application
ASTM A 990/A 990M – 14a	Castings, Iron-Nickel-Chromium and Nickel Alloys, Specially Controlled for Pressure Retaining Parts for Corrosive Service
ASTM A 995/A 995M – 13	Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts
ISO 4991:2015	Steel Castings for Pressure Purposes
ISO 11972:2015	Corrosion-Resistant Cast Steels for General Applications
ISO 11973:2015	Heat-Resistant Cast Steels for General Applications
ISO 12725:1997	Nickel and Nickel Alloy Castings
ISO 19960:2015	Cast Steels and Alloys with Special Physical Properties
Lloyd's Register Rule 2.4.8 – 16	Steel Castings Part 2, Chapter 4, Section 8: Austenitic Stainless Steel Castings
MIL-C-24707/3 – 89	Castings, Ferrous, Corrosion-Resistant, Austenitic, Chromium-Nickel
MIL-C-24707/6 – 89	Castings, Ferrous, Chromium Steel, for Pressure-Containing Parts Suitable for High-Temperature

ASTM A 128/A128M – 12 STEEL CASTINGS, AUSTENITIC MANGANESE

This specification covers Hadfield austenitic manganese steel castings and alloy modifications.

GRADE & HEAT TREATMENT		CHEMICAL COMPOSITION, % (maximum percent unless range given)						
Grade[A] and UNS	Heat Treatment	C	Mn	Cr	Mo	Ni	Si	P
A[B] J91109	Q	1.05 1.35	11.0 min	…	…	…	1.00	0.07
B-1 J91119	Q	0.9 1.05	11.5 14.0	…	…	…	1.00	0.07
B-2 J91129	Q	1.05 1.2	11.5 14.0	…	…	…	1.00	0.07
B-3 J91139	Q	1.12 1.28	11.5 14.0	…	…	…	1.00	0.07
B-4 J91149	Q	1.2 1.35	11.5 14.0	…	…	…	1.00	0.07
C J91309	Q	1.05 1.35	11.5 14.0	1.5 2.5	…	…	1.00	0.07
D J91459	Q	0.7 1.3	11.5 14.0	…	…	3.0 4.0	1.00	0.07
E-1 J91249	Q	0.7 1.3	11.5 14.0	…	0.9 1.2	…	1.00	0.07
E-2 J91339	Q	1.05 1.45	11.5 14.0	…	1.8 2.1	…	1.00	0.07
F J91340	Q	1.05 1.35	6.0 8.0	…	0.9 1.2	…	1.00	0.07

[A] Section size precludes the use of all grades and the producer should be consulted as to grades practically obtainable for a particular design required. Final selection shall be by mutual agreement between manufacturer and purchaser.
[B] Unless otherwise specified, Grade A will be supplied.

ASTM A 297/A 297M – 14 STEEL CASTINGS, IRON-CHROMIUM AND IRON-CHROMIUM-NICKEL, HEAT RESISTANT, FOR GENERAL APPLICATION

This specification covers iron-chromium and iron-chromium-nickel alloy castings for heat-resistant service. The grades covered by this specification are general purpose alloys and no attempt has been made to include heat-resisting alloys used for special production application.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)					CHEMICAL COMPOSITION, %[B] (maximum percent unless range given)								
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong %[C]	C	Mn	Si	P	S	Cr	Ni	Mo[D]	Other[E]
HF J92603		70	485	35	240	25	0.20 0.40	2.00	2.00	0.04	0.04	18.0 23.0	8.0 12.0	0.50	
HH J93503		75	515	35	240	10	0.20 0.50	2.00	2.00	0.04	0.04	24.0 28.0	11.0 14.0	0.50	
HI J94003		70	485	35	240	10	0.20 0.50	2.00	2.00	0.04	0.04	26.0 30.0	14.0 18.0	0.50	

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)					CHEMICAL COMPOSITION, %[B] (maximum percent unless range given)								
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong %[C]	C	Mn	Si	P	S	Cr	Ni	Mo[D]	Other[E]
HK J94224		65	450	35	240	10	0.20 0.60	2.00	2.00	0.04	0.04	24.0 28.0	18.0 22.0	0.50	
HE J93403		85	585	40	275	9	0.20 0.50	2.00	2.00	0.04	0.04	26.0 30.0	8.0 11.0	0.50	
HT N08605		65	450	…	…	4	0.35 0.75	2.00	2.50	0.04	0.04	15.0 19.0	33.0 37.0	0.50	
HU N08004		65	450	…	…	4	0.35 0.75	2.00	2.50	0.04	0.04	17.0 21.0	37.0 41.0	0.50	
HW N08001		60	415	…	…	…	0.35 0.75	2.00	2.50	0.04	0.04	10.0 14.0	58.0 62.0	0.50	
HX N06006		60	415	…	…	…	0.35 0.75	2.00	2.50	0.04	0.04	15.0 19.0	64.0 68.0	0.50	
HC J92605		55	380	…	…	…	0.50	1.00	2.00	0.04	0.04	26.0 30.0	4.00	0.50	
HD J93005		75	515	35	240	8	0.50	1.50	2.00	0.04	0.04	26.0 30.0	4.0 7.0	0.50	
HL N08604		65	450	35	240	10	0.20 0.60	2.00	2.00	0.04	0.04	28.0 32.0	18.0 22.0	0.50	
HN J94213		63	435	…	…	8	0.20 0.50	2.00	2.00	0.04	0.04	19.0 23.0	23.0 27.0	0.50	
HP N08705		62.5	430	34	235	4.5	0.35 0.75	2.00	2.50	0.04	0.04	24 28	33 37	0.50	
HG10MNN J92604		76	525	33	225	20	0.07 0.11	3.0 5.02	0.70	0.040	0.03	18.5 20.5	11.5 13.5	0.25 0.45	Cu 0.50 Nb (Cb)[F] N 0.20-0.30
CT15C N08151		63	435	25	170	20.0	0.05 0.15	0.15 1.50	0.15 1.50	0.03	0.03	19.0 21.0	31.0 34.0	…	

[A] As-cast or as agreed upon by the manufacturer and purchaser.
[B] Where ellipses (…) appear in this table there is no requirement, and the element need not be analyzed or reported.
[C] When ICI test bars are used in tensile tests as provided for in this specification, the gage length to reduced section diameter ratio shall be 4:1.
[D] Castings having a specified molybdenum range agreed upon by the manufacturer and the purchaser may also be furnished under this specification.
[E] Niobium (Nb) and columbium (Cb) both designate element 41.
[F] Grade HG10MNN shall have a niobium content of not less than 8 times the carbon, but not over 1.00%.

ASTM A 351/A 351M – 16 CASTINGS, AUSTENITIC, AUSTENITIC-FERRITIC (DUPLEX), FOR PRESSURE-CONTAINING PARTS

This specification covers austenitic and austenitic-ferritic (duplex) steel castings for valves, flanges, fittings, and other pressure-containing parts.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)											
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength[B] ksi	Yield Strength[B] MPa	Elong$_D$ %[C]	C	Mn	Si	S	P	Cr	Ni	Mo	Cb (Nb)[D]	V	N	Cu
CE20N[E] J92802	ST[F]	80	550	40	275	30	0.20	1.50	1.50	0.040	0.040	23.0 26.0	8.0 11.0	0.50	…	…	0.08 0.20	…
CF3 J92700	ST	70	485	30	205	35	0.03	1.50	2.00	0.040	0.040	17.0 21.0	8.0 12.0	0.50	…	…	…	…

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)											
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength[B] ksi	Yield Strength[B] MPa	Elong$_D$ %[C]	C	Mn	Si	S	P	Cr	Ni	Mo	Cb (Nb)[D]	V	N	Cu
CF3A[E] J92700	ST	77	530	35	240	35	0.03	1.50	2.00	0.040	0.040	17.0 21.0	8.0 12.0	0.50	…	…	…	…
CF8 J92600	ST	70	485	30	205	35	0.08	1.50	2.00	0.040	0.040	18.0 21.0	8.0 11.0	0.50	…	…	…	…
CF8A[E] J92600	ST	77	530	35	240	35	0.08	1.50	2.00	0.040	0.040	18.0 21.0	8.0 11.0	0.50	…	…	…	…
CF3M J92800	ST	70	485	30	205	30	0.03	1.50	1.50	0.040	0.040	17.0 21.0	9.0 13.0	2.0 3.0	…	…	…	…
CF3MA[E] J92800	ST	80	550	37	255	30	0.03	1.50	1.50	0.040	0.040	17.0 21.0	9.0 13.0	2.0 3.0	…	…	…	…
CF8M J92900	ST	70	485	30	205	30	0.08	1.50	1.50	0.040	0.040	18.0 21.0	9.0 12.0	2.0 3.0	…	…	…	…
CF3MN J92804	ST	75	515	37	255	35	0.03	1.50	1.50	0.040	0.040	17.0 21.0	9.0 13.0	2.0 3.0	…	…	0.10 0.20	…
CF8C J92710	ST	70	485	30	205	30	0.08	1.50	2.00	0.040	0.040	18.0 21.0	9.0 12.0	0.50	[H]	…	…	…
CF10 J92590	ST	70	485	30	205	35	0.04 0.10	1.50	2.00	0.040	0.040	18.0 21.0	8.0 11.0	0.50	…	…	…	…
CF10M J92901	ST	70	485	30	205	30	0.04 0.10	1.50	1.50	0.040	0.040	18.0 21.0	9.0 12.0	2.0 3.0	…	…	…	…
CF10MC	ST	70	485	30	205	20	0.10	1.50	1.50	0.040	0.040	15.0 18.0	13.0 16.0	1.75 2.225	[I]	…	…	…
CF10SMnN J92972	ST	85	585	42.5	295	30	0.10	7.00 9.00	3.50 4.50	0.030	0.060	16.0 18.0	8.0 9.0	…	…	…	0.08 0.18	…
CG3M J92999	ST	75	515	35	240	25	0.03	1.50	1.50	0.04	0.04	18.0 21.0	9.0 13.0	3.0 4.0	…	…	…	…
CG6MMnN J93790	ST	85	585	42.5	295	30	0.06	4.0 6.0	1.00	0.030	0.040	20.5 23.5	11.5 13.5	1.50 3.00	0.10 0.30	0.10 0.30	0.20 0.40	…
CG8M J93000	ST	75	515	35	240	25	0.08	1.50	1.50	0.04	0.04	18.0 21.0	9.0 13.0	3.0 4.0	…	…	…	…
CH8 J93400	ST	65	450	28	195	30	0.08	1.50	1.50	0.040	0.040	22.0 26.0	12.0 15.0	0.50	…	…	…	…
CH10 J93401	ST	70	485	30	205	30	0.04 0.10	1.50	2.00	0.040	0.040	22.0 26.0	12.0 15.0	0.50	…	…	…	…
CH20 J93402	ST	70	485	30	205	30	0.04 0.20	1.50	2.00	0.040	0.040	22.0 26.0	12.0 15.0	0.50	…	…	…	…
CK20 J94202	ST	65	450	28	195	30	0.04 0.20	1.50	1.75	0.040	0.040	23.0 27.0	19.0 22.0	0.50	…	…	…	…
CK3MCuN J93254	ST[G]	80	550	38	260	35	0.025	1.20	1.00	0.010	0.045	19.5 20.5	17.5 19.5	6.0 7.0	…	…	0.18 0.24	0.50 1.00
CN3MN J94651	ST[G]	80	550	38	260	35	0.03	2.00	1.00	0.010	0.040	20.0 22.0	23.5 25.5	6.0 7.0	…	…	0.18 0.26	0.75
CN7M N08007	ST	62	425	25	170	35	0.07	1.50	1.50	0.040	0.040	19.0 22.0	27.5 30.5	2.0 3.0	…	…	…	3.0 4.0
CT15C N08151	as cast	63	435	25	170	20	0.05 0.15	0.15 1.50	0.50 1.50	0.03	0.03	19.0 21.0	31.0 34.0	…	0.50 1.50	…	…	…
HG10MnN J92604	as cast	76	525	33	225	20	0.07 0.11	3.0 5.0	0.70	0.030	0.040	18.5 20.5	11.5 13.5	0.25 0.45	[J]	…	0.20 0.30	0.50

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)											
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength[B] ksi	Yield Strength[B] MPa	Elong$_D$ %[C]	C	Mn	Si	S	P	Cr	Ni	Mo	Cb (Nb)[D]	V	N	Cu
HK30 J94203	as cast	65	450	30	240	10	0.25 0.35	1.50	1.75	0.040	0.040	23.0 27.0	19.0 22.0	0.50	…	…	…	…
HK40 J94204	as cast	62	425	35	240	10	0.35 0.45	1.50	1.75	0.040	0.040	23.0 27.0	19.0 22.0	0.50	…	…	…	…
HT30 N08030	as cast	65	450	28	195	15	0.25 0.35	2.00	2.50	0.040	0.040	13.0 17.0	33.0 37.0	0.50	…	…	…	…

[A] ST = to be solution treated. Refer to original specification for additional information on heat treatment requirements.
[B] Determine by the 0.2% offset method.
[C] When ICI test bars are used in tensile tests as provided for in this specification, the gage length to reduced section diameter ratio shall be 4:1.
[D] Columbium (Cb) and niobium (Nb) are alternate names for Element 41.
[E] Because of thermal instability, Grades CE20N, CF3A, CF3MA, and CF8A are not recommended for service at temperatures above 800ºF [425ºC].
[F] Grade shall be quenched in water or the castings may be furnace cooled to 2050ºF [1120ºC] minimum, held for 15 min minimum and then quenched in water or rapidly cooled by other means.
[G] Castings of these grades shall be held at the specified temperature for a minimum of 4 hours.
[H] Grade CF8C shall have a columbium (niobium) content of not less than 8 times the carbon content but not over 1.00%.
[I] Grade CF10MC shall have a columbium (niobium) content of not less than 10 times the carbon content but not over 1.20%.
[J] Grade HG10MnN shall have a columbium (niobium) content of not less than 8 times the carbon content but not over 1.00%.

ASTM A 447/A 447M – 11 STEEL CASTINGS, CHROMIUM-NICKEL-IRON ALLOY (25-12 CLASS), FOR HIGH-TEMPERATURE SERVICE

This specification covers iron-base, heat-resisting alloy castings of the 25% chromium, 12% nickel class, intended for structural elements, containers, and supports in electric furnaces, petroleum still tube supports, and for similar applications up to 2000°F [1095°C]. The purchaser should inform the manufacturer when the service temperatures are to exceed 1800°F [980°C].

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)				CHEMICAL COMPOSITION, % (maximum percent unless range given)								
Grade and UNS	Heat Treatment[A]	Tensile Strength[B,C] ksi	Tensile Strength[B,C] MPa	Elong % [B,D]	Other Tests[E,F] Magnetic Permeability	C	Mn	P	S	Si	Ni[G]	Cr	N	Fe
I J93303	as cast	80	550	9	1.70	0.20 0.45	2.50	0.030	0.030	1.75	10.00 14.00	23.00 28.00	0.20	[H]
II J93303	as cast	80	550	4	1.05	0.20 0.45	2.50	0.030	0.030	1.75	10.00 14.00	23.00 28.00	0.20	[H]

[A] As agreed upon by manufacturer and purchaser.
[B] Properties after aging.
[C] Short term, high temperature tensile property requirements for the grades are as follows: Type I is to be agreed upon by manufacturer and producer, and Type II is to have a minimum of 20 ksi [140 MPa] tensile strength and a minimum elongation of 8%.
[D] These minima shall apply when tested according to Test Methods E8. Minimum elongation in 5D for Type I and II are 8.7 and 3.9, respectively according to Test Methods E8M.
[E] The stress rupture test for the grades is as follows with the tensile stress being sustained for at least 16h: Type I at 5 ksi [34 MPa] and Type II at 8 ksi [55 MPa].
[F] Refer to original specification for details; note that out of the four tests (tension after aging, magnetic permeability, stress rupture, and short time high-temperature) the purchaser shall specify no more than two tests.
[G] Commercial nickel usually carries a small amount of cobalt, and within the usual limits cobalt shall be counted as nickel.
[H] The manufacturer and purchaser may agree upon allowable limits of iron and other elements.

This specification covers nickel, nickel-copper, nickel-copper-silicon, nickel-molybdenum, nickel chromium, and nickel-molybdenum-chromium alloy castings for corrosion resistant service.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)												
Grade and UNS	Heat Treatment[A]	Tensile Strength		Yield Strength		Elong %[B]	Other Tests	C	Mn	Si	P	S	Cu	Mo	Fe	Ni	Cr	Cb (Nb)	W	V	Bi	Sn
		ksi	MPa	ksi	MPa		Hardness (HBW)															
CZ100 N02100	as cast	50	345	18	125	10	…	1.00	1.50	2.00	0.03	0.02	1.25	…	3.00	95.00 min	…	…	…	…	…	…
M25S N24025	as cast or ST[D]	…	…	…	…	…	300[E]	0.25	1.50	3.5 4.5	0.03	0.02	27.0 33.0	…	3.50	balance	…	[F]	…	…	…	…
M30C[C] N24130	as cast	65	450	32.5	225	25	…	0.30	1.50	1.0 2.0	0.03	0.02	26.0 33.0	…	3.50	balance	…	1.0 3.0	…	…	…	…
M30H N24030	as cast	100	690	60	415	10	…	0.30	1.50	2.7 3.7	0.03	0.02	27.0 33.0	…	3.50	balance	…	[F]	…	…	…	…
M35-1[C] N24135	as cast	65	450	25	170	25	..	0.35	1.50	1.25	0.03	0.02	26.0 33.0	…	3.50	balance	…	0.5	…	…	…	…
M35-2 N04020	as cast	65	450	30	205	25	…	0.35	1.50	2.00	0.03	0.02	26.0 33.0	…	3.50	balance	…	0.5	…	…	…	…
N3M J30003	ST	76	525	40	275	20.0	…	0.03	1.00	0.50	0.030	0.020	…	30.0 33.0	3.00	balance	1.0	…	…	[F]	…	…
N7M N30007	ST	76	525	40	275	20	…	0.07	1.00	1.00	0.030	0.020	…	30.0 33.0	3.00	balance	1.0	…	…	[F]	…	…
N12MV N30012	ST	76	525	40	275	6	…	0.12	1.00	1.00	0.030	0.020	…	26.0 30.0	4.0 6.0	balance	1.00	…	…	0.20 0.60	…	…
CU5MCuC N08826	ST	75	520	35	240	20	…	0.050	1.0	1.0	0.030	0.020	1.50 3.50	2.5 3.5	balance	38.0 44.0	19.5 23.5	0.60 1.20	[F]	[F]	…	…
CW2M N26455	ST	72	495	40	275	20	…	0.02	1.00	0.80	0.03	0.02	[F]	15.0 17.5	2.0	balance	15.0 17.5	[F]	1.0	[F]	…	…
CW6M N30107	ST	72	495	40	275	25	…	0.07	1.00	1.00	0.030	0.020	[F]	17.0 20.0	3.0	balance	17.0 20.0	[F]	[F]	[F]	…	…
CW6MC N26625	ST	70	485	40	275	25	…	0.06	1.00	1.00	0.015	0.015	[F]	8.0 10.0	5.0	balance	20.0 23.0	3.15 4.50	[F]	[F]	…	…
CW12MW N30002	ST	72	495	40	275	4	…	0.12	1.00	1.00	0.030	0.020	[F]	16.0 18.0	4.5 7.5	balance	15.5 17.5	[F]	3.75 5.25	0.20 0.40	…	…
CX2M N26059	ST	72	495	39	270	40	…	0.02	1.00	0.50	0.020	0.020	[F]	15.0 16.5	1.50	balance	22.0 24.0	[F]	[F]	[F]	…	…
CX2MW N26022	ST	80	550	45	310	30	…	0.02	1.00	0.80	0.025	0.020	[F]	12.5 14.5	2.0 6.0	balance	20.0 22.5	[F]	2.5 3.5	0.35	…	…
CY40 N06040	as cast or ST	70	485	28	195	30	…	0.40	1.50	3.00	0.03	0.02	[F]	B	11.0	balance	14.0 17.0	[F]	[F]	[F]	…	…
CY5SnBiM N26055	as cast	…	…	…	…	…	…	0.05	1.5	0.5	0.03	0.02	…	2.0 3.5	2.0	balance	11.0 14.0	…	…	…	3.0 5.0	3.0 5.0

[A] Refer to original specification for additional information on heat treatment requirements.
[B] When ICI test bars are used in tensile tests as provided for per Specification A 732/A 732M, the gage length to reduced section diameter ratio shall be 4 to 1.
[C] Order Grade M35-1 or M30C when weldability is required.
[D] M25S, while machinable in the "as cast" condition is capable of being solution treated for improved machinability; it may be subsequently age-hardened to the specified hardness specified in Table 3 (original specification) and finished machined or ground.

[E] Minimum hardness for the age-hardened condition.
[F] Element to be analyzed and reported for information only.

ASTM A 560/A 560M – 12 CASTINGS, CHROMIUM-NICKEL ALLOY

This specification covers chromium-nickel alloy castings intended for heat resisting and elevated-temperature corrosion applications such as structural members, containers, supports, hangers, spacers and the like in corrosive environments up to 2000°F [1090°C].

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)						CHEMICAL COMPOSITION, %[B,C] (maximum percent unless range given)											
Grade and UNS	Heat Treatment[A]	Tensile Strength		Yield Strength		Elong %	Other Tests	C	Mn	Si	S	P	N	N+C	Fe	Ti	Al	Cb	Cr	Ni
		ksi	MPa	ksi	MPa		Impact Test ft-lb [J]													
50 Cr-50 Ni R20500	as cast	80	550	50	340	5.0	50 [78]	0.10	0.30	1.00	0.02	0.02	0.30	…	1.00	0.50	0.25	…	48.0 52.0	balance
60 Cr-40 Ni R20600	as cast	110	760	85	590	…	10 [14]	0.10	0.30	1.00	0.02	0.02	0.30	…	1.00	0.50	0.25	…	58.0 62.0	balance
50 Cr-50 Ni-Cb R20501	as cast	80	550	50	345	5.0	…	0.10	0.30	0.50	0.02	0.02	0.16	0.20	1.00	0.50	0.25	1.4 1.7	47.0 52.0	balance

[A] Heat treatment as agreed upon by manufacturer and purchaser.
[B] Where ellipses appear (…) in this table, there is no minimum and analysis for the element need not be determined or reported.
[C] The total of the nickel, chromium, and columbium contents must exceed 97.5%.

ASTM A 743/A 743M – 13a$^{\varepsilon 1}$ CASTINGS, IRON-CHROMIUM, IRON-CHROMIUM-NICKEL, CORROSION RESISTANT, FOR GENERAL APPLICATION

This specification covers iron-chromium and iron-chromium-nickel-alloy castings for general corrosion-resistant application. The grades covered by this specification represent types of alloy castings suitable for broad ranges of application which are intended for a wide variety of corrosion environments.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)							CHEMICAL COMPOSITION, % (maximum percent unless range given)													
Grade and UNS	Heat Treatment[A]	Tensile Strength		Yield Strength		Elong$_D$ %[B]	Red A %	Other Tests	C	Mn	Si	P	S	Cr	Ni	Mo	Cb	Se	Cu	W	V	N
		ksi	MPa	ksi	MPa																	
CA6N J91650	ST	140	965	135	930	15	50		0.06	0.50	1.00	0.02	0.02	10.5 12.5	6.0 8.0	…	…	…	…	…	…	…
CA6NM J91540	NT	110	755	80	550	15	35	[E]	0.06	1.00	1.00	0.04	0.03	11.5 14.0	3.5 4.5	0.40 1.0	…	…	…	…	…	…
CA15 J91150	NT or A	90	620	65	450	18	30	[E]	0.15	1.00	1.50	0.04	0.04	11.5 14.0	1.00	0.50	…	…	…	…	…	…
CA15M J91151	NT or A	90	620	65	450	18	30	[E]	0.15	1.00	0.65	0.040	0.040	11.5 14.0	1.0	0.15 1.0	…	…	…	…	…	…
CA28MWV J91422	NT, QT, or A	140[C]	965[C]	110[C]	760[C]	10[C]	24[C]	[E]	0.20 0.28	0.50 1.00	1.0	0.030	0.030	11.0 12.5	0.50 1.00	0.90 1.25	…	…	…	0.90 1.25	0.20 0.30	…
CA40 J91153	NT or A	100	690	70	485	15	25	[E]	0.20 0.40	1.00	1.50	0.04	0.04	11.5 14.0	1.0	0.5	…	…	…	…	…	…
CA40F J91154	NT or A	100	690	70	485	12	…	[E]	0.20 0.40	1.00	1.50	0.04	0.20 0.40	11.5 14.0	1.0	0.5	…	…	…	…	…	…

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)							CHEMICAL COMPOSITION, % (maximum percent unless range given)													
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong[D] %[B]	Red A %	Other Tests	C	Mn	Si	P	S	Cr	Ni	Mo	Cb	Se	Cu	W	V	N
CB6 J91804	NT	115	790	85	580	16	35		0.06	1.00	1.00	0.04	0.03	15.5 17.5	3.5 5.5	0.5	…	…	…	…	…	…
CB30 J91803	ST	65	450	30	205	…	…	[E]	0.30	1.00	1.50	0.04	0.04	18.0 21.0	2.00	…	…	…	[H]	…	…	…
CC50 J92615	ST	55	380	…	…	…	…	[E]	0.50	1.00	1.50	0.04	0.04	26.0 30.0	4.00	…	…	…	…	…	…	…
CE30 J93423	ST	80	550	40	275	10	…		0.30	1.50	2.00	0.04	0.04	26.0 30.0	8.0 11.0	…	…	…	…	…	…	…
CF3 J92500	as cast or ST	70	485	30	205	35	…	[F]	0.03	1.50	2.00	0.04	0.04	17.0 21.0	8.0 12.0	…	…	…	…	…	…	…
CF3M J92800	as cast or ST	70	485	30	205	30	…	[F]	0.03	1.50	1.50	0.04	0.04	17.0 21.0	9.0 13.0	2.0 3.0	…	…	…	…	…	…
CF3MN J92804	as cast or ST	75	515	37	255	35	…		0.03	1.50	1.50	0.040	0.040	17.0 22.0	9.0 13.0	2.0 3.0	…	…	…	…	…	0.10 0.20
CF8 J92600	ST	70[D]	485[D]	30[D]	205[D]	35	…	[F]	0.08	1.50	2.00	0.04	0.04	18.0 21.0	8.0 11.0	…	…	…	…	…	…	…
CF8C J92710	ST	70	485	30	205	30	…	[F]	0.08	1.50	2.00	0.04	0.04	18.0 21.0	9.0 12.0	…	[G]	…	…	…	…	…
CF8M J92900	ST	70	485	30	205	30	…	[F]	0.08	1.50	2.00	0.04	0.04	18.0 21.0	9.0 12.0	2.0 3.0	…	…	…	…	…	…
CF10SMnN J92972	ST	85	585	42	290	30	…		0.10	7.00 9.00	3.50 4.50	0.060	0.030	16.0 18.0	8.0 9.0	…	…	…	…	…	…	0.08 0.18
CF16F J92701	ST	70	485	30	205	25	…		0.16	1.50	2.00	0.17	0.04	18.0 21.0	9.0 12.0	1.50	…	0.20 0.35	…	…	…	…
CF16Fa	ST	70	485	30	205	25	…		0.16	1.50	2.00	0.04	0.20 0.40	18.0 21.0	9.0 12.0	0.40 0.80	…	…	…	…	…	…
CF20 J92602	ST	70	485	30	205	30	…		0.20	1.50	2.00	0.04	0.04	18.0 21.0	8.0 11.0	…	…	…	…	…	…	…
CG3M J92999	ST	75	515	35	240	25	…	[F]	0.03	1.50	1.50	0.04	0.04	18.0 21.0	9.0 13.0	3.0 4.0	…	…	…	…	…	…
CG6MMN J93790	ST	85	585	42	290	30	…		0.06	4.00 6.00	1.00	0.04	0.03	20.5 23.5	11.5 13.5	1.50 3.00	0.10 0.30	…	…	…	0.10 0.30	0.20 0.40
CG8M J93000	ST	75	520	35	240	25	…		0.08	1.50	1.50	0.04	0.04	18.0 21.0	9.0 13.0	3.0 4.0	…	…	…	…	…	…
CG12 J93001	ST	70	485	28	195	35	…		0.12	1.50	2.00	0.04	0.04	20.0 23.0	10.0 13.0	…	…	…	…	…	…	…
CH10 J93401	ST	70	485	30	205	30	…		0.10	1.50	2.00	0.04	0.04	22.0 26.0	12.0 15.0	…	…	…	…	…	…	…
CH20 J93402	ST	70	485	30	205	30	…		0.20	1.50	2.00	0.04	0.04	22.0 26.0	12.0 15.0	…	…	…	…	…	…	…
CK35MN	ST	83	570	41	280	35	…		0.035	2.00	1.00	0.035	0.020	22.0 24.0	20.0 22.0	6.0 6.8	…	…	0.40	…	…	0.21 0.32
CK3MCuN J93254	ST	80	550	38	260	35	…		0.025	1.20	1.00	0.045	0.010	19.5 20.5	17.5 19.5	6.0 7.0	…	…	0.50 1.00	…	…	0.180 0.240
CK20 J94202	ST	65	450	28	195	30	…		0.20	2.00	2.00	0.04	0.04	23.0 27.0	19.0 22.0	…	…	…	…	…	…	…
CN3M J94652	ST	63	435	25	170	30	…		0.03	2.0	1.0	0.03	0.03	20.0 22.0	23.0 27.0	4.5 5.5	…	…	…	…	…	…

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)							CHEMICAL COMPOSITION, % (maximum percent unless range given)													
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong$_D$ %[B]	Red A %	Other Tests	C	Mn	Si	P	S	Cr	Ni	Mo	Cb	Se	Cu	W	V	N
CN3MN J94651	ST	80	550	38	260	35	…		0.03	2.00	1.00	0.040	0.010	20.0 22.0	23.5 25.5	6.0 7.0	…	…	0.75	…	…	0.18 0.26
CN7M N08007	ST	62	425	25	170	35	…		0.07	1.50	1.50	0.04	0.04	19.0 22.0	27.5 30.5	2.0 3.0	…	…	3.0 4.0	…	…	…
CN7MS J94650	ST	70	485	30	205	35	…		0.07	1.00	2.50 3.50	0.04	0.03	18.0 20.0	22.0 25.0	2.5 3.0	…	…	1.5 2.0	…		
HG10MNN J92604	as cast	76	525	33	225	20	…		0.07 0.11	3.0 5.0	0.70	0.040	0.030	18.5 20.5	11.5 13.5	0.25 0.45	[I]	…	0.50	…	…	0.20 0.30

[A] Refer to original specification for additional heat treatment information.
[B] When ICI test bars are used in tensile tests as provided for in this specification, the gage length to reduced section diameter ratio shall be 4:1.
[C] These mechanical properties apply only when heat-treatment (1) has been used.
[D] For low ferrite or nonmagnetic castings of this grade, the following values shall apply: tensile strength, min, 65 ksi [450 MPa]; yield point, min, 28 ksi [195 MPa].
[E] Supplementary requirement for hardness tests when desired by the purchaser.
[F] Supplementary intergranular corrosion test if specified by the customer.
[G] Grade CF8C shall have a columbium content of not less than eight times the carbon content and not more than 1.0%. If a columbium-plus-tantalum alloy in the approximate Cb:Ta ratio of 3:1 is used for stabilizing this grade, the total columbium-plus-tantalum content shall not be less than nine times the carbon content and shall not exceed 1.1%.
[H] For Grade CB30 a copper content of 0.90 to 1.20% is optional.
[I] Grade HG10MNN shall have a columbium content of not less than eight times the carbon, but not over 1.00%.

ASTM A 744/A 744M – 13 CASTINGS, IRON-CHROMIUM-NICKEL, CORROSION RESISTANT, FOR SEVERE SERVICE

This specification covers iron-chromium-nickel-alloy, stainless steel castings intended for particularly corrosive applications.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)														
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong$_B$ %[B]	Other Tests[C]	C	Mn	Si	P	S	Cr	Ni	Mo	Cb	Cu	Se	W	V	Fe	N
CF8 J92600	ST	70[E]	485[E]	30[E]	205[E]	35		0.08	1.50	2.0	0.04	0.04	18.0 21.0	8.0 11.0	…	…	…					
CF8M J92900	ST[D]	70	485	30	205	30		0.08	1.50	2.0	0.04	0.04	18.0 21.0	9.0 12.0	2.0 3.0	…	…					
CF8C J92710	ST	70	485	30	205	30		0.08	1.50	2.0	0.04	0.04	18.0 21.0	9.0 12.0	…	[G]	…					
CF3 J92500	ST	70	485	30	205	35		0.03[F]	1.50	2.0	0.04	0.04	17.0 21.0	8.0 12.0	…	…	…					
CF3M J92800	ST[D]	70	485	30	205	30		0.03[F]	1.50	1.50	0.04	0.04	17.0 21.0	9.0 13.0	2.0 3.0	…	…					
CG3M J92999	ST	75	515	35	240	25		0.03	1.50	1.50	0.04	0.04	18.0 21.0	9.0 13.0	3.0 4.0	…	…	…	…	…	…	…
CG8M J93000	ST[D]	75	520	35	240	25		0.08	1.50	1.50	0.04	0.04	18.0 21.0	9.0 13.0	3.0 4.0	…	…					
CN7M N08007	ST	62	425	25	170	35		0.07	1.50	1.50	0.04	0.04	19.0 22.0	27.5 30.5	2.0 3.0	…	3.0 4.0					
CN7MS J94650	ST	70	485	30	205	35		0.07	1.0	2.50 3.50	0.04	0.03	18.0 20.0	22.0 25.0	2.5 3.0	…	1.5 2.0					
CN3MN J94651	ST	80	550	38	260	35		0.03	2.00	1.00	0.040	0.010	20.0 22.0	23.5 25.5	6.00 7.00	…	0.75	…	…	…	…	0.18 0.26

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)														
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong$_B$ %[B]	Other Tests[C]	C	Mn	Si	P	S	Cr	Ni	Mo	Cb	Cu	Se	W	V	Fe	N
CK3MCuN J93254	ST	80	550	38	260	35		0.025	1.20	1.00	0.045	0.010	19.5 20.5	17.5 19.5	6.0 7.0	…	0.50 1.00	…	…	…	…	0.180 0.240
CN3MCu J80020	ST	62	425	25	170	35		0.03	1.50	1.0	0.030	0.015	19.0 22.0	27.5 30.5	2.0 3.0	…	3.0 3.5	…				

[A] Refer to original specification for additional heat treatment information.
[B] When ICI test bars are used in tensile tests as provided for in this specification, the gage length to reduced section diameter ratio shall be 4:1.
[C] Supplementary intergranular corrosion test if specified by the customer.
[D] For optimum tensile strength, ductility, and corrosion resistance, the solution annealing temperature should be in excess of 1900°F [1040°C].
[E] For low ferrite or nonmagnetic castings of this grade, the following values shall apply: tensile strength, min, 65 ksi [450 MPa]; yield point, min, 28 ksi [195 MPa].
[F] For purposes of determining conformance with this specification, the observed or calculated value for carbon content shall be rounded to the nearest 0.01% in accordance with rounding method of Recommended Practice E29.
[G] Grade CF8C shall have a columbium content of not less than 8 times the carbon content and not more than 1.0%. If a columbium-plus-tantalum alloy in the approximate Cb:Ta ratio of 3:1 is used for stabilizing this grade, the total columbium-plus-tantalum content shall not be less than 9 times the carbon content sand shall not exceed 1.1%.

ASTM A 747/A 747M – 16a STEEL CASTINGS, STAINLESS, PRECIPITATION HARDENING

This specification covers iron-chromium-nickel-copper corrosion-resistant steel castings, capable of being strengthened by precipitation hardening heat treatment.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[A] (minimum unless range given)						CHEMICAL COMPOSITION, %[B] (maximum percent unless range given)									
Grade and UNS	Heat Treatment	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong %	Other Tests Hardness HBW [HRC]	C	Mn	P	S	Si	Cr	Ni	Cu	Cb (Nb)	N[C]
CB7Cu-1 J92180	H900$_A$	170	1170	145	1000	5	375 [40]	0.07	0.70	0.035	0.03	1.00	15.50 17.70	3.60 4.60	2.50 3.20	0.15 0.35[B]	0.05
	H925$_A$	175	1205	150	1035	5	375 [40]										
	H1025$_A$	150	1035	140	965	9	311 [33]										
	H1075$_A$	145	1000	115	795	9	277 [29]										
	H1100$_A$	135	930	110	760	9	269 [28]										
	H1150$_A$	125	860	97	670	10	269 [28]										
	H1150M	…	…	…	…	…	310 max [33 max]										
	H1150 DBL	…	…	…	…	…	310 max [33 max]										
CB7Cu-2 J92110	H900$_A$	170	1170	145	1000	5	375 [40]	0.07	0.70	0.035	0.03	1.00	14.0 15.50	4.50 5.50	2.50 3.20	0.15 0.35[B]	0.05
	H925$_A$	175	1205	150	1035	5	375 [40]										
	H1025$_A$	150	1035	140	965	9	311 [33]										

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[A] (minimum unless range given)						CHEMICAL COMPOSITION, %[B] (maximum percent unless range given)									
Grade and UNS	Heat Treatment	Tensile Strength		Yield Strength		Elong %	Other Tests	C	Mn	P	S	Si	Cr	Ni	Cu	Cb (Nb)	N[C]
		ksi	MPa	ksi	MPa		Hardness HBW [HRC]										
	H1075[A]	145	1000	115	795	9	277 [29]										
	H1100[A]	135	930	110	760	9	269 [28]										
	H1150[A]	125	860	97	670	10	269 [28]										
	H1150M	…	…	…	…	…	310 max [33 max]										
	H1150 DBL	…	…	…	…	…	310 max [33 max]										

[A] All mechanical properties are supplementary and are not required unless stipulated by the customer, see original specification for additional information.
[B] See 5.2.4 and 6.2 (original specification). When the H900 condition is ordered, the minimum columbium content shall not apply.
[C] To be determined and reported when specified by the order or contract.

ASTM A 890/A 890M – 13 CASTINGS, IRON-CHROMIUM-NICKEL-MOLYBDENUM CORROSION-RESISTANT, DUPLEX (AUSTENITIC/FERRITIC) FOR GENERAL APPLICATION

This specification covers a group of cast duplex stainless steels (austenitic/ferritic).

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)													
Grade and UNS	Heat Treatment[A]	Tensile Strength		Yield Strength		Elong %[C]	C	Mn	Si	P	S	Cr	Ni	Mo	Cu	W	N	B	Ba	Ce+La
		ksi	MPa	ksi	MPa															
1B[D] CD4MCuN J93372	ST	100	690	70	485	16	0.04	1.0	1.0	0.04	0.04	24.5 26.5	4.7 6.0	1.7 2.3	2.7 3.3	…	0.10 0.25			
1C[E] CD3MCuN J93373	ST	100	690	65	450	25	0.030	1.20	1.10	0.030	0.030	24.0 26.7	5.6 6.7	2.9 3.8	1.40 1.90	…	0.22 0.33			
2A CE8MN J93345	ST	95	655	65	450	25	0.08	1.00	1.50	0.04	0.04	22.5 25.5	8.0 11.0	3.0 4.5	…	…	0.10 0.30			
3A CD6MN J93371	ST	95	655	65	450	25	0.06	1.00	1.00	0.040	0.040	24.0 27.0	4.0 6.0	1.75 2.5	…	…	0.15 0.25	…	…	…
4A CD3MN J92205	ST	90	620	60	415	25	0.03	1.50	1.00	0.04	0.020	21.0 23.5	4.5 6.5	2.5 3.5	1.00	…	0.10 0.30	…	…	…
5A[E] CE3MN J93404	ST	100	690	75	515	18	0.03	1.50	1.00	0.04	0.04	24.0 26.0	6.0 8.0	4.0 5.0	…	…	0.10 0.30	…	…	…
6A[E] CD3MWCuN J93380	ST	100	690	65	450	25	0.03	1.00	1.00	0.030	0.025	24.0 26.0	6.5 8.5	3.0 4.0	0.5 1.0	0.5 1.0	0.20 0.30	…	…	…

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)													
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong %[C]	C	Mn	Si	P	S	Cr	Ni	Mo	Cu	W	N	B	Ba	Ce+La
7A[F] CD3MWN J93379	ST	100	690	75	515	20	0.030	1.00 3.00	1.00	0.030	0.020	26.0 28.0	6.0 8.0	2.0 3.5	1.00	3.0 4.0	0.30 0.40	0.0010 0.0100	0.0002 0.0100	0.005 0.030

[A] See original specification for additional details on heat treatment.
[B] Tensile requirement is a supplementary requirement. See original specification for additional details.
[C] When ICI test bars are used in tensile tests as provided for in this specification, the gage length to reduced section diameter ratio shall be 4:1.
[D] CD4MCu has been removed from the standard. CD4MCuN is an acceptable substitute for CD4MCu.
[E] %Cr + 3.3%Mo + 16%N ≥ 40.
[F] %Cr + 3.3 (%Mo + 0.5%W) + 16%N ≥ 45.

ASTM A 990/A 990M – 14a CASTINGS, IRON-NICKEL-CHROMIUM AND NICKEL ALLOYS, SPECIALLY CONTROLLED FOR PRESSURE RETAINING PARTS FOR CORROSIVE SERVICE

This specification covers iron-nickel-chromium and nickel alloy castings specially processed with restricted melt practices, weldability testing and nondestructive examination (NDE) requirements.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)													
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong %[B]	Other Tests[C]	C	Mn	Si	P	S	Mo	Fe	Ni	Cr	N	Cu	W	V	Cb
CK3MCuN	ST	80	550	38	260	35		0.025	1.20	0.75	0.020	0.010	6.0 7.0	balance	17.5 19.5	19.5 20.5	0.18 0.24	0.50 1.00			
CW-2M N26455	ST	72	495	40	275	20		0.020	1.00	0.80	0.030	0.015	15.0 17.5	2.00	balance	15.0 17.5		…	1.00	…	…
CN3MCu	ST	62	425	25	170	35		0.030	1.50	1.00	0.030	0.015	2.0 3.0	balance	27.5 30.5	19.0 22.0		3.0 3.5	…	…	…
M35-1 N24135	as cast	65	450	25	170	25		0.35	1.50	1.25	0.030	0.015	…	3.5	balance	…		26.0 33.0	…	…	…
CW2MC	ST	70	485	40	275	25		0.020	1.00	0.45	0.015	0.015	8.0 10.0	5.0	balance	20.0 23.0		0.50	0.50	0.20	3.1 4.5
N2M	ST	76	525	40	275	20		0.020	1.00	0.80	0.030	0.015	30.0 33.0	3.00	balance	1.00		0.20	0.20	0.20	…

[A] See original specification for additional details on heat treatment.
[B] When ICI test bars are used in tensile tests as provided for in specification A 985/A 985M, the gage length to reduced section diameter ratio shall be 4 to 1.
[C] See original specification for additional details on Nondestructive Examination Requirements.

ASTM A 995/A 995M – 13 CASTINGS, AUSTENITIC-FERRITIC (DUPLEX) STAINLESS STEEL, FOR PRESSURE-CONTAINING PARTS

This specification covers austenitic-ferritic (duplex) stainless steel castings for valves, flanges, fittings, and other pressure-containing parts.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)													
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong %[B]	C	Mn	Si	P	S	Cr	Ni	Mo	Cu	W	N	B	Ba	Ce+La
1B CD4MCuN J93372	ST	100	690	70	485	16	0.040	1.00	1.00	0.040	0.040	24.5-26.5	4.7-6.0	1.70-2.30	2.7-3.3	…	0.10-0.25	…	…	…
2A CE8MN J93345	ST	95	655	65	450	25	0.080	1.00	1.50	0.040	0.040	22.5-25.5	8.0-11.0	3.0-4.5	…	…	0.10-0.30	…	…	…
3A CD6MN J93371	ST	95	655	65	450	25	0.060	1.00	1.00	0.040	0.040	24.0-27.0	4.0-6.0	1.75-2.50	…	…	0.15-0.25	…	…	…
4A CD3MN J92205	ST	90	620	60	415	25	0.030	1.50	1.00	0.040	0.020	21.0-23.5	4.5-6.5	2.5-3.5	1.00	…	0.10-0.30	…	…	…
5A[C] CE3MN J93404	ST	100	690	75	515	18	0.030	1.50	1.00	0.040	0.040	24.0-26.0	6.0-8.0	4.0-5.0	…	…	0.10-0.30	…	…	…
6A[C] CD3MWCuN J93380	ST	100	690	65	450	25	0.030	1.00	1.00	0.030	0.025	24.0-26.0	6.5-8.5	3.0-4.0	0.50-1.00	0.50-1.00	0.20-0.30	…	…	…
7A[D] CD3MWN J93379	ST	100	690	75	515	20	0.030	1.00-3.00	1.00	0.030	0.020	26.0-28.0	6.0-8.0	2.0-3.5	1.00	3.0-4.0	0.30-0.40	0.0010-0.0100	0.0002-0.0100	0.005-0.030

[A] See original specification for additional details on heat treatment.
[B] When ICI test bars are used in tensile tests as provided for in specification A 985/A 985M, the gage length to reduced section diameter ratio shall be 4 to 1.
[C] %Cr + 3.3%Mo + 16%N ≥ 40
[D] %Cr + 3.3 (%Mo + 0.5%W) + 16%N ≥ 45

ISO 4991:2015 STEEL CASTINGS FOR PRESSURE PURPOSES

This International Standard covers steel castings used for pressure purposes. It includes materials which are used for the manufacture of components subject to pressure vessel codes and for other pressure containing components not subject to codal requirements.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)[C]								CHEMICAL COMPOSITION, % (maximum percent unless range given)										
		AT ROOM TEMPERATURE					AT LOW TEMPERATURE													
		Tensile Test				Impact Test	Impact Test		Other Tests[D]											
Grade and UNS	Heat Treatment[A]	Yield Strength $R_{p0.2}$ MPa	Yield Strength $R_{p1.0}$ MPa	Tensile Strength R_m MPa	A %	KV J	KV J	°C		C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu	Other
GX15CrMo5	QT	420	-	630 760	16	27				0.12 0.19	0.80	0.50 0.80	0.025	0.025	4.00 6.00	0.45 0.65	-	0.05	0.30	
GX10CrMoV9-1	NT	415	-	585 760	16					0.08 0.12	0.20 0.50	0.30 0.60	0.030	0.010	8.0 9.5	0.85 1.05	0.40	0.18 0.25	-	Nb 0.060-0.10 N 0.030-0.070 Al 0.02 Ti 0.01

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)[C]								CHEMICAL COMPOSITION, % (maximum percent unless range given)										
Grade and UNS	Heat Treatment[A]	AT ROOM TEMPERATURE					AT LOW TEMPERATURE		Other Tests[D]	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu	Other
		Tensile Test				Impact Test	Impact Test													
		Yield Strength $R_{p0.2}$ MPa	Yield Strength $R_{p1.0}$ MPa	Tensile Strength R_m MPa	A %	KV J	KV J	°C												
																				Zr 0.01
GX15CrMo9-1	QT	415	-	620 795	18	27				0.12 0.19	1.00	0.35 0.65	0.030	0.030	8.00 10.00	0.90 1.20	0.40	0.05	0.30	
GX8CrNi12-1	QT1	355	-	540 690	18	45				0.10	0.40	0.50 0.80	0.030	0.020	11.50 12.50	0.50	0.80 1.50	0.08	0.30	
GX8CrNi12-1	QT2	500	-	600 800	16	40				0.10	0.40	0.50 0.80	0.030	0.020	11.50 12.50	0.50	0.80 1.50	0.08	0.30	
GX23CrMoV12-1	QT	540	-	740 880	15	27				0.20 0.26	0.40	0.50 0.80	0.030	0.020	11.30 12.20	1.00 1.20	1.00	0.25 0.35	0.30	W 0.50
GX3CrNi13-4	QT	500	-	700 900	15	50	27	-120		0.05	1.00	1.00	0.035	0.015	12.00 13.50	0.70	3.50 5.00	0.08	0.30	
GX4CrNi13-4	QT	550	-	760 960	15	50				0.06	1.00	1.00	0.035	0.025	12.00 13.50	0.70	3.50 5.00	0.08	0.30	
GX4CrNiMo16-5-1	QT	540	-	760 960	15	60				0.06	0.80	1.00	0.035	0.025	15.00 17.00	0.70 1.50	4.00 6.00	0.08	0.30	
GX2CrNiN19-11	AT	-	230	440 640	30		70	-196		0.030	1.50	2.00	0.035	0.030	18.00 20.00	-	9.00 12.00	-	0.50	0.12 ≤ N ≤ 0.20
GX5CrNi19-9	AT	-	200	440 640	30		60	-196												
GX6CrNiNb19-10	AT	-	200	440 640	25					0.07	1.50	1.50	0.040	0.030	18.00 20.00	-	8.00 11.00	-	0.50	
GX5CRNiNb19-11										0.07	1.50	1.50	0.040	0.030	18.00 20.00	-	9.00 12.00	-	0.50	8xC ≤ Nb ≤ 1.00
GX2CrNiMoN19-11-2	AT	-	230	440 640	30		70	-196		0.030	1.50	2.00	0.035	0.030	18.00 20.00	2.00 2.50	9.00 12.00	-	0.50	0.12 ≤ N ≤ 0.20
GX5CrNiMo19-11-2	AT	-	210	440 640	30		60	-196		0.07	1.50	1.50	0.040	0.030	18.00 20.00	2.00 2.50	9.00 12.00	-	0.50	
GX5CrNiMoNb19-11-2	AT	-	210	440 640	25					0.07	1.50	1.50	0.040	0.030	18.00 20.00	2.00 2.50	9.00 12.00	-	0.50	8xC ≤ Nb ≤ 1.00
GX2CrNiMoN22-5-3	AT	420	-	600 800	20		40	-40		0.030	1.00	2.00	0.035	0.025	21.00 23.00	2.50 3.50	4.50 6.50	-	0.50	0.12 ≤ N ≤ 0.20
GX2CrNiMoCuN26-5-3-3	AT	480	-	650 850	22		35	-70		0.030	1.00	1.50	0.035	0.025	25.00 27.00	2.50 3.50	5.00 7.00	-	2.75 3.50	0.12 ≤ N ≤ 0.22
GX2CrNiMoN26-7-4	AT	480	-	650 850	22		35	-70		0.030	1.00	1.00	0.035	0.025	25.00 27.00	3.00 5.00	6.00 8.00	-	1.30	0.12 ≤ N ≤ 0.22
GX2NiCrMo28-20-2	AT	-	190	430 630	30		60	-196		0.030	1.00	2.00	0.035	0.025	19.00 22.00	2.00 2.50	26.00 30.00	-	2.00	N ≤ 0.20

[A] The type of heat treatment is mandatory. N= normalized, QT= quenched and tempered, AT= solution annealed. Refer to the original specification for additional information on heat treatment requirements.

[B] Tempering is permitted.

[C] $R_{p0.2}$: 0.2% offset yield strength or 0.2% proof strength, $R_{p1.0}$: 1% proof strength (for austenitic stainless steel), R_m: tensile strength, A%: elongation after fracture on original gage length $L_o=5.65\sqrt{S_o}$ (where S_o is the original cross sectional area), KV: ISO V-notch impact strength

[D] Refer to the original specification for additional information on other tests at high temperatures.

[E] For each reduction of 0.01% carbon below the maximum specified, an increase of 0.04% manganese above the maximum specified will be permitted to a maximum of 1.40%.
[F] %Cr + %Mo + %Ni + %V + %Cu ≤ 1.00%

ISO 11972:2015 CORROSION-RESISTANT CAST STEELS FOR GENERAL APPLICATIONS

This International Standard specifies cast steels for general corrosion-resistant applications. The grades covered by this International Standard represent types of alloy steel castings suitable for broad ranges of application which are intended for a wide variety of corrosion applications.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)								
Grade	Heat Treatment[A]	Ruling Thickness mm	Tensile Strength R_m MPa	Yield Strength $R_{p0.2}$ MPa	A %	Other Tests Impact KV J	C	Si	Mn	P	S	Cr	Mo	Ni	Other
GX12Cr12	A&T	150	620	450	15	20	0.15	1.0	1.0	0.035	0.025	11.5 13.5	0.50	1.0	
GX7CrNiMo12-1	A&T	300	590	440	15	27	0.10	1.0	1.0	0.035	0.025	12.0 13.5	0.20 0.50	1.0 2.0	
GX4CrNi13-4 (QT1)	A&T	300	750	550	15	50	0.06	1.0	1.0	0.035	0.025	12.0 13.5	0.70	3.5 5.0	
GX4CrNi13-4 (QT2)	A&T	300	900	830	12	35	0.06	1.0	1.0	0.035	0.025	12.0 13.5	0.70	3.5 5.0	
GX4CrNiMo16-5-1	A&T	300	760	540	15	60	0.06	0.8	1.0	0.035	0.025	15.0 17.0	0.70 1.50	4.0 6.0	
GX2CrNi19-11	ST	150	440	185	30	80	0.03	1.5	2.0	0.035	0.025	18.0 20.0	-	9.0 12.0	N 0.20
GX2CrNiN19-11	ST	150	510	230[C]	30	80	0.03	1.5	1.5	0.040	0.030	18.0 20.0	-	9.0 12.0	N 0.12-0.20
GX5CrNi19-10	ST	150	440	175[C]	30	60	0.07	1.5	1.5	0.040	0.030	18.0 20.0	-	8.0 11.0	
GX5CrNiNb19-11	ST	150	440	175[C]	25	40	0.07	1.5	1.5	0.040	0.030	18.0 20.0	-	9.0 12.0	8xC ≤ Nb ≤ 1.00
GX2CrNiMo19-11-2	ST	150	440	195[C]	30	80	0.03	1.5	2.0	0.035	0.025	18.0 20.0	2.00 2.50	9.0 12.0	N 0.20
GX2CrNiMoN19-11-2	ST	150	510	230[C]	30	80	0.03	1.5	2.0	0.035	0.030	18.0 20.0	2.00 2.50	9.0 12.0	N 0.12-0.20
GX4CrNiMoN26-5-2	ST	150	600	420	20	30	0.05	1.0	2.0	0.035	0.025	25.0 27.0	1.30 2.00	4.5 6.5	N 0.12-0.20
GX5CrNiMo19-11-2	ST	150	440	185[C]	30	60	0.07	1.5	1.5	0.040	0.030	18.0 20.0	2.00 2.50	9.0 12.0	
GX5CrNiMoNb19-11-2	ST	150	440	185[C]	25	40	0.07	1.5	1.5	0.040	0.030	18.0 20.0	2.00 2.50	9.0 12.0	8xC ≤ Nb ≤ 1.00
GX2CrNiMo19-11-3	ST	150	440	180[C]	30	80	0.03	1.5	1.5	0.040	0.030	18.0 20.0	3.00 3.50	9.0 12.0	
GX2CrNiMoN19-11-3	ST	150	510	230[C]	30	80	0.03	1.5	1.5	0.040	0.030	18.0 20.0	3.00 3.50	9.0 12.0	N 0.10-0.20
GX2CrNiMoN22-5-3	ST	150	600	420	20	30	0.03	1.0	2.0	0.035	0.025	21.0 23.0	2.50 3.50	4.5 6.5	N 0.12-0.20

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)								
Grade	Heat Treatment[A]	Ruling Thickness mm	Tensile Strength R_m MPa	Yield Strength $R_{p0.2}$ MPa	A %	Other Tests: Impact KV J	C	Si	Mn	P	S	Cr	Mo	Ni	Other
GX2CrNiMoN25-7-3	ST	150	650	480	22	50	0.03	1.0	1.5	0.030	0.020	24.0 26.0	3.00 4.00	6.0 8.5	Cu 1.00 N 0.15-0.25 W 1.00
GX2CrNiMoN26-7-4	ST	150	650	480	22	50	0.03	1.0	1.0	0.035	0.025	25.0 27.0	3.00 5.00	6.0 8.0	N 0.12-0.22 Cu 1.30
GX5CrNiMo19-11-3	ST	150	440	205[C]	30	60	0.07	1.5	1.5	0.040	0.030	18.0 20.0	3.00 3.50	10.0 13.0	
GX2NiCrMoCuN25-20-6	ST	50	480	210	30	60	0.02	1.0	2.00	0.035	0.020	19.0 21.0	6.00 7.00	24.0 26.0	N 0.10-0.25 Cu 0.50-1.50
GX2CrNiMoCuN20-18-6	ST	50	500	260	35	50	0.02	1.0	1.20	0.030	0.010	19.5 20.5	6.00 7.00	17.5 19.5	N 0.18-0.24 Cu 0.50-1.00
GX2CrNiMoCuN25-6-3-3	ST	150	650	480	22	50	0.03	1.0	1.50	0.035	0.025	24.5 26.5	2.50 3.50	5.0 7.0	N 0.12-0.22 Cu 2.75-3.50
GX3CrNiMoCuN26-6-3	ST	200	650	480	22	60	0.03	1.0	2.00	0.030	0.020	24.5 26.5	2.50 3.50	5.5 7.0	N 0.12-0.25 Cu 0.80-1.30
GX2CrNiMoN25-6-3	ST	150	650	480	22	50	0.03	1.0	2.0	0.035	0.025	24.5 26.5	2.50 3.50	5.5 7.0	N 0.12-0.25

[A] A&T= austenitize, air cool, & temper; ST = solution treat. See original specifications for additional information.
[B] $R_{p0.2}$: 0.2% offset yield strength or 0.2% proof strength, R_m: tensile strength, A%: elongation after fracture on original gage length $L_o=5.65\sqrt{S_o}$ (where S_o is the original cross sectional area), KV: ISO V-notch impact strength
[C] The minimum $R_{p1.0}$ value is 25 MPa higher.

ISO 11973:2015 HEAT-RESISTANT CAST STEELS FOR GENERAL APPLICATIONS

This International Standard covers cast steels for heat resistant service.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)								
Grade	Heat Treatment[A]	Tensile Strength R_m MPa	Yield Strength $R_{p0.2}$ MPa	A %	Other Tests: Hardness HBW	Other Tests: Maximum Use Temperature °C[C]	C	Si	Mn	P	S	Cr	Mo	Ni	Others
GX30CrSi7	A or as-cast					750	0.20 0.35	1.0 2.5	0.5 1.0	0.035	0.030	6.0 8.0	0.15	0.5	
GX40CrSi13	A				300[D]	850	0.30 0.50	1.0 2.5	1.0	0.040	0.030	12.0 14.0	0.15	0.5	
GX40CrSi17	A				300[D]	900	0.30 0.50	1.0 2.5	1.0	0.040	0.030	16.0 19.0	0.50	1.0	
GX40CrSi24	A				300[D]	1050	0.30 0.50	1.0 2.5	1.0	0.040	0.030	23.0 26.0	0.50	1.0	
GX40CrSi28	A				320[D]	1100	0.30 0.50	1.0 2.5	1.0	0.040	0.030	27.0 30.0	0.50	1.0	

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)								
					Other Tests										
Grade	Heat Treatment[A]	Tensile Strength R_m MPa	Yield Strength $R_{p0.2}$ MPa	A %	Hardness HBW	Maximum Use Temperature °C[C]	C	Si	Mn	P	S	Cr	Mo	Ni	Others
GX130CrSi29	A				400[D]	1100	1.20 1.40	1.0 2.5	0.5 1.0	0.035	0.030	27.0 30.0	0.50	1.0	
GX25CrNiSi18-9	as-cast	450	230	15		900	0.15 0.35	0.5 2.5	2.0	0.040	0.030	17.0 19.0	0.50	8.0 10.0	
GX25CrNiSi20-14	as-cast	450	230	10		900	0.15 0.35	0.5 2.5	2.0	0.040	0.030	19.0 21.0	0.50	13.0 15.0	
GX40CrNiSi22-10	as-cast	450	230	8		950	0.30 0.50	1.0 2.5	2.0	0.040	0.030	21.0 23.0	0.50	9.0 11.0	
GX40CrNiSiNb24-24	as-cast	400	220	4		1050	0.30 0.50	1.0 2.5	2.0	0.040	0.030	23.0 25.0	0.50	23.0 25.0	Nb 0.80-1.80
GX40CrNiSi25-12	as-cast	450	220	6		1050	0.30 0.50	1.0 2.5	0.5 2.0	0.040	0.030	24.0 27.0	0.50	11.0 14.0	
GX40CrNiSi25-20	as-cast	450	220	6		1100	0.30 0.50	1.0 2.5	2.0	0.040	0.030	24.0 27.0	0.50	19.0 22.0	
GX40CrNiSi27-4	as-cast	400	250	3	400[E]	1100	0.30 0.50	1.0 2.5	1.5	0.040	0.030	25.0 28.0	0.50	3.0 6.0	
GX40NiCrCo20-20-20	as-cast	400	320	6		1150	0.35 0.60	1.0	2.0	0.040	0.030	19.0 22.0	2.50 3.00	18.0 22.0	Co 18.5-22.0 Nb 0.75-1.25 W 2.0-3.0
GX10NiCrNb32-20	as-cast	440	170	20		1000	0.05 0.12	0.5 1.5	2.0	0.040	0.030	19.0 21.0	0.50	31.0 33.0	Nb 0.50-1.50
GX40NiCrSi35-17	as-cast	420	220	6		980	0.30 0.50	1.0 2.5	2.0	0.040	0.030	16.0 18.0	0.50	34.0 36.0	
GX40NiCrSi35-26	as-cast	440	220	6		1050	0.30 0.50	1.0 2.5	2.0	0.040	0.030	24.0 27.0	0.50	33.0 36.0	
GX40NiCrSiNb35-26	as-cast	440	220	4		1050	0.30 0.50	1.0 2.5	2.0	0.040	0.030	24.0 27.0	0.50	33.0 36.0	Nb 0.80-1.80
GX40NiCrSi38-19	as-cast	420	220	6		1050	0.30 0.50	1.0 2.5	2.0	0.040	0.030	18.0 21.0	0.50	36.0 39.0	
GX40NiCrSiNb38-19	as-cast	420	220	4		1000	0.30 0.50	1.0 2.5	2.0	0.040	0.030	18.0 21.0	0.50	36.0 39.0	Nb 1.20-1.80
G-NiCr28W	as-cast	400	220	3		1200	0.35 0.55	1.0 2.0	1.5	0.040	0.030	27.0 30.0	0.50	47.0 50.0	W 4.0-6.0
G-NiCr50Nb	as-cast	540	230	8		1050	0.10	1.0	1.0	0.020	0.020	48.0 52.0	0.50	balance	Fe 1.00 N 0.16 Nb 1.00-1.80
G-NiCr19	as-cast	440	220	5		1100	0.40 0.60	0.5 2.0	1.5	0.040	0.030	16.0 21.0	0.50	50.0 55.0	
G-NiCr15	as-cast	400	200	3		1100	0.35 0.65	2.0	1.3	0.040	0.030	13.0 19.0	-	64.0 69.0	
GX50NiCrCoW35-25-15-5	as-cast	480	270	5		1200	0.45 0.55	1.0 2.0	1.0	0.040	0.030	24.0 26.0	-	33.0 37.0	W 4.0-6.0 Co 14.0-16.0
G-CoCr28	as-cast	[F]	[F]	[F]		1200	0.05 0.25	0.5 1.5	1.5	0.040	0.030	27.0 30.0	0.50	4.0	Co 48.0-52.0 Fe balance

[A] A= anneal. See original specifications for additional information

[B] $R_{p0.2}$: 0.2% offset yield strength or 0.2% proof strength, R_m: tensile strength, A%: elongation after fracture on original gage length $L_o=5.65\sqrt{S_o}$ (where S_o is the original cross sectional area)

[C] Maximum use temperature depends upon the actual use conditions and these values are being given only to aid the user. These are given for oxidizing environments. The actual alloy composition will also affect performance.
[D] Maximum hardness in annealed condition – castings may also be supplied in the "as cast" condition, in which case hardness limits will not apply.
[E] Maximum HBW
[F] Properties as agreed upon by manufacturer and purchaser.

ISO 12725:1997 NICKEL AND NICKEL ALLOY CASTINGS

This International Standard specifies requirements for nickel and nickel alloy castings. The grades covered represent types of alloys suitable for a broad range of application in a wide variety of corrosive and high temperature environments.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)				CHEMICAL COMPOSITION, % (maximum percent unless range given)[C]														
Grade and UNS	Heat Treatment[A]	Tensile Strength R_m MPa	Yield Strength $R_{p0.2}$ MPa	A %	Other Tests Hardness HBN	C	Co	Cr	Cu	Fe	Mn	Mo	Ni	P	S	Si	W	Nb	V	Nb+Ta
C-Ni99, HC	as cast	345 545	125	10		1.00			1.25	3.0	1.50		95.0	0.030	0.030	2.00				
C-NiCu30Si	as cast	450 650	205	25		0.35			26.0 33.0	3.5	1.50		balance	0.030	0.030	2.00		0.5		
C-NiCu30	as cast	450	170	25		0.35			26.0 33.0	3.5	1.50		balance	0.030	0.030	1.25		0.5		
C-NiCu30Si3	as cast	690 890	415	10		0.30			27.0 33.0	3.5	1.50		balance	0.030	0.030	2.7 3.7				
C-NiCu30Nb2Si2	as cast	450	225	25		0.30			26.0 33.0	0.5	1.50		balance	0.030	0.030	1.0 2.0		1.0 3.0		
C-NiMo31	WQ	525 725	275	6		0.03		1.0		3.0	1.00	30.0 33.0	balance	0.030	0.030	1.00				
C-NiMo30Fe5	WQ	525 725	275	20		0.05		1.0		4.0 6.0	1.00	26.0 33.0	balance	0.030	0.030	1.00			0.20 0.60	
C-NiCr22Fe20Mo7Cu2	WQ	550 750	220	30		0.02	5.0	21.5 23.5	1.5 2.5	18.0 21.0	1.00	6.0 8.0	balance	0.025	0.030	1.00	1.50			0.5
C-NiCr22Mo9Nb4	WQ	485 685	275	25		0.06		20.0 23.0		5.0	1.00	8.0 10.0	balance	0.030	0.030	1.00		3.2 4.5		
C-NiCr16Mo16	WQ	495 695	275	20		0.02		15.0 17.5		2.0	1.00	15.0 17.5	balance	0.030	0.030	0.80	1.00			
C-NiMo17Cr16Fe6W4	WQ	495 695	275	4		0.06		15.5 17.5		4.5 7.5	1.00	16.0 18.0	balance	0.030	0.030	1.00	3.8 5.3		0.20 0.40	
C-NiCr21Mo14Fe4W3	WQ	550	280	30		0.02		20.0 22.5		2.0 6.0	1.00	12.5 14.5	balance	0.025	0.025	0.80	2.5 3.5		0.35	
C-NiCr18Mo18	WQ	495 695	275	25		0.03		17.0 20.0		3.0	1.00	17.0 20.0	balance	0.030	0.030	1.00				
C-NiCr15Fe	WQ	485 685	195	30		0.40		14.0 17.0		11.0	1.50		balance	0.030	0.030	3.00				
C-NiFe30Cr20Mo3CuNb	AC	450 650	170	25		0.05		19.5 23.5	1.5 3.0	28.0 32.0	1.00	2.5 3.5	balance	0.030	0.030	0.75 1.20		0.70 1.00		
C-NiSi9Cu3	AC				300	0.12		1.0	2.4 4.0		1.50		balance	0.030	0.030	8.5 10.0				

[A] See original specification for full details.
[B] $R_{p0.2}$: 0.2% offset yield strength or 0.2% proof strength, R_m: tensile strength, A%: elongation after fracture on original gage length $L_o=5.65\sqrt{S_o}$ (where S_o is the original cross sectional area)

[C] Single values are maximum limits, except for nickel for which single values are minimum.

ISO 19960:2015 CAST STEELS AND ALLOYS WITH SPECIAL PHYSICAL PROPERTIES

This International Standard specifies cast steel and alloy grades with special physical properties. The cast steel and alloy grades covered by this International Standard are used in applications which require low linear thermal expansion, or low ferromagnetic responses, or low galling properties.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)				CHEMICAL COMPOSITION, % (maximum percent unless range given)										
Grade	Heat Treatment[A]	Tensile Strength R_m MPa	Yield Strength $R_{p.02}$ MPa	A %	Other Tests Impact Test KV J	C	Si	Mn	P	S	Cr	Mo	Ni	N	Co	Others
GX12CrNi18-11[C]	ST	440 590	195	20	80	0.15	1.00	2.0	0.045	0.030	16.5 18.5	0.75	10.0 12.0			
GX2CrNiN18-13[C]	ST	440 640	210	30	115	0.030	1.00	2.0	0.035	0.020	16.5 18.5	-	12.0 14.0	0.10 0.20		
GX2CrNiMoN18-14[C]	ST	490 690	240	30	80	0.030	1.00	2.0	0.035	0.020	16.5 18.5	2.5 3.0	13.0 15.0	0.15 0.25		
GX2CrNiN19-11[C]	ST	≥ 440	180	30		0.030	1.5	2.0	0.035	0.020	18.0 20.0	1.0	10.0 12.0	0.10 0.20		
GX3CrNiMnSi17-9-8[C]	ST	≥ 580	290	24		0.05	3.5 4.5	7.0 9.0	0.045	0.030	16.0 18.0	1.0	8.0 9.0	0.08 0.18		
GX4CrNiMnN22-12-5[C]	ST	≥ 580	290	24		0.06	1.0	4.0 6.0	0.040	0.030	20.5 23.5	1.50 3.00	11.5 13.5	0.20 0.40		Nb 0.10-0.30 V 0.10-0.30
GX2CrNiMnMoNNb21-16-5-3[C]	ST	570 800	315	20	65	0.030	1.0	4.0 6.0	0.025	0.010	20.0 21.5	3.0 3.5	15.0 17.0	0.20 0.35		Nb 0.25
GX3NiCo32[D]	ST + T					0.05	0.50	0.6	0.030	0.02	0.25	1.0	30.5 33.5		4.0 6.5	Al 0.10
GX1NiCo29-17[D]	ST + T					0.05	0.50	0.5	0.030	0.02	0.25	1.0	28.0 30.0		16.0 18.0	
GX3Ni36[D]	ST + T	≥ 395	275	28		0.05	0.5	0.5	0.030	0.02	0.25	1.0	35.0 37.0			
GX5NiS36[D]	ST + T	≥ 395	275	25		0.05	0.5	0.5	0.030	0.10 0.20	0.25	1.0	35.0 37.0			
G-NiCr13SnBiMo[E]	as cast					0.05	0.5	1.5	0.030	0.030	11.0 14.0	2.0 3.5	balance			Fe 2.0 Bi 3.0-5.0 Sn 3.0-5.0

[A] ST=solution treat; ST+T = solution treat + temper. See original specification for more details.
[B] $R_{p0.2}$: 0.2% offset yield strength or 0.2% proof strength, R_m: tensile strength, A%: elongation after fracture on original gage length $L_o=5.65\sqrt{S_o}$ (where S_o is the original cross sectional area), KV: ISO V-notch impact strength
[C] Low ferromagnetic response grades with magnetic permeability, $\mu_r \leq 1.01$
[D] For low linear-expansion grades, see original specification Table 4.
[E] Low galling grade

Lloyd's Register Rule 2.4.8 – 16 STEEL CASTINGS PART 2, CHAPTER 4, SECTION 8: AUSTENITIC STAINLESS STEEL CASTINGS

This Section gives the requirements for castings in austenitic stainless steels for piping systems in ships for liquefied gases, and in bulk chemical tankers.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)								
Grade	Heat Treatment[A]	Tensile Strength MPa	Yield Strength $R_{p1.0}$ MPa	Elong %	Red A %	Other Tests[B] Impact Test J	Impact Test °C	C	Si	Mn	S	P	Cr	Mo	Ni	Others
304L	ST	430	215	26	40	41	-196	0.03	0.20 1.5	0.50 2.0	0.040	0.040	17.0 21.0	-	8.0 12.0	-
304	ST	480	220	26	40	41	-196	0.08	0.20 1.5	0.50 2.0	0.040	0.040	17.0 21.0	-	8.0 12.0	-
316L	ST	430	215	26	40	41	-196	0.03	0.20 1.5	0.50 2.0	0.040	0.040	17.0 21.0	2.0 3.0	9.0 13.0	-
316	ST	480	220	26	40	41	-196	0.08	0.20 1.5	0.50 2.0	0.040	0.040	17.0 21.0	2.0 3.0	9.0 13.0	-
317	ST	480	240	26	40	41	-196	0.08	0.20 1.5	0.50 2.0	0.040	0.040	17.0 21.0	3.0 4.0	9.0 12.0	-
347	ST	480	215	22	35	41	-196	0.06	0.20 1.5	0.50 2.0	0.040	0.040	17.0 21.0	-	9.0 12.0	Nb ≥ 8 x C ≤ 0.90 [D]
J92205[C]	ST	600	420	20	35	41	0	0.03	1.00	1.50	0.020	0.035	21.0 23.0	2.5 3.5	4.5 6.5	N 0.15 – 0.20 Cu 1.00

[A] See original specification for full details on heat treatment.
[B] See original specification for full details such as non-destructive examination and intercrystalline corrosion tests.
[C] The grade UNS J92205 is the cast equivalent of UNS S31803.
[D] When guaranteed impact values at low temperature are not required, the maximum carbon content may be 0.08% and the maximum niobium may be 1.00%

MIL-C-24707/3 – 89 CASTINGS, FERROUS, CORROSION-RESISTANT, AUSTENITIC, CHROMIUM-NICKEL

This specification covers austenitic chromium-nickel alloy castings for corrosion-resistant and low magnetic permeability applications.

PREVIOUS SPECIFICATION MIL specification (class)	REPLACEMENT SPECIFICATION MIL-C-24707/3 ASTM specification (grade)
MIL-S-17509 (I)	A 744 (CF8)
MIL-S-17509 (II)	A 744 (CF8C)
MIL-S-17509 (III)	A 744 (CF8M)
MIL-S-867 (I)	A 744 (CF8)
MIL-S-867 (II)	A 744 (CF8C)
MIL-S-867 (III)	A 744 (CF8M)

Additional notes for specification are as follows; see original military specification booklet for further information, including Quality Assurance Provisions. Two different levels may be specified; level I has no magnetic restrictions and level II has low relative magnetic permeability. For all grades, supplementary requirements SZ1 (intergranular corrosion test) and SZ2 (tension test) of ASTM A 744 shall be mandatory. When type II is specified, the relative magnetic permeability of the castings shall not exceed 1.3 for first article and 1.6 for quality conformance tests; unless otherwise specified, the field strength shall be 0.5 oersteds for first article testing. Heat treat casting per ASTM A 744 except the minimum temperature shall be 1950°F. After all cleaning and machining, the casting shall be passivated in accordance with QQ-P-35.

MIL-C-24707/6 – 89

CASTINGS, FERROUS, CHROMIUM STEEL, FOR PRESSURE-CONTAINING PARTS SUITABLE FOR HIGH-TEMPERATURE SERVICE

This specification covers 12% chromium steel castings for high temperatures and for impact at low temperatures.

PREVIOUS SPECIFICATION MIL specification (class)	REPLACEMENT SPECIFICATION MIL-C-24707/6 ASTM specification (grade)
MIL-S-16993 (1)	A 217 (CA15)
MIL-S-16993 (2)	A 487 (CA15M, class A)

Additional notes for specification are as follows; see original military specification booklet for further information, including Quality Assurance Provisions. ASTM A 757 grade E3N castings are intended for use where either CA-15 or CA-15M is used; grade E3N has better weldability, corrosion and erosion resistance, low temperature properties such as notch toughness, and improved soundness and casting characteristics. CA15M castings shall be normalized and tempered only with a tempering temperature not less than 1100°F; a liquid quench shall not be used without the permission of the Command or agency concerned.

SUMMARY OF MATERIAL SPECIFICATIONS FOR CENTRIFUGALLY CAST STEELS

Below is a list of centrifugally cast steel specifications, with summary details on the following pages. Note that the values given in the summary of the specifications are stated with either U.S. Conventional Units (USCS) or Metric (SI) units, and are to be regarded separately. Units given in brackets are SI units. The values stated in each system are not exact equivalents (soft conversion); therefore, each system must be used independently of the other. Combining values from the two systems, by using conversion equations (hard conversion), may result in nonconformance with the specification. Also note that the values in the table are given in a minimum over maximum format. This means that if the value is a minimum it will be listed in the upper portion of the specification's table row and in the lower portion of the row if it is a maximum value. Finally, note that tables and their footnotes may be split across two or more pages.

ASTM A 426/A 426M – 13	Centrifugally Cast Ferritic Alloy Steel Pipe for High-Temperature Service
ASTM A 451/A 451M – 14	Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service
ASTM A 608/A 608M – 14	Centrifugally Cast Iron-Chromium-Nickel High-Alloy Tubing for Pressure Application at High Temperatures
ASTM A 660/A 660M – 11	Centrifugally Cast Carbon Steel Pipe for High Temperature Service
ASTM A 872/A 872M – 14	Centrifugally Cast Ferritic/Austenitic Stainless Steel Pipe for Corrosive Environments
ISO 13583-2:2015	Centrifugally Cast Steel and Alloy Products: Heat Resistant Materials

ASTM A 426/A 426M – 13 CENTRIFUGALLY CAST FERRITIC ALLOY STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

This specification covers centrifugally cast alloy steel pipe intended for use in high-temperature, high-pressure service.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)							CHEMICAL COMPOSITION, %[D] (maximum percent unless range given)						
		Tensile Strength		Yield Strength				Other Tests[C]							
Grade and UNS	Heat Treatment[A]	ksi	MPa	ksi	MPa	Elong %[B]	Red A %	Hardness (max) HBW	C	Mn	P	S	Si	Cr	Mo
CP1 J12521	NT or QT	65	450	35	240	24	35	201	0.25	0.30 0.80	0.030	0.025	0.10 0.50	…	0.44 0.65
CP2 J11547	NT or QT	60	415	30	205	22	35	201	0.10 0.20	0.30 0.61	0.030	0.025	0.10 0.50	0.50 0.81	0.44 0.65
CP5 J42045	NT or QT	90	620	60	415	18	35	225	0.20	0.30 0.70	0.030	0.025	0.75	4.00 6.50	0.45 0.65
CP5b J51545	NT or QT	60	415	30	205	22	35	225	0.15	0.30 0.60	0.030	0.025	1.00 2.00	4.00 6.00	0.45 0.65
CP9 J82090	NT or QT	90	620	60	415	18	35	225	0.20	0.30 0.65	0.030	0.025	0.25 1.00	8.00 10.00	0.90 1.20
CP11 J12072	NT or QT	70	485	40	275	20	35	201	0.05 0.20	0.30 0.80	0.030	0.025	0.60	1.00 1.50	0.44 0.65
CP12 J11562	NT or QT	60	415	30	205	22	35	201	0.05 0.15	0.30 0.61	0.030	0.025	0.50	0.80 1.25	0.44 0.65
CP15 J11522	NT or QT	60	415	30	205	22	35	201	0.15	0.30 0.60	0.030	0.025	1.15 1.65	…	0.44 0.65
CP21 J31545	NT or QT	60	415	30	205	22	35	201	0.05 0.15	0.30 0.60	0.030	0.025	0.50	2.65 3.35	0.80 1.06
CP22 J21890	NT or QT	70	485	40	275	20	35	201	0.05 0.15	0.30 0.70	0.030	0.025	0.60	2.00 2.75	0.90 1.20
CPCA15 J91150	NT or QT	90	620	65	450	18	30	225	0.15	1.00	0.030	0.025	1.50	11.5 14.0	0.50

[A] See original specification for additional details on heat treatment.
[B] Elongation in 2 in. [50 mm] using a standard round specimen, in either the transverse or longitudinal direction.
[C] Hydrostatic test – see original specification for further details.
[D] Where ellipses (…) appear in this table, there is no requirement.

ASTM A 451/A 451M – 14 CENTRIFUGALLY CAST AUSTENITIC STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

This specification covers austenitic alloy steel pipe for use in high-temperature, corrosive, or nuclear pressure service.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)										
		Tensile Strength		Yield Strength			Other Tests											
Grade and UNS	Heat Treatment[A]	ksi	MPa	ksi	MPa	Elong %	Hydrostatic Test[C]	C	Mn	P	S	Si	Ni	Cr	Mo	Cb	Ta	N
CPF3 J92500	ST	70	485	30	205	35		0.03	1.50	0.040	0.040	2.00	8.0 12.0	17.0 21.0	…	…		

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)						CHEMICAL COMPOSITION, % (maximum percent unless range given)										
Grade and UNS	Heat Treatment[A]	Tensile Strength		Yield Strength		Elong %	Other Tests	C	Mn	P	S	Si	Ni	Cr	Mo	Cb	Ta	N
		ksi	MPa	ksi	MPa		Hydrostatic Test[C]											
CPF3A J92500	ST	77[B]	535[B]	35[B]	240[B]	35[B]		0.03	1.50	0.040	0.040	2.00	8.0 12.0	17.0 21.0	…	…		
CPF8 J92600	ST	70	485	30	205	35		0.08	1.50	0.040	0.040	2.00	8.0 11.0	18.0 21.0	…	…		
CPF8A J92600	ST	77[B]	535[B]	35[B]	240[B]	35[B]		0.08	1.50	0.040	0.040	2.00	8.0 11.0	18.0 21.0	…	…	…	…
CPF3M J92800	ST	70	485	30	205	30		0.03	1.50	0.040	0.040	1.50	9.0 13.0	17.0 21.0	2.0 3.0	…	…	…
CPF8M J92804	ST	70	485	30	205	30		0.08	1.50	0.040	0.040	1.50	9.0 12.0	18.0 21.0	2.0 3.0	…	…	…
CPF10MC	ST	70	485	30	205	20		0.10	1.50	0.040	0.040	1.50	13.0 16.0	15.0 18.0	1.75 2.25	1.2 max 10 x C min[E]	…[E]	…
CPF8C J92710	ST	70	485	30	205	30		0.08	1.50	0.040	0.040	2.00	9.0 12.0	18.0 21.0	…	1 max 8 x C min[E]	…[E]	…
CPF8C (Ta max)[D]	ST	70	485	30	205	30		0.08	1.50	0.040	0.040	2.00	9.0 12.0	18.0 21.0	…	1 max 8 x C min	0.10	…
CPH8 J93400	ST	65	448	28	195	30		0.08	1.50	0.040	0.040	1.50	12.0 15.0	22.0 26.0	…	…	…	…
CPH20 or CPH10 J93402	ST	70	485	30	205	30		0.20[F]	1.50	0.040	0.040	2.00	12.0 15.0	22.0 26.0	…	…	…	…
CPK20 J94202	ST	65	448	28	195	30		0.20	1.50	0.040	0.040	1.75	19.0 22.0	23.0 27.0	…	…	…	…
CPE20N J92802	ST	80	550	40	275	30		0.20	1.50	0.040	0.040	1.50	8.0 11.0	23.0 26.0	…	…	…	0.08 0.20

[A] See original specification for additional details on heat treatment.
[B] The properties shown are obtained by adjusting the composition within the limits shown in the table to obtain a ferrite-austenite ratio that will result in the higher ultimate and yield strengths indicated. A lowering of impact values may develop in these materials when exposed to service temperature above 800°F [425°C].
[C] Hydrostatic test – see original specification for further details.
[D] No designation as yet assigned by ASTM or SFSA.
[E] Grades CPF10MC and CPF8C may have a columbium plus tantalum content maximum of 1.35%.
[F] By agreement between the manufacturer and the purchaser, the carbon content of Grade CPH20 may be restricted to 0.10% max. When so agreed, the grade designation shall be CPH10.

ASTM A 608/A 608M – 14 CENTRIFUGALLY CAST IRON-CHROMIUM-NICKEL HIGH-ALLOY TUBING FOR PRESSURE APPLICATION AT HIGH TEMPERATURES

This specification covers iron-chromium-nickel, high-alloy tubes made by the centrifugal casting process intended for use under pressure at high temperatures.

GRADE & HEAT TREATMENT		CHEMICAL COMPOSITION, % (maximum percent unless range given)[A]								
Grade and UNS	Heat Treatment	C	Mn	Si	Cr	Ni	P	S	Mo	Nb
HC30 J92613	as cast	0.25 0.35	0.5 1.0	0.50 2.00	26 30	4.0	0.04	0.04	0.50	…
HD50 J92615	as cast	0.45 0.55	1.50	0.50 2.00	26 30	4 7	0.04	0.04	0.50	…
HE35 J93413	as cast	0.30 0.40	1.50	0.50 2.00	26 30	8 11	0.04	0.04	0.50	…
HF30 J92803	as cast	0.25 0.35	1.50	0.50 2.00	19 23	9 12	0.04	0.04	0.50	…
HH30 J93513	as cast	0.25 0.35	1.50	0.50 2.00	24 28	11 14	0.04	0.04	0.50	…
HH33[B] J93633	as cast	0.28 0.38	1.50	0.50 2.00	24 26	12 14	0.04	0.04	0.50	…
HI35 J94613	as cast	0.30 0.40	1.50	0.50 2.00	26 30	14 18	0.04	0.04	0.50	…
HK30 J94203	as cast	0.25 0.35	1.50	0.50 2.00	23 27	19 22	0.04	0.04	0.50	…
HK40 J94204	as cast	0.35 0.45	1.50	0.50 2.00	23 27	19 22	0.04	0.04	0.50	…
HL30 N08613	as cast	0.25 0.35	1.50	0.50 2.00	28 32	18 22	0.04	0.04	0.50	…
HL40 N08614	as cast	0.35 0.45	1.50	0.50 2.00	28 32	18 22	0.04	0.04	0.50	…
HN40	as cast	0.35 0.45	1.50	0.50 2.00	19 23	23 27	0.04	0.04	0.50	…
HPNb N28701	as cast	0.38 0.45	0.50 1.50	0.50 1.50	24 27	34 37	0.03	0.03	0.50	0.5 1.5
HPNbS N28702	as cast	0.38 0.45	0.50 1.50	0.50 2.00	24 27	34 37	0.03	0.03	0.50	0.5 1.5
HT50 N08050	as cast	0.40 0.60	1.50	0.50 2.00	15 19	33 37	0.04	0.04	0.50	…
HU50 N08005	as cast	0.40 0.60	1.50	0.50 2.00	17 21	37 41	0.04	0.04	0.50	…
HW50 N08006	as cast	0.40 0.60	1.50	0.50 2.00	10 14	58 62	0.04	0.04	0.50	…
HX50 N06050	as cast	0.40 0.60	1.50	0.50 2.00	15 19	64 68	0.04	0.04	0.50	…

[A] Where ellipses (…) appear in this table there is no requirement, and the element need not be analyzed or reported.
[B] Manufacturing control should ensure that this composition contain a minimal amount of ferrite

ASTM A 660/A 660M – 11 CENTRIFUGALLY CAST CARBON STEEL PIPE FOR HIGH TEMPERATURE SERVICE

This specification covers carbon steel pipe made by the centrifugal casting process intended for use in high-temperature, high-pressure service. Pipe ordered under this specification shall be suitable for fusion welding, bending, and other forming operations.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES (minimum unless range given)							CHEMICAL COMPOSITION, % (maximum percent unless range given)				
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong %	Red A %	Other Tests[B]	C	Mn	P	S	Si
WCA J02504		60	415	30	210	24	35		0.25[C]	0.70[C]	0.035	0.035	0.60
WCB J03003		70	485	36	250	22	35		0.30	1.00	0.035	0.035	0.60
WCC J02505		70	485	40	275	22	35		0.25[D]	1.20[D]	0.035	0.035	0.60

[A] Heat treatment per design and chemical composition.
[B] Hydrostatic and flattening tests – see original specification for further details.
[C] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted to a maximum of 1.10%
[D] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted to a maximum of 1.40%

ASTM A 872/A 872M – 14 CENTRIFUGALLY CAST FERRITIC/AUSTENITIC STAINLESS STEEL PIPE FOR CORROSIVE ENVIRONMENTS

This specification covers centrifugally cast ferritic/austenitic steel pipe intended for general corrosive service. These steels are susceptible to embrittlement if used for prolonged periods at elevated temperatures.

GRADE & HEAT TREATMENT		MECHANICAL PROPERTIES[B] (minimum unless range given)						CHEMICAL COMPOSITION, %[B] (maximum percent unless range given)										
Grade and UNS	Heat Treatment[A]	Tensile Strength ksi	Tensile Strength MPa	Yield Strength ksi	Yield Strength MPa	Elong %	Other Tests Hardness (max) HBW [HRC]	C	Mn	P	S	Si	Ni	Cr	Mo	N	Cu	Co
J93183	WQ	90	620	65	420	25	290 [30.5]	0.030	2.0	0.040	0.030	2.0	4.00 6.00	20.0 23.0	2.00 4.00	0.08 0.25	1.00	0.50 1.50
J93550	WQ	90	620	65	420	20	297 [31.5]	0.030	2.0	0.040	0.030	2.0	5.00 8.00	23.0 26.0	2.00 4.00	0.08 0.25	1.00	0.50 1.50
CD4MCuMN J94300	WQ	110	760	70	480	20	…	0.04	0.50 1.50	0.04	0.04	1.10	4.5 6.0	24.5 26.5	2.5 4.0	0.18 0.26	1.3 3.0	…

[A] See original specification for additional details on heat treatment.
[B] Where ellipses (…) appear in this table there is no requirement, and the element need not be analyzed or reported.

ISO 13583-2:2015 CENTRIFUGALLY CAST STEEL AND ALLOY PRODUCTS: HEAT-RESISTANT MATERIALS

This International Standard specifies cast steel and nickel alloy grades for elevated temperature service products manufactured by centrifugal casting.

GRADE	MECHANICAL PROPERTIES[A] (minimum unless range given)					CHEMICAL COMPOSITION, % (maximum percent unless range given)											
	Tensile Strength R_m MPa	Yield Strength $R_{p0.2}$ MPa	A %	Other Tests 100 hr Rupture Test Test Temperature °C	Other Tests 100 hr Rupture Test Stress MPa	C	Si	Mn	P	S	Cr	Ni	Mo	Nb	W	Co	Others
GX25CrNiSi18-9	450	230	15	800	60	0.15 0.35	0.5 2.5	2.0	0.040	0.030	17.0 19.0	8.0 10.0	0.50				
GX40CrNiSi25-12	450	220	10	900	34	0.30 0.50	1.0 2.5	2.0	0.040	0.030	24.0 27.0	11.0 14.0	0.50				
GX40CrNiSi25-20	450	220	8	900	47	0.30 0.50	1.0 2.5	2.0	0.040	0.030	24.0 27.0	19.0 22.0	0.50				
GX40CrNiSiNb24-24	450	220	10	900	48	0.30 0.50	1.0 2.5	2.0	0.040	0.030	23.0 25.0	23.0 25.0	0.50	0.80 1.80			
GX10NiCrSiNb32-20	440	180	20	800	84	0.050 0.15	0.5 1.5	2.0	0.040	0.030	19.0 21.0	31.0 33.0	0.50	0.50 1.50			
GX40NiCrSi38-19	420	220	6	900	34	0.30 0.50	1.0 2.5	2.0	0.040	0.030	18.0 21.0	36.0 39.0	0.50				
GX12NiCrSiNb35-26	440	175	20	800	70	0.08 0.15	0.5 1.5	0.5 1.5	0.030	0.030	24.0 27.0	34.0 37.0	0.50	0.60 1.30			
GX40NiCrSiNb35-26	440	220	4	900	49	0.30 0.50	1.0 2.5	2.0	0.040	0.030	24.0 27.0	33.0 36.0	0.50	0.80 1.80			
GX42NiCrSiNbTi35-25	450	220	8	950	42	0.38 0.48	1.5 2.5	0.5 1.5	0.030	0.030	24.0 27.0	34.0 37.0	0.50	0.60 1.80			Ti 0.06 min.[B] Addition required
GX42NiCrWSi35-25-5	450	220	4	950	35	0.38 0.45	1.0 2.0	0.5 1.5	0.030	0.030	24.0 27.0	34.0 37.0	0.50		4.0 6.0		
GX42NiCrSiNbTi45-35	480	270	5	1050	21	0.38 0.45	1.0 2.0	0.5 1.5	0.030	0.030	33.0 36.0	44.0 47.0	0.50	0.50 1.50			Ti 0.06 min.[B] Addition required
GX50NiCrCoW35-25-15-5	450	250	5	950	40	0.45 0.55	1.0 2.0	1.0	0.040	0.030	24.0 26.0	33.0 37.0	0.50		4.0 6.0	14.0 16.0	
G-NiCr28W	440	240	3	1050	20	0.35 0.55	1.0 2.0	1.5	0.040	0.030	27.0 30.0	47.0 50.0	0.50		4.0 6.0		Fe balance
G-NiCr28WCo	400	220	5	1050	20	0.40 0.55	1.0 2.0	0.5 1.5	0.030	0.030	27.0 30.0	47.0 50.0	0.50		4.0 6.0	2.5 3.5	
G-NiCr50Nb	540	230	8	900	60	0.10	1.0	0.5	0.020	0.020	48.0 52.0	balance	0.50	1.00 1.80			N 0.16 Fe 1.0

[A] $R_{p0.2}$: 0.2% offset yield strength or 0.2% proof strength, R_m: tensile strength, A%: elongation after fracture on original gage length $L_o=5.65\sqrt{S_o}$ (where S_o is the original cross sectional area), KV: ISO V-notch impact strength

[B] Other micro alloying elements can be substituted for titanium. The total micro alloying elements shall be 0.06% min.

SUMMARY OF STANDARD TEST METHODS FOR STEEL CASTINGS

Overview

Testing is required to ensure that the product will perform safely and economically in service. Excessive testing and overly stringent requirements increase the cost of the product without increasing value. On the other hand, insufficient testing or overly lax requirements are meaningless. Therefore, it becomes the task of the customer to decide what tests and requirements are necessary for his or her application.

Mechanical properties and chemical compositional limits are generally the subject of ASTM material specifications. These must be controlled and tested in products ordered to those specifications. Consult the latest revisions of the ASTM Standards referenced in this document for more information.

Mechanical Testing

Background

Mechanical testing is generally carried out in accordance with methods described in ASTM A 370, “Standard Test Methods and Definitions for Mechanical Testing of Steel Products”. These methods cover procedures and definitions for the mechanical testing of wrought and cast steel products. The various mechanical tests herein described are used to determine properties required in the product specifications. Variations in testing methods are to be avoided and standard methods of testing are to be followed to obtain reproducible and comparable results. The test methods most often used in steel castings include tension testing, hardness testing, and impact testing.

The mechanical properties are obtained from test bars and represent the quality of the steel from which the castings have been poured. The properties are not identical with the properties of the castings, which are affected by solidification rates and cooling rates during heat treating, which in turn are influenced by casting thickness, size, and shape.

Tension Testing

The tension test is the most uniformly applied test used to verify the mechanical performance of the material. The test results include tensile strength, yield strength, elongation and reduction in area. The strength measurements are useful in determining the load bearing capabilities of the material. Ductility measurements give an indication of the ability of the material to undergo deformation. The tension test is used to verify that the mechanical performance of the material is consistent. Evaluating performance in service environments may require information of other material properties such as fracture toughness, fatigue, creep-rupture, etc.

Hardness Testing

Hardness testing is used as a quick estimation of strength and/or wear resistance. It is particularly useful in the control of heat treatment for carbon and low to medium alloy steels. The most commonly used method for determining hardness in steel castings is the Brinell Test. The Rockwell test uses a much smaller probe and when used on cast steels is subject to variations. Converting numbers must be done with care because the conversions from Brinell to Rockwell is not exact and varies somewhat depending on the actual alloy tested. Stainless cast steels, excluding martensitic grades, are treated for corrosion resistance, not to develop strength and the hardness does not relate to heat treatment.

Impact Testing

Impact testing gives the amount of energy absorbed by a material. A sample of the material is hit with a hammer that has a known energy. The difference in energy the hammer has after striking the material is the impact strength of the material. This provides a useful measure of toughness or resistance to sudden failure. For low temperature service this test becomes increasingly important because most steels become less tough as the temperature

decreases. Impact testing is an ASTM requirement in specifications for material used in low temperature service. The Charpy V-notch is the most commonly applied method.

Nondestructive Examination

Background

Nondestructive examination testing is done to verify the mechanical integrity or soundness of the steel casting. It can be separated in to surface examination methods which include visual, liquid penetrant, and magnetic particle and subsurface or internal examination methods which include radiography and ultrasonics. Not only must a test method be chosen, but also an acceptance criterion must be applied. Acceptance criteria should be related to the service requirements because overly stringent criteria add directly to the cost. For critical service both surface and internal examination may be required to assure the attainment of the level of soundness specified.

Visual Examination

Equipment Required	Enables Detection of	Advantages	Limitations	Remarks
Surface comparator Pocket rule Straight Edge Workmanship standards	Surface flaws – cracks, porosity, slag inclusions, adhering sand, scale, etc.	Low cost Can be applied while work is in process, permitting correction of faults	Applicable to surface defects only Provides no permanent record	Should always be the primary method of inspection, no matter what other techniques are required

ASTM A 802 – 15	Standard Practice for Steel Castings, Surface Acceptance Standards, Visual Examination
SCRATA Comparators	Steel Casting Research and Trade Association (SCRATA) Comparator Plates - for establishing mutually agreeable acceptance criteria for a specific part
ISO 11971:2008	Steel and Iron Castings – Visual Examination of Surface Quality
MSS SP-55-2011	Quality Standard for Steel Castings for Valves, Flanges, and Fittings, and Other Piping Components (Visual Method for Evaluation of Surface Irregularities)

Liquid Penetrant Examination (PT)

Equipment Required	Enables Detection of	Advantages	Limitations	Remarks
Commercial kits, containing fluorescent or dye penetrants and developers Application equipment for the developer A source of ultraviolet light – if fluorescent method is used	Surface discontinuities not readily visible to the unaided eye	Applicable to magnetic, nonmagnetic materials Easy to use Low cost	Only surface discontinuities are detectable	

ASTM A 903/A 903M – 12	Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection
ASTM E 165/E 165M – 12	Standard Test Method for Liquid Penetrant Examination
ASTM E 433 – 13	Standard Reference Photographs for Liquid Penetrant Examination
ISO 3452-1:2013	Non-Destructive Testing – Penetrant Testing – General principles

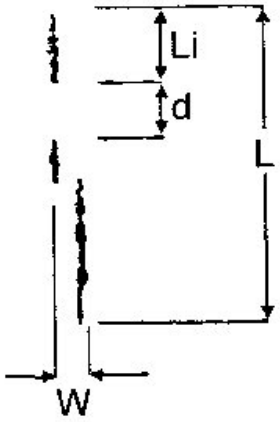
ISO 4987:2010	Steel castings – Liquid Penetrant Inspection
MSS SP-93-2014	Quality Standard for Steel Castings and Forgings for Valves, Flanges, Fittings, and Other Piping Components – Liquid Penetrant Examination Method

Magnetic Particle Examination (MT)

Equipment Required	Enables Detection of	Advantages	Limitations	Remarks
Special commercial equipment Magnetic powders – dry or wet form; may be fluorescent for viewing under ultraviolet light	Excellent for detecting surface and subsurface discontinuities to approximately ¼" below the surface – especially cracks	Permits controlled sensitivity Relatively low cost method	Applicable to ferromagnetic materials only Requires skill in interpretation of indications and recognition of irrelevant patterns Difficult to use on rough surfaces	Elongated discontinuities parallel to the magnetic field may not give pattern; for this reason the filed should be applied from two directions at or near right angles to each other

ASTM A 903/A 903M – 12	Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection
ASTM E 709 – 15	Standard Guide for Magnetic Particle Examination
ASTM E 125 – 13	Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings
ASTM E 1444/E 1444M – 16$^{\varepsilon 1}$	Standard Practice for Magnetic Particle Examination
ISO 4986:2010	Steel castings – Magnetic particle inspection
MSS SP-53-2012	Quality Standard for Steel Castings and Forgings for Valves, Flanges, Fittings, and Other Piping Components – Magnetic Particle Examination Method

All the surface examinations require severity levels to be set for acceptance. Methods of establishing severity levels by assigning numerical values to discontinuity attributes are illustrated in Figure 1 for the length of single linear discontinuities and arrays of aligned linear or nonlinear discontinuities. For nonlinear indications, acceptance criteria are typically expressed by limiting the "major" dimension of the indication, the length and width, or the area of the indication. Note, Figure 1 is an example and is not part of any acceptance standard unless agreed upon by the producer and buyer of steel castings.



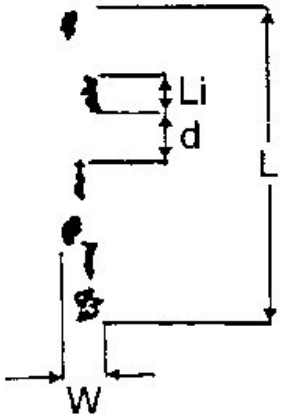
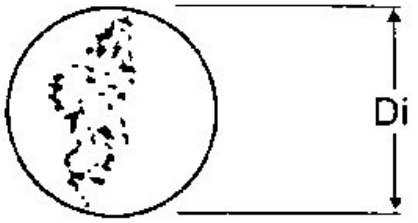
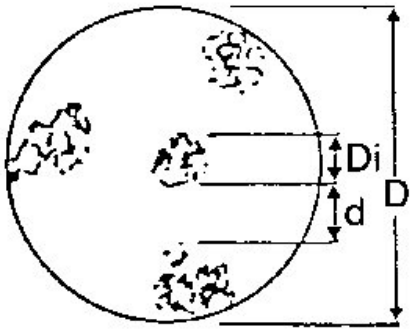


Figure 1: Length measurement of linear discontinuities; linear arrays of linear and non-linear discontinuities





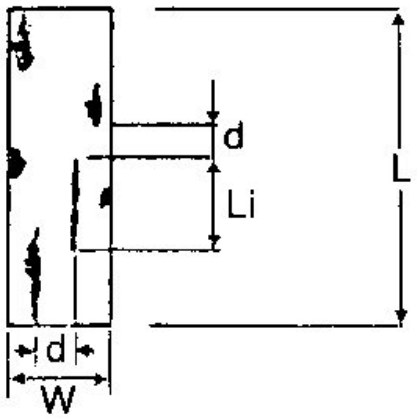


Figure 2: Area measurement; diameter or length, and width measurement of discontinuity arrays

Li, Wi, Di = Length, width, diameter of individual discontinuities, or clusters
L, W, D = Length, width, diameter of discontinuity arrays
d = Distance between discontinuities, or discontinuity clusters
Linear discontinuity = $Li \geq 3Wi$
Linear array = $L \geq 5W$
Distance between discontinuities within an array = $d < Li_{max}$, that is, $d < Di_{max}$
Li_{max}, Di_{max} = Largest length, or diameter of discontinuity, or cluster within an array

The ASME Code has methods and acceptance criteria in Section III and Section VIII. In Section VIII (non-nuclear) para. 9-103(a) and 9-230(a) no linear discontinuities are allowed. This is a classic example of overly strict requirements because it requires all discontinuities to be eliminated. In Section III (nuclear) para. NB-2545.3 and NB-2546.3 allow indications of 1/16". The nuclear section is actually easier to comply with because it does allow for some small indications without rework. The code contains high standards of quality, but these need not be used for all castings for all applications. Rather, the service conditions should be used to help choose appropriate levels of acceptance.

Radiographic Examination (RT)

Equipment Required	Enables Detection of	Advantages	Limitations	Remarks
Commercial x-ray or gamma units, made especially for inspecting welds, castings, and forgings Film and processing facilities	Internal macroscopic flaws – cracks, porosity, blow holes, non-metallic inclusions, shrinkage, etc.	When the indications are recorded on film, gives a permanent record	Requires skill in choosing angles of exposure, operating equipment, and interpreting indications Requires safety precautions Cracks difficult to detect	Radiographic inspection is required by many codes and specifications Useful in qualification of processes Because of cost, its use should be limited to those areas where other methods will not provide the assurance required

ASTM E 94/E 94M – 17 Standard Guide for Radiographic Examination Using Industrial Radiographic Film

ASTM E 142 – 92 Standard Method for Controlling Quality of Radiographic Testing

ASTM E 446 – 15 Standard Reference Radiographs for Steel Castings up to 2 in. in Thickness (3 Sets; X-rays, Iridium, Cobalt)

ASTM E 186 – 15 Standard Reference Radiographs for Heavy-walled (2 to 4-1/2 in.) Steel Castings (3 Sets; X-ray, Gamma Rays, Betatron)

ASTM E 280 – 15 Standard Reference Radiographs for Heavy-walled (4-1/2 to 12 in.) Steel Castings (2 Sets; X-ray, Betatron)

ASTM E 192 – 15 Standard Radiographs of Investment Steel Castings for Aerospace Applications

ASTM E 1742/E 1742M – 12 Standard Practice for Radiographic Examination

ASTM E 2868 – 17 Standard Digital Reference Images for Steel Castings up to 2 in. (50.8 mm) in Thickness

ISO 4993:2015 Steel and Iron Castings – Radiographic Testing

ISO 5579:2013 Non-destructive testing – Radiographic Testing of Metallic Materials Using Film and X- or Gamma Rays – Basic Rules

MSS SP-54-2013 Quality Standard for Steel Castings for Valves, Flanges, Fittings, and Other Piping Components – Radiographic Examination Method

Ultrasonic Testing (UT)

Equipment Required	Enables Detection of	Advantages	Limitations	Remarks
Special commercial equipment, either of the pulse-echo or transmission type	Sub-surface discontinuities, including those too small to be detected by other methods Especially for detecting subsurface, planar discontinuities	Very sensitive Permits probing of joints inaccessible to radiography	Requires high degree of skill in interpreting pulse-echo patterns Permanent record is not readily obtained	

ASTM A 609/A 609M - 12 Standard Practice for Castings, Carbon, Low-alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof

ISO 4992:2006 Steel castings – Ultrasonic Examination

MSS SP-94-2015	Quality Standard for Ferritic and Martensitic Steel Castings and Forgings for Valves, Flanges, Fittings, and Other Piping Components – Ultrasonic Examination Method

SPECIAL STANDARD PRACTICES

Ferrite Content

ASTM A 800/A 800M – 14 STEEL CASTINGS, AUSTENITIC ALLOY, ESTIMATING FERRITE CONTENT THEREOF

This practice covers procedures and definitions for estimating ferrite content in certain grades of austenitic iron-chromium-nickel alloy castings that have compositions balanced to create the formation of ferrite as a second phase in amounts controlled to be within specified limits. Methods are described for estimating ferrite content by chemicals, magnetic, and metallographic means.

The tensile and impact properties, the weldability, and the corrosion resistance of iron-chromium-nickel alloy castings may be influenced beneficially or detrimentally by the ratio of the amount of ferrite to the amount of austenite in the microstructure. The ferrite content may be limited by purchase order requirements or by the design construction codes governing the equipment in which the castings will be used. The quantity of ferrite in the structure is fundamentally a function of the chemical composition of the alloy and its thermal history. Because of segregation, the chemical composition, and, therefore, the ferrite content, may differ from point to point on a casting. Determination of the ferrite content by any of the procedures described in the following practice ASTM A 800/A 800M is subject to varying degrees of imprecision which must be recognized in setting realistic limits on the range of ferritic content specified. Sources of error include the following:

1. In Determinations from Chemical Composition – Deviations from the actual quantity of each element present because of chemical analysis variance, although possibly minor in each case, can result in substantial differences in the ratio of total ferrite-promoting to total austenite-promoting elements. Therefore, the precision of the ferrite content estimated from chemical composition depends on the accuracy of the chemical analysis procedure.

2. In Determinations from Magnetic Response – Phases other than ferrite and austenite may be formed at certain temperatures and persist at room temperature. These may so alter the magnetic response of the alloy that the indicated ferrite content is quite different from that of the same chemical composition that has undergone different thermal treatment. Also, because the magnets or probes of the various measuring instruments are small, different degrees of surface roughness or surface curvature will vary the magnetic linkage with the material being measured.

3. In Determinations from Metallographic Examinations – Metallographic point count estimates of ferrite percentage may vary with the etching technique used for identification of the ferrite phase and with the number of grid points chosen for the examination, as explained in Test Method E 562.

ISO 13520:2015 DETERMINATION OF FERRITE CONTENT IN AUSTENITIC STAINLESS STEEL CASTINGS

See original specification for details.

Welding

ASTM A 488/A 488M – 17 STEEL CASTINGS, WELDING, QUALIFICATIONS OF PROCEDURES AND PERSONNEL

This practice established the qualifications of procedures, welders, and operators for the fabrication and repair of steel castings by electric arc welding.

ASME BPVC Section IX – 17 QUALIFICATION STANDARD FOR WELDING AND BRAZING PROCEDURES, WELDERS, BRAZERS, AND WELDING AND BRAZING OPERATORS

Section IX of the ASME Boiler and Pressure Vessel Code relates to the qualification of welders, welding operators, brazers, and brazing operators, and the procedures that they employ in welding and brazing according to the ASME Boiler and Pressure Vessel Code and the ASME B31 Code for Pressure Piping.

ISO 11970:2016 SPECIFICATION AND QUALIFICATION OF WELDING PROCEDURES FOR PRODUCTION WELDING OF STEEL CASTINGS

This International Standard specifies how a welding procedure specification (WPS) for production welding of steel castings is qualified.

NAVSEA TP248 – 95 REQUIREMENTS FOR WELDING AND BRAZING PROCEDURE AND PERFORMANCE QUALIFICATION

This document contains the requirements for the qualification of welding and brazing procedures, welders, welding operators, brazers and brazing operators that must be met prior to any production fabrication.

TARDEC 12479550 Rev A – 06 GROUND COMBAT VEHICLE WELDING CODE – STEEL

This code contains welding requirements applicable to welding ground combat vehicles, other alloy structures and components.

AWS D1.6/D1.6M – 17 STRUCTURAL WELDING CODE – STAINLESS STEEL

This code covers the requirements for welding stainless structural assemblies.

CODE AND SPECIFICATION AGENCIES

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American National Standards Institute
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(ASME) - Boiler and Pressure Vessel Code Committee
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Warrendale, PA 15096
(724) 776-4841
[www.sae.org]

American Bureau of Shipping
(ABS)
16855 Northchase Drive
Houston, TX 77060
(281) 877-6000
[www.eagle.org]

Lloyd's Register of Shipping
(LR)
71 Fenchurch Street
London, EC3M 4BS, UK
+44 (0)20-7488-4796
[www.lr.org]

National Association of Corrosion Engineers
(NACE)
15835 Park Ten Place
Houston, TX 77084
(281) 228-6200
[www.nace.org]

Association of American Railroads
(AAR)
425 3rd Street SW
Washington, D.C. 20024
(202) 639-2345
[www.aar.org]

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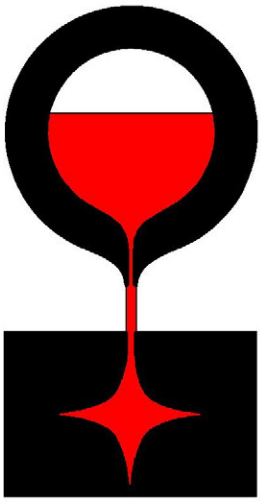

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