STEEL
CASTINGS
HANDBOOK

Supplement 8
High Alloy Data Sheets
Corrosion Series

Steel Founders' Society of America
2004

Corrosion Resistant Type CA6NM (UNS J91540)

Description

Type CA6NM is an iron-chromium-nickel-molybdenum alloy that is hardenable by heat treatment. It is similar in general corrosion resistance to type CA15, but the addition of nickel and molybdenum to the CA6NM composition improves its resistance to attack by sea water. Although the tensile strength properties of CA6NM are comparable to those of CA15, the impact strength is about twice as high, as is the resistance to damage from cavitation effects. Heavy sections and complex structures are cast in CA6NM with less difficulty than experienced with the CA15 alloy, and for cast-weld construction, or where field welding is involved, type CA6NM offers the advantage of not requiring a preheat. A major application of the alloy has been in large hydraulic turbine runners for power generation.

The alloy normally is used in the normalized and tempered condition in which the microstructure is essentially 100 percent martensite. CA6NM can contain appreciable amounts of retained austenite because this structure provides the optimum combination of strength, ductility, hardness, and toughness. Variations in heat treatment can be selected to enhance one or more of these properties. Improved corrosion resistance, particularly resistance to sulfide stress corrosion, can be obtained with a lower carbon as in grade CA6NM Class B (ASTM A487). A lower carbon content, as in grade CA6NM Class B, permits heat treating to a lower maximum hardness (and strength) which results in improved corrosion resistance, particularly resistance to sulfide stress corrosion cracking.

Castings of type CA6NM alloy have good machining and welding properties if proper techniques are employed. The alloy is magnetic and has a coefficient of thermal expansion slightly less than that of carbon steel. Thermal conductivity is

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Mo	Fe
min.						11.5	3.5	0.4	
max.	0.060	1.00	1.00	0.040	0.030	14.0	4.5	1.0	bal

Physical properties

Modulus of elasticity, psi x 10^6	29.0
Density, lb/in^3	0.278
Sp. Heat, Btu/lb.°F, at 70 °F	0.11
Electrical resistivity, μΩ.m, at 70 °F	0.78
Melting point, approximate °F	2750
Magnetic permeability	Ferromagnetic

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion μ in./(in. °F)	
At 212 °F	14.5	70 - 212 °F	6.0
At 1000 °F	16.7	70 - 1000 °F	7.0

Mechanical properties at room temperature

	Representative tensile properties air cooled from >1900 °F temper at 1100-1150 °F	Minimum tensile & toughness requirements ASTM A743, A757
Tensile strength, ksi	120.0	110.0
Yield strength, 0.2% offset, ksi	100.0	80.0
Elongation, in 2in., %	24	15
Reduction of area, %	60	35
Brinell hardness (HBW)	268	-
Charpy V-notch, @ -100 °F, ft.lbs	-	20/12 (A757)[A]

Toughness and impact properties

Impact, Charpy V-notch - see Fig.1
Fracture toughness, $_{Kic}$ - see Fig.2

At elevated temperatures

Short time elevated temperature properties - see Fig.3

Creep rupture properties - see Table 1 and Figs. 4 - 6

[A] 20 ft.lb average on three specimens, 15 ft.lb minimum allowed on one specimen only about 45 percent less than carbon steel but almost 60 percent greater than the CF alloy types. Electrical resistivity is about five times that of carbon steel.

Heat Treatment

The alloy is hardened by heating between 1900 and 1950°F (1038 to 1066°C) followed by cooling in either air or oil. After the castings have cooled below the martensite finish temperature, which varies with the compositional balance, they should be tempered as soon as possible. Depending on strength requirements, the alloy is tempered at 600°F (316°C) or more commonly in the range of 1100 to 1150°F (593 to 621°C). Tempering in the vicinity of 900°F (482°C) should be avoided because lower toughness will result. Some re-austenitization may occur if tempering temperatures above 1200°F (649°C) are employed, and upon cooling, the microstructure may contain untempered martensite. Double tempers are employed to achieve hardness values below 22 HRC for castings intended for wet H_2S environments. A typical double temper heat treatment would consist of a 1250°F (677°C) temper followed by a 1125°F (607°C) temper.

Highest strength and hardness are obtained by tempering at 600°F (316°C); however, impact strength is reduced by 50 percent and ductility is reduced to about 12 percent. Holding times for austenitizing and tempering will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CA6NM alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Chemical, Marine, Oilfield, Petroleum Refining, Pollution Control, Power Plant.

Castings Casings, compressor impellers, diaphragms, diffusers, discharge spacers, Francis runners, hydraulic turbine parts, impulse wheels, packing housings, propellers, pump impellers, suction spacers, valve bodies and parts.

Corrosives Boiler feed water [250°F (115°C)], sea water, steam, sulfur, water to 400°F (204°C).

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CA6NM is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CA6NM. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CA6NM alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Complex designs involving light and heavy sections are successfully made in this alloy, but drastic changes in section should be avoided as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 1/4 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Welds in light sections and in unstressed areas can be made without preheating. Welding in the heat treated condition is generally preferred. For welding very heavy sections or highly stressed regions, castings may require preheating in the range of 212 to 350°F (100 to 176°C) and should be maintained at 300 to 500°F (176 to 260°C) during welding as a guideline. After welding, cool to at least 212°F (100°C) or below the martensite finish temperature prior to re-tempering at 1100 to 1150°F (593 to 621°C). Cooling through the range of 1100 to 950°F (593 to 266°C) should be as rapid as possible to avoid loss in toughness.

Welding procedure utilizing SMAW technique is described in this section.

Machining Most machining operations can be performed satisfactorily on castings of CA6NM alloy. The work-hardening rate of this grade is much lower than the iron-chromium-nickel types, but it is advisable in all cases that the tool be kept continually entering into the metal. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Chips are stringy but not abrasive. Chip curlers are recommended for carbide tools.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work.

Information on the procedures for specific machining operations is contained in SFSA Steel Castings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy

Cast ASTM: A743 (CA6NM), A757 (E3N), A487 (CA6NM), A352 (CA6NM).

Wrought A-182, Grade F6NM.

Table 1 Creep-Rupture Properties for CA6NM[B]

[Air cooled from above 1900°F (1038°C);Tempered at 1100-1150°F (593-621°C)]

Rupture strength, ksi

°F	°C	10^4 hrs	10^5 hrs
800	427	54.5	41.0
850	454	39.0	29.0
900	482	28.0	20.0
950	510	19.7	14.3
1000	538	14.2	10.1

Creep strength, ksi

°F	°C	0.1%/1000 hrs.	0.01%/1000 hrs.
800	427	41.0	31.0
850	454	29.6	22.5
900	482	22.0	16.3
950	510	16.0	11.8
1000	538	11.8	--

[B] "The Elevated Temperature Properties of Alloy CA6NM", G.V. Smith, CAST METALS FOR STRUCTURAL AND PRESSURE CONTAINMENT APPLICATIONS, ASME 1979.

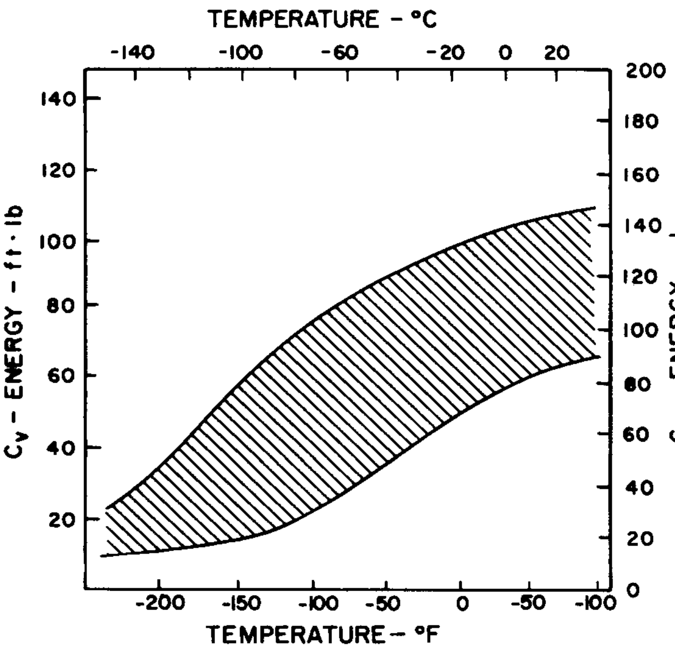


Fig. 1. Charpy V-notch impact energy data band for CA-6NM.

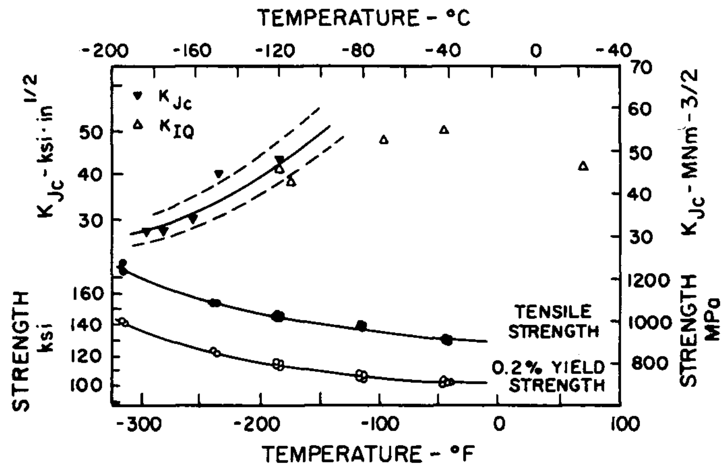


Fig. 2. Change in plane strain fracture toughness and tensile strength with temperature below 32° F (0° C) for CA-6NM.

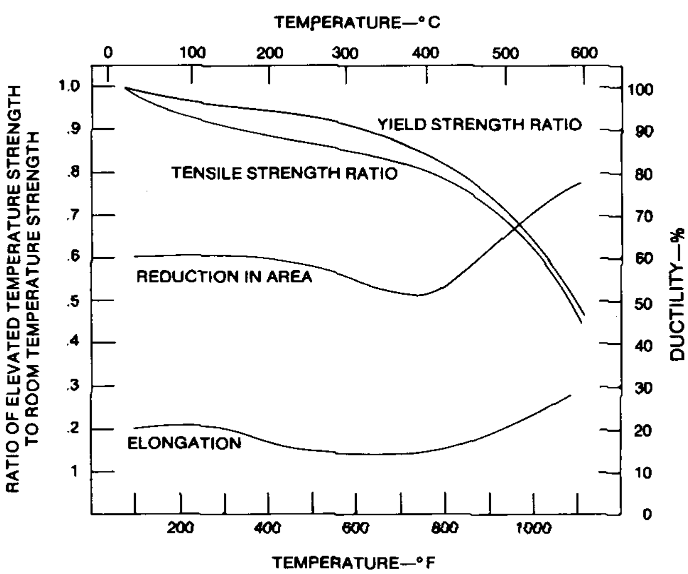


Fig. 3. Elevated Temperature Tensile Properties of CA-6NM.

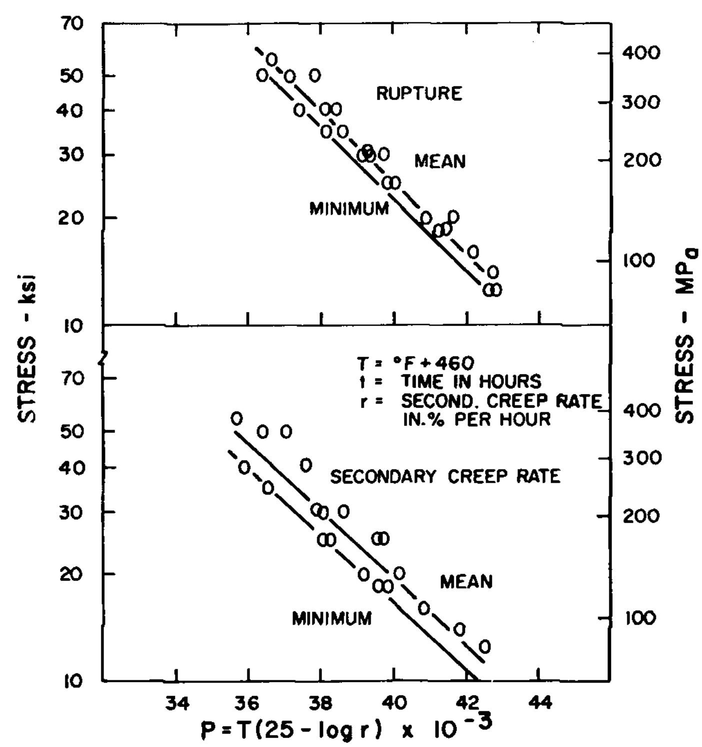


Fig. 4. Larson-Miller analyses of rupture and creep rate test for CA-6NM.

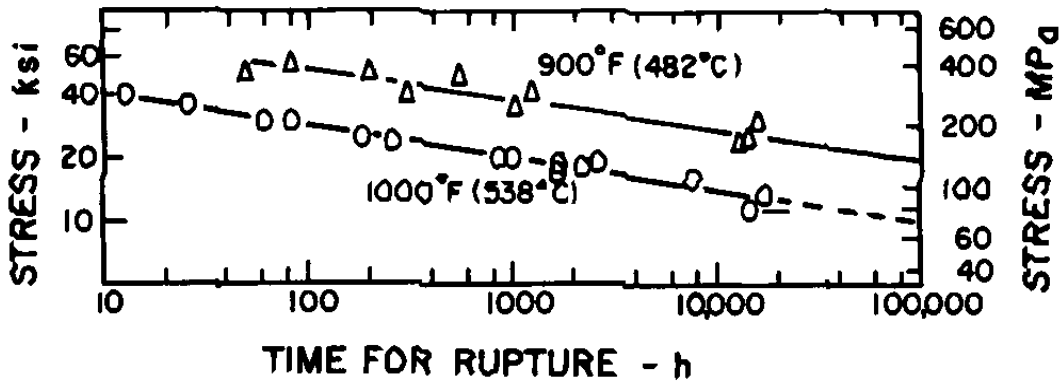


Fig. 5. Stress vs. time for rupture of CA-6NM. The super-imposed trend lines were computed from the mean parameter curve of Fig. 4.

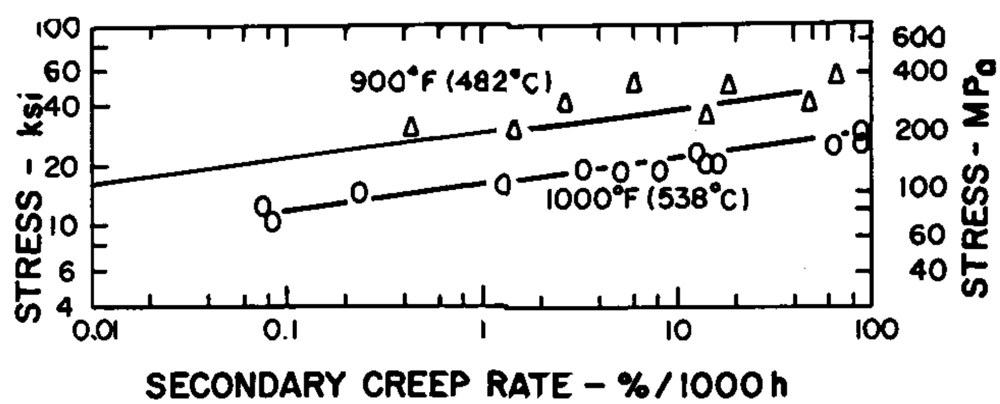


Fig. 6. Stress vs. secondary creep rate for CA-6NM. The super-imposed trend lines were computed from the mean parameter trend line in Fig 4.

Corrosion Resistant Type CA15 (UNS J91150)

Description

Type CA15 is an iron-chromium alloy containing the minimum amount of chromium necessary to make the metal virtually rustproof, and is similar to the original "stainless steel" used for cutlery. In addition to good atmospheric corrosion resistance, the alloy provides excellent resistance to corrosion or staining by many organic media in relatively mild service.

The alloy has a high hardenability so that a wide range of hardness (144 to about 400 BHN) and other mechanical properties may be obtained even in heavy sections. In the annealed condition, the ferrite matrix contains agglomerated carbide particles. Depending on the temperature of heat treatment, the hardened alloy exhibits a pearlitic to martensitic structure that results in a tough, erosion resistant material.

Castings of type CA15 alloy have fairly good machining and welding properties if proper techniques are employed. For improved machinability, this grade is sometimes made with the addition of selenium. The alloy is magnetic and has a coefficient of thermal expansion less than that of carbon steel.

Chemical composition, %

	C	Mn	Si	P	S	Cr	Ni	Mo	Fe
min.						11.5			
max.	0.15	1.00	1.50	0.04	0.04	14.0	1.0	0.5[1]	bal

[1]Mo not intentionally added

Physical propeties

Modulus of elasticity, psi x 10^6	29.0
Density, lb/in^3	0.275
Sp. Heat, Btu/lb.°F, at 70 °F	0.11
Electrical resistivity, µΩ.m, at 70 °F	0.56
Melting point, approximate °F	2750
Magnetic permeability (at H = 100 Oersted)	500

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion µ in./(in. °F)	
At 212 °F	14.5	70 - 212 °F	5.5
At 1000 °F	16.7	70 - 1000 °F	6.4
		70 - 1300 °F	6.7

Mechanical properties at room temperature

	Representative values air cooled from 1800 °F				Minimum tensile requirements ASTM A743
Tempered at, °F	600	1100	1200	1450	
Tensile strength, ksi	200	135	115	100	90
Yield strength, 0.2% offset, ksi	150	115	100	75	65
Elongation, in 2 in %	7	17	22	30	18
Reduction of area, %	25	55	55	60	30
Brinell hardness (HBW)	390	260	225	185	[a]
Charpy, keyhole, ft.lbs	15	10	20	35	-

[a] 241 max. unless otherwise specified

At elevated temperatures
Short-time elevated temperature tensile properties - See Fig. 1

Heat Treatment

To obtain maximum softness, castings of type CA15 alloy may be annealed at 1450°F (788°C) minimum, usually 1550 to 1650°F (843 to 899°C), and slowly furnace cooled. The alloy is hardened by heating to 1800 to 1850°F (982 to 1010°C), and cooling in oil or air. After hardening, castings should be tempered as soon as possible at 600°F (316°C) maximum, or in the range 1100 to 1500°F (593 to 816°C). Tempering in the vicinity of 900°F (482°C) should be avoided because low impact strength will result. Highest strength and hardness is obtained by tempering at 600°F (316°C) or below, and the alloy has best corrosion resistance in this fully hardened condition. When tempered above 1100°F (593°C), castings have improved ductility and impact strength, but corrosion resistance is somewhat decreased. Poorest corrosion resistance results from tempering around 1100°F (593°C). Holding times for hardening and tempering will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CA15 alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Aircraft, Architecture, Chemical Processing, Food Processing, Marine, Oil Refining, Metallurgical, Power Plant, Pulp and Paper.

Castings Burning torch gas distributor heads, bushings and liners, catalyst trays, fittings, furnace burner tips and pilot cones, gears, hydrafiner parts, impellers, jet engine components, letters, plaques, pump casings, railings, shafts, ship propellers, skimmer ladles, stuffing boxes, turbine blades, valve bodies, valve trim.

Corrosives Abrasive chemicals, alkaline liquors, ammonia water, atmosphere, boiler feed water, brass dross, coke oven gas, corrosive oils at high pressures and temperatures, food products, oxidizing acids, pulp, sodium carbonate, sodium nitrate, steam.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CA15 is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CA15. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CA15 alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Some difficulty is encountered in running thin sections, however, and designs involving appreciable changes in section should be avoided. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Unless the hardness and strength attainable with CA15 (or physical properties such as expansion coefficient or heat conductivity) are required, consideration should be given to other grades when designs are intricate. Normally used patternmakers' shrinkage allowance for this alloy is 1/4 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CA15 castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Castings should be heated in the range 400 to 600°F (204 to 316°C) before welding. After welding, cool to not less than 300°F (149°C), heat to 1125 to 1400°F (607 to 760°C), hold until uniform temperature throughout, then air cool.

Welding procedures utilizing SMAW, GMAW and GTAW techniques are described in this section.

Machining Most machining operations can be performed satisfactorily on castings of CA15 alloy. The work-hardening rate of this grade is much lower than the iron-chromium-nickel types, but it is advisable in all cases that the tool be kept continually entering into the metal. The alloy should not be too soft; hardness of about 225 BHN is recommended. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Chips are stringy but not abrasive.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6^{th} Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy

Cast ASTM: A217 (CA15), A426 (CFCA15), A743 (CA15), A487 (CA15), SAE 60410, MIL-S 16993A(1), AMS 5351B.

Wrought AISI 410.

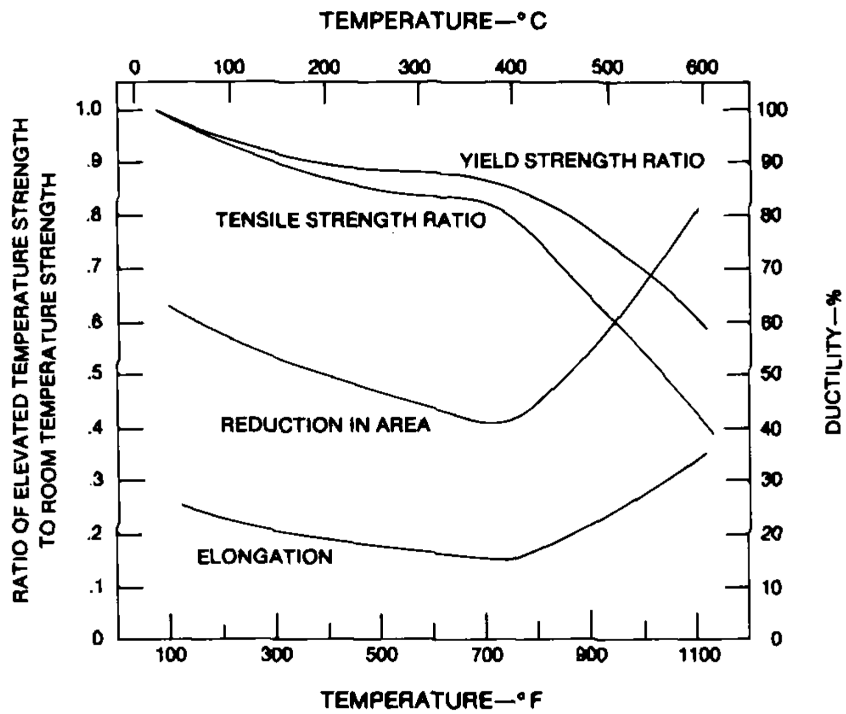


Fig. 1. Elevated Temperature Tensile Properties of CA-15.

Corrosion Resistant Type CA40 (UNS J91153)

Description

Type CA40 is an iron-chromium alloy similar to type CA15, but its higher carbon content permits hardening this grade to a maximum of about 500 BHN. Corrosion resistance and other characteristics are about the same as for the lower carbon CA15 alloy.

Chemical composition, %

	C	Mn	Si	P	S	Cr	Ni	Mo	Fe
min.	0.20					11.5			
max.	0.40	1.00	1.50	0.04	0.04	14.0	1.0	0.5[1]	bal

[1]Mo not intentionally added

Physical properties

Modulus of elasticity, psi x 10^6	29.0
Density, lb/in^3	0.275
Sp. Heat, Btu/lb.°F, at 70 °F	0.11
Electrical resistivity, μΩ.m, at 70 °F	0.56
Melting point, approximate °F	2750
Magnetic permeability (at H = 100 Oersted)	500

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion μ in./(in. °F)	
At 212 °F	14.5	70 - 212 °F	5.5
At 1000 °F	16.7	70 - 1000 °F	6.4
		70 - 1300 °F	6.7

Mechanical properties at room temperature

	Representative values air cooled from 1800 °F				Minimum tensile requirements ASTM A743
Tempered at, °F	600	1100	1200	1450	
Tensile strength, ksi	200	135	115	100	90
Yield strength, 0.2% offset, ksi	150	115	100	75	65
Elongation, in 2 in %	7	17	22	30	18
Reduction of area, %	25	55	55	60	30
Brinell hardness (HBW)	390	260	225	185	269[2]
Charpy, keyhole, ft.lbs	1	2	4	3	-

[2] Maximum

Heat Treatment

To obtain maximum softness, castings of type CA40 alloy may be annealed at 1450°F (788°C) minimum, usually 1550 to 1650°F (843 to 899°C), and slowly furnace cooled. The alloy is hardened by heating to 1800 to 1850°F (982 to 1010°C), and cooling in oil or air. After hardening, castings should be tempered as soon as possible at 600°F (316°C) maximum, or in the range 1100 to 1500°F (593 to 816°C). Tempering in the vicinity of 900°F (482°C) should be avoided. Highest strength and hardness is obtained by tempering at 600°F (316°C) or below, and the alloy has best corrosion resistance in this fully hardened condition. When tempered above 1100°F (593°C), castings have improved ductility and impact strength, but corrosion resistance is somewhat decreased. Poorest corrosion resistance results from tempering around 1100°F (593°C). Holding times for hardening and tempering will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CA40 alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Food Processing, Glass, Oil Refining, Power Plants, Pulp and Paper.

Castings Choppers, cutting blades, cylinder liners, dies, grinding plugs, hot oil plungers, flow control, molds, pump parts, casings, impellers, pump sleeve, shredder sleeves, steam turbine parts, valve trim, seat rings, and wedges.

Corrosives Air, abrasives, dilute oxidizing acids, food products, glass, oxidizing atmosphere to 1200°F, sour crude oil (hot, high pressure), steam.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CA40 is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CA40. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CA40 alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Some difficulty is encountered in running thin sections, however, and designs involving appreciable changes in section should be avoided. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Unless the hardness and strength attainable with CA40 (or physical properties such as expansion coefficient or heat conductivity) are required, consideration should be given to other grades when designs are intricate. Normally used patternmakers' shrinkage allowance for this alloy is 1/4 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CA40 castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Castings should be heated in the range 400 to 600°F (204 to 316°C) before welding. After welding, cool to not less than 300°F (149°C), heat to 1125 to 1400°F (607 to 760°C), hold until uniform temperature throughout, then air cool.

The welding procedures outlined for alloy CA15 are applicable to alloy CA40. Welding procedures utilizing SMAW, GMAW and GTAW techniques are described in this section.

Machining Most machining operations can be performed satisfactorily on castings of CA40 alloy. The work-hardening rate of this grade is much lower than the iron-chromium-nickel types, but it is advisable in all cases that the tool be kept continually entering into the metal. Hardness of about 225 BHN is recommended. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Chips are stringy and abrasive to tools.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy
The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A743 (CA40), SAE 60420.

Wrought AISI 420.

Corrosion Resistant Type CB7Cu
(UNS J92110 [CB7Cu-2]) (UNS J92180 [CB7Cu-1])

Description

Type CB7Cu is a high strength, precipitation hardenable iron-chromium-nickel-copper alloy having corrosion resistance intermediate between the non-hardenable austenitic type CF alloys and the hardenable martensitic type CA grades. Castings of type CB7Cu have good resistance to atmospheric corrosion and many aqueous corrodents including sea water, food products, and paper mill liquors. Because of the range of mechanical properties attainable, the alloy finds wide application in service requiring both corrosion resistance and high strength at temperatures up to 600°F (316°C). It is especially useful where machining is involved since the work can be done when castings are in the solution annealed condition. Subsequent precipitation hardening to the desired mechanical strength may then be conducted at relatively low temperature so that there is little danger of cracking, distortion or oxidation of the machined surfaces.

As shown in the table of properties, the broad alloy type covers two sub-grades differing only in chromium and nickel contents. Although the mechanical properties are essentially the same for both grades, the 15 Cr, 4 Ni type CB7Cu-2 retains ductility somewhat better than the 17 Cr, 4 Ni type as thickness increases. For this reason, it is useful for parts with heavy sections. In the solution annealed state, the microstructure of the alloy consists of martensite formed upon cooling the casting from the solution temperature at which the original as-cast structure was austenite containing dissolved copper. This copper remains in the martensite as a super-saturated solution but, if the alloy is later reheated to the range 900-1150°F (482-621°C), it precipitates sub-microscopically and substantially increases the strength and hardness of the casting.

Castings of type CB7Cu alloy have good machining and welding properties if proper techniques are employed. The alloy has a low coefficient of thermal expansion similar to

Chemical composition, %

		C	Mn	Si	P	S	Cr
CB7Cu-1	min.						15.50
	max.	0.07	0.70	1.00	0.035	0.03	17.70
CB7Cu-2	min.						14.00
	max.	0.07	0.70	1.00	0.035	0.03	15.50

		Ni	Cu	Cb[1]	N	Fe
CB7Cu-1	min.	3.60	2.50	0.20		
	max.	4.60	3.20	0.35	0.05	bal
CB7Cu-2	min.	4.50	2.50	0.20		
	max.	5.50	3.20	0.35	0.05	bal

[1]Cb not added when alloy is to be hardened by 900°F aging treatment

Physical properties

Modulus of elasticity, psi x 10^6	28.5[2]
Density, lb/in^3	0.280
Sp. Heat, Btu/lb.°F, at 70 °F	0.11
Electrical resistivity, μΩ.m, at 70 °F	0.77
Melting point, approximate °F	2750
Magnetic permeability (at H = 100 Oersted)	ferromagnetic

[2]See Fig.1 for effect of temperature on modulus

Thermal conductivity Btu/(ft.h. °F)

At 212 °F	9.9
At 500 °F	11.3
At 860 °F	13.0
At 900 °F	13.1

Mean coefficient of Linear thermal expansion μ in./(in. °F)

Aged at	900 °F	1100°F
70 - 200 °F	6.0	6.6
70 - 400 °F	6.1	6.9
70 - 600 °F	6.3	7.1
70 - 800 °F	6.5	7.2

Mechanical properties at room temperature

Representative values air cooled from 1925 °F

Aged at, °F	900	925	1025	1075	1100	1150
Tensile strength, ksi	187	189	165	155	145	140
Yield strength, 0.2% offset, ksi	161	165	158	141	132	120
Elongation, in 2 in %	10	11	14	14	15	16
Reduction of area, %	21	26	35	35	39	42
Brinell hardness (HBW)	412	412	350	319	315	307
Impact, Charpy V ft.lbs	7	12	22	27	30	37

Minimum requirements - ASTM A747

Aged at, °F	900	925	1025	1075	1100	1150
Tensile strength, ksi	170	175	150	145	135	125
Yield strength, 0.2% offset, ksi	145	150	140	115	110	97
Elongation, in 2 in %	5	5	9	9	9	10
Reduction of area, %	-	-	-	-	-	-
Brinell hardness (HBW)	412	412	350	319	315	307
Impact, Charpy V ft.lbs	-	-	-	-	-	-

at Elevated temperatures - see Fig.2

the type CA alloys. Electrical resistance is about five times that of carbon steel and thermal conductivity is 40 percent less. Because the alloy is ferromagnetic, magnetic particle testing is sometimes used for non-destructive inspection. If minor amounts of non-magnetic retained austenite occur in the form of stringers, or if untransformed ferrite stringers are present, false linear indications may be obtained. (The type CB7Cu-2 is less susceptible than the type CB7Cu-1 alloy to ferrite stringer formation.) Such stringers do not in any way affect the soundness of the casting. It is preferable to use dye penetrant or fluorescent dye inspection instead of magnetic particle for testing this alloy.

Heat Treatment

Type CB7Cu castings are supplied in either the solution annealed or hardened condition, depending on the desire of the user. Solution annealing consists of heating the castings to 1925°F (1050°C) ± 50°F (30°C), holding them for 30 minutes per inch of the heaviest section (30 minutes minimum), and then cooling them to below 90°F (30°C).

To ensure complete transformation of austenite, it is occasionally necessary to cool the castings in dry ice. Prior to solution annealing, castings sometimes are specified to be given a homogenizing heat treatment consisting of heating the castings to 1900°F (1040°C) minimum, holding them 1.5 hours minimum, and then cooling them to below 90°F (30°C). Castings of type CB7Cu alloy are intended to be used only in the precipitation hardened condition, but may be supplied in the solution annealed condition if machining is to be done prior to hardening. Precipitation hardening involves heating the solution annealed castings: a) at 900°F (480°C) for 1 hour; b) at 925°F (495°C) for 1.5 hours; or c) at 1025°F (550°C), 1075°F (580°C), 1100°F (595°C) or 1150°F (620°C) for 4 hours. After the required time at temperatures the castings are air cooled. Because of the expansion that occurs when austenite transforms to martensite, it is advisable to avoid steep thermal gradients in castings when they are cooling from the solution annealing temperature. Lack of attention to this may result in cracking of the surfaces that cooled earliest on the casting.

A dimensional change also takes place upon hardening and should be given consideration when large castings in the solution annealed condition are to be machined to close tolerances prior to hardening. This change is a *contraction* of 0.0004 to 0.0006 inch per inch.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CB7Cu alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Aerospace, Aircraft, Chemical, Food Processing, Gas Turbine, Marine, Petrochemical, Pulp and Paper.

Castings Airframe components, centrifuge bowls, compressor impellers, food machinery parts, machine tool parts, propeller shafts, pump impellers, rotors, screw flights, valve bodies, discs, and trim.

Corrosives Air, ethylene glycol-water (-65 to 200°F), food products, pulp liquor, sea water, water (up to 400°F).

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CB7Cu is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloys

CB7Cu-1 and CB7Cu-2. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CB7Cu alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Complex designs involving light and heavy sections are successfully made in this alloy, but drastic changes in section should be avoided as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 1/4 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CB7Cu castings can be welded by shielded metal-arc, inert-gas arc, and oxyacetylene gas methods. Oxyacetylene welding is not advisable because of possible impairment of both corrosion resistance and mechanical properties caused by carbon pick-up. In either the annealed or overaged condition (i.e., 1000°F or over), castings can be welded without preheat, although it is sometimes desirable to preheat to 500°F (260°C) when welding heavy sections. Sections which require multiple-pass welds are handled better in the annealed condition than after aging because the prolonged heat of welding will introduce non-uniform hardening characteristics to the weld zone. Thus, after welding, such castings may require a solution heat treatment in the temperature range 1875-1975°F (1024-1079°C) followed by rapid cooling before being hardened by reheating to the precipitation temperature. Only the aging treatment is needed to harden the weld zone on single pass welds. Castings having a copper content near the high end of the copper range may suffer underbead cracking when welded. Accordingly, when castings are intended to be welded, it is desirable to have the copper content below 3.00 percent.

Welding procedures utilizing SMAW, GMAW and GTAW techniques are described in this section.

Machining Most machining operations can be performed satisfactorily on castings of CB7Cu alloy. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface from rubbing or scraping. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Type CB7Cu castings can be machined in either the annealed or hardened condition. An advantage of this alloy is that it can be machined in the annealed condition and later hardened by a low temperature heat treatment with minimal scaling or distortion.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Localized heating such as resulting from heavy grinding or abrasive wheel cutting may cause castings to crack. For this reason, cold sawing is preferred for cutting, and care should be taken to avoid overheating during grinding operations.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy
The wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A747 (CB7Cu-1 and CB7Cu-2); AMS 5398B.

Wrought 17-4PH; 15-5PH.

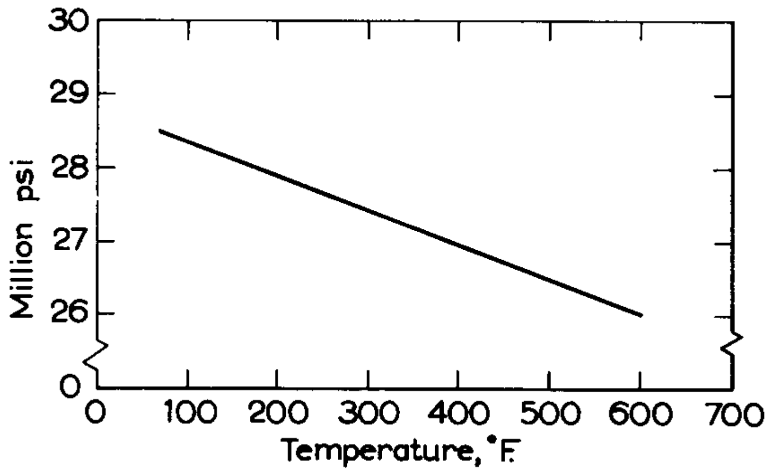


Fig. 1. Effect of temperature on modulus of elasticity of Type CB-7 Cu.

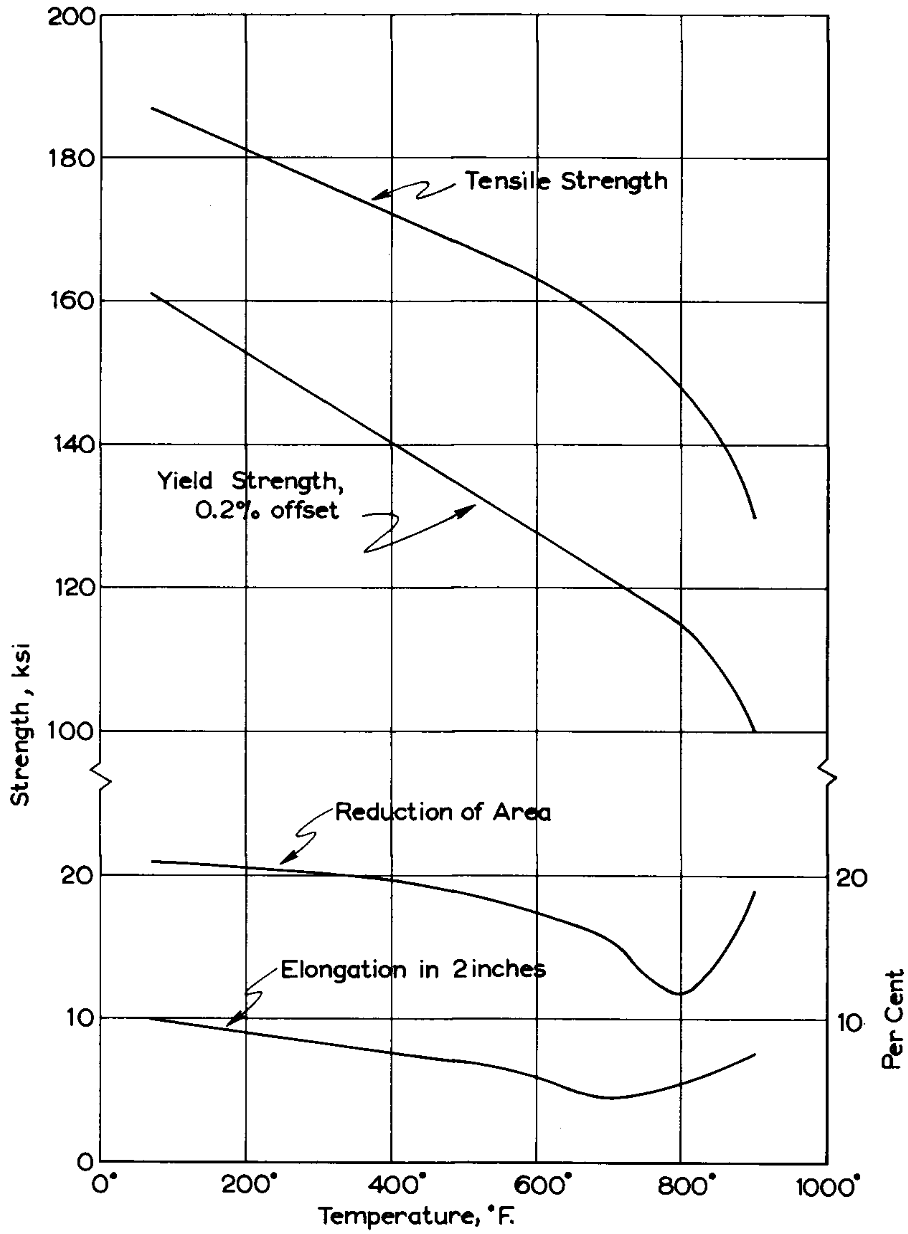


Fig. 2. Trend of tensile properties of Type CB-7 Cu aged at 900 F. tested at elevated temperature.

Corrosion Resistant Type CB30 (UNS J91803)

Description

Type CB30 is an iron-chromium alloy sufficiently high in chromium content to provide excellent resistance to corrosion by nitric acid, alkaline solutions, and many organic chemicals. Maximum corrosion resistance is obtained when the carbon content is held below 0.20 percent, but the alloy is normally made with carbon 0.20 to 0.30 percent in order to improve castability.

The alloy maintains predominantly ferritic structure, and even at the higher carbon levels only a small amount of ferrite transforms at elevated temperature to austenite for subsequent change to martensite upon cooling. Thus, in contrast to the hardenable CA15 grade, the CB30 type is practically non-hardenable by heat treatment. By balancing the composition toward the low end of the chromium and the high end of the nickel and carbon ranges, however, the hardening characteristics of the alloy are increased. In this case, the grade corresponds more nearly to the wrought alloy AISI type 431, whereas normally the properties of the alloy correspond to those of AISI type 442.

Castings of the type CB30 alloy have fair ductility, but poor impact strength. They are readily machinable and can be welded successfully if proper technique is employed. The alloy is magnetic and has a lower coefficient of thermal expansion than carbon steel.

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Fe
min.						18		
max.	0.30	1.00	1.50	0.04	0.04	21	2.0	bal

Physical properties

Modulus of elasticity, psi x 10^6	29.0
Density, lb/in^3	0.272
Sp. Heat, Btu/lb.°F, at 70 °F	0.11
Electrical resistivity, µΩ.m, at 70 °F	0.76
Melting point, approximate °F	2725
Magnetic permeability	Ferromagnetic

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion µ in./(in. °F)	
At 212 °F	12.8	70 - 212 °F	5.7
At 1000 °F	14.5	70 - 1000 °F	6.5
		70 - 1300 °F	6.7

Mechanical properties at room temperature

	Representative values[1] Annealed at 1450 °F F.C. to 1000 °F then A.C.	Minimum tensile requirements ASTM A743
Tensile strength, ksi	95.0	65.0
Yield strength, 0.2% offset, ksi	60.0	30.0
Elongation, in 2in., %	15	-
Brinell hardness (HBW)	195	[2]
Charpy V-notch, @ -100 °F, ft.lbs	-	
Toughness and impact properties		

[1] Values may vary considerably depending on composition balance and heat treatment

[2] 241 max unless otherwise specified

Heat Treatment

Type CB30 castings are normally supplied in the annealed condition. Annealing consists of heating to 1450°F (788°C) minimum, furnace cooling to about 1000°F (538°C), then air cooling. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CB30 alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Chemical Processing, Food Processing, Heat Treating, Oil Refining, Ore Roasting, Power Plants.

Castings Furnace brackets and hangers, pump parts, rabble arms, tube supports, valve bodies, valve parts.

Corrosives Food products, hot ore, nitric acid, oil, oxidizing atmospheres to 1400°F (760°C), steam, sulfur atmospheres.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CB30 is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CB30. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CB30 alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Some difficulty is encountered in running thin sections, however, and designs involving appreciable changes in section should be avoided. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. If toughness is an important requirement, consideration should be given to one of the CF, CH or CK grades unless the greater thermal expansion of these alloys cannot be tolerated. Normally used patternmakers' shrinkage allowance for this alloy is 1/4 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CB30 castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Castings should be heated in the range 600 to 800°F (316 to 427°C) before welding. After welding, cool to 150°F (666°C) or lower, heat to 1450°F (788°C) minimum, hold until uniform temperatures throughout, then air cool.

Machining Most machining operations can be performed satisfactorily on castings of CB30 alloy. The work-hardening rate of this grade is much lower than the iron-chromium-nickel types, but it is advisable in all cases that the tool be kept continually entering into the metal. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Chips are short and brittle.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy
The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A743 (CB30); SAE 60442.

Wrought AISI 442.

Corrosion Resistant Type CC50 (UNS J92615)

Description

Type CC50 is an iron-chromium alloy containing about 28 percent chromium and up to 4 percent nickel. It provides excellent resistance to dilute sulfuric acid in mine waters, mixed nitric and sulfuric acids, and oxidizing acids of all types.

The alloy has a ferritic structure at all temperatures and for this reason cannot be hardened by heat treatment. The ductility and impact strength are very low unless some nickel is present. In the CC50 type containing over 2 percent nickel, substantial improvement in the strength and ductility is obtained by increasing the nitrogen content to 0.15 percent or more.

Castings of the type CC50 alloy are readily machinable. They can be welded successfully if proper technique is employed. The alloy is magnetic and has a lower coefficient of thermal expansion than carbon steel.

Heat Treatment

Type CC50 castings are normally supplied in the annealed condition. Annealing consists of heating to 1450°F (788°C) minimum followed by air or furnace cooling. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout. Heating in the range 850 to 950°F (454 to 510°C) will result in a significant loss of ductility and toughness.

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Fe
min.						26		
max.	0.50	1.00	1.50	0.04	0.04	30	4.0	bal

Physical properties

Modulus of elasticity, psi x 10^6	29.0
Density, lb/in^3	0.272
Sp. Heat, Btu/lb.°F, at 70 °F	0.12
Electrical resistivity, µΩ.m, at 70 °F	0.77
Melting point, approximate °F	2725
Magnetic permeability	Ferromagnetic

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion µ in./(in. °F)	
At 212 °F	12.6	70 - 212 °F	5.9
At 1000 °F	17.9	70 - 1000 °F	6.4

Mechanical properties at room temperature

	Representative values Annealed at 1450 °F F.C. to 1000 °F then Air Cool			Minimum tensile requirements ASTM A743
	As Cast (a)[1]	(b)[2]	(b)[2]	
Tensile strength, ksi	70.0	95.0	97.0	55.0
Yield strength, 0.2% offset, ksi	65.0	60.0	65.0	-
Elongation, in 2in., %	2	15	18	-
Brinell hardness (HBW)	212	193	210	-
Impact, Izod V-notch, ft.lbs.	2	45	-	-

[1](a) Under 1.0% Ni
[2](b) Over 2.0% Ni with 0.15% N min.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CC50 alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Chemical Manufacturing, Mining, Pulp and Paper, Synthetic Fibre Manufacturing.

Castings Bushings, cylinder liners, digester parts, pump casings and impellers, valve bodies, valve seats.

Corrosives Acid mine water, alkaline liquors, nitric acid, sulfurous liquors.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CC50 is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CC50. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CC50 alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Some difficulty is encountered in running thin sections, however, and designs involving appreciable changes in section should be avoided. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. If toughness is an important requirement, consideration should be given to one of the CF, CH or CK grades unless the greater thermal expansion of these alloys cannot be tolerated. Normally used patternmakers' shrinkage allowance for this alloy is 1/4 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding

Type CC50 castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Castings should be heated in the range 400 to 1300°F (204 to 704°C) before welding. After welding, heat to 1550 to 1900°F (879 to 1038°C), hold until uniform temperature throughout, then air cool.

The welding procedures outlined for alloy HC are applicable to alloy CC50. Welding procedures utilizing SMAW, and GTAW techniques are described in this section.

Machining Most machining operations can be performed satisfactorily on castings of CC50 alloy. The work-hardening rate of this grade is much lower than the iron-chromium-nickel types, but it is advisable in all cases that the tool be kept continually entering into the metal. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Chips are short and brittle. Local overheating caused by dull tools or excessive speed may result in cracking the work.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy
The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A743 (CC50); SAE 60446.

Wrought AISI 446.

Corrosion Resistant Types

Duplex Stainless Steels; **CD4MCu (UNS J93370), CD4MCuN (UNS J93372), CD3MCuN (J93373),CE8MN (UNSJ93371), CD3MN (UNSJ92205),**

Super Duplex Stainless Steels; CE3MN (UNS93404), CD3MWCuN (J93380)

Description

This data sheet includes both duplex stainless steels and super duplex stainless steels. The difference between duplex stainless steels (DSS) and super duplex stainless steels (SDSS) is a function of the Pitting Resistance Number (PREN). The PREN is a function of the chromium, molybdenum and nitrogen content. For SDSS the PREN is generally 40 or higher.

Chemical composition - %

ASTM A890		C	Mn	Si	P	S	Cr	Ni	Mo	Cu	W	N	Fe	UTS	YS	Elong.
CD4MCu[1]	min.						24.5	4.75	1.75	2.7				ksi	ksi	%
	max.	0.04	1	1	0.04	0.04	26.5	6	2.25	3.3			bal	100	70	16
CD4MCuN[1]	min.						24.5	4.7	1.7	2.7		0.1				
	max.	0.04	1	1	0.04	0.04	26.5	6	2.3	3.3		0.25	bal	95	65	25
CD3MCuN[1]	min.						24	5.6	2.9	1.4		0.22				
	max.	0.03	1.2	1.1	0.03	0.03	26.7	6.7	3.8	1.9		0.33	bal	95	65	25
CE8MN[1]	min.						22.5	8	3			0.1				
	max.	0.08	1	1.5	0.04	0.04	25.5	11	4.5			0.3	bal	90	60	25
CD6MN[1]	min.						24	4	1.75			0.15				
	max.	0.06	1	1	0.04	0.04	27	6	2.5			0.25	bal	100	75	18
CD3MN[1]	min.						21	4.5	2.5			0.1				
	max.	0.03	1.5	1	0.04	0.02	23.5	6.5	3.5	1		0.3	bal	100	65	25
CE3MN[2]	min.						24	6	4			0.1				
	max.	0.03	1.5	1	0.04	0.04	26	8	5			0.3	bal	100	70	16
CD3MWCuN[2]	min.						24	6.5	3	0.5	0.5	0.2				
	max.	0.03	1	1	0.03	0.025	26	8.5	4	1	1	0.3	bal	100	65	25

[1]DSS
[2]SDSS

It should be recognized that the ferrite balance of duplex alloys must be controlled to avoid cracking during processing and welding. To this end nitrogen levels must be controlled. ASTM has addressed this issue by introducing CDMCuN into A890. Although CD4MCu still exists in A890 it is strongly recommended that CD4MCuN be substituted for this grade.

Type CD4MCuN is an iron-chromium-nickel-copper-molybdenum alloy having corrosion resistance in many media superior to the CF8 and CF8M types, but having about double the yield strength of those alloys. Combining good ductility with high hardness, castings of type CD4MCuN alloy have excellent resistance to environments involving abrasion or erosion-corrosion. The alloy also shows exceptional resistance to stress-corrosion cracking in chloride-containing solutions or vapors, and is usefully employed in handling both oxidizing and reducing corrodents.

As cast, these alloys have a two-phase, ferrite plus austenite structure. Because of the low carbon content (0.04 percent maximum), there are only small amounts of chromium carbides distributed throughout the matrix, but for maximum corrosion resistance, these must be dissolved by suitable heat treatment. Generally these alloys are used only in the solution annealed condition, aging of these grades will result in a loss of ductility and toughness. Elevated temperature applications in the range 500 to 950°F (260 to 510°C) should be avoided because long time heating at this range will result in a serious loss of ductility and toughness.

Castings of these types have good machining and welding characteristics. Thermal expansion of this alloy is about 20 percent greater than for carbon steel, but about 30 percent less than for the CF alloy types. Thermal conductivity and electrical resistivity are comparable to the CF alloys and are roughly five times the values for carbon steel. The alloys are ferromagnetic.

Physical properties CD4MCu

Modulus of elasticity, psi x 10^6	29.0
Density, lb/in^3	0.28
Sp. Heat, Btu/lb.°F, at 70 °F	0.11
Electrical resistivity, µΩ.m, at 70 °F	0.75
Melting point, approximate °F	2700
Magnetic permeability	Ferromagnetic

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion µ in./(in. °F)	
At 212 °F	8.8	70 - 212 °F	6.3
At 1000 °F	13.4	70 - 600 °F	6.6
		70 - 1000 °F	6.9
		70 - 1200 °F	7.0

Additional properties at room temperature, CD4MCu

	Representative values Water quenched From 1900 °F
Tensile strength, ksi	108.0
Yield strength, 0.2% offset, ksi	81.5
Elongation, in 2in., %	25
Reduction of Area, %	45
Brinell hardness (HBW)	253
Charpy V-notch see figs.1a and 1b at Elevated temperatures see fig.2	

Heat Treatment

For complete solution of carbides and maximum corrosion resistance, castings should be heated for a sufficient time to be uniformly at the temperatures shown in Table 1, and quenched in water, oil or air. The temperature from which castings are quenched should be as close to the high side of the previously stated range as is consistent with avoidance of cracking for the casting configuration involved. Time to attain solution temperature will vary with the thickness of casting sections, and should be sufficiently long to heat all sections to a uniform temperature throughout.

The solution treatment temperature shown in Table 1 have been shown to be adequate in dissolving all carbides and intermetallic precipitates. The lower hold temperatures mentioned in Table 1 do not appear to impart any improvement in processing capability or properties of these grades.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where these alloys has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Chemical Processing, Marine, Municipal Water Supply, Naval, Paint, Petroleum Refining, Power Plant, Pulp and Paper, Soap Manufacturing, Textile, Transportation.

Castings Compressor cylinders, digester valves, feed screws, impellers, liners, pump casings, runway light fixtures (aircraft carriers, airports), safety valves, seal rings (centrifugal pumps), valve parts.

Corrosives Concentrated brine, fatty acids, potable water, pulp liquors at 220°F (104°C), sea water, steam, sulfuric acid [15-30% at 140-160°F (60-71°C)], sulfuric acid [35-40% at 185°F (85°C) plus 5% organics], titanium dioxide plus sulfuric acid solution, titanium sulfate.

<u>NOTE</u>: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made

to an experienced high alloy foundry and to corrosion data surveys published by the NACE to determine whether DSS and SDSS alloys are suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The methods in ASTM A923 may be used to determine the presence of detrimental intermetallic precipitates in various duplex stainless steels.

The mechanical properties are taken from ASTM. The physical property data presented in tabular and graphical form are representative for the alloy CD4MCu. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily. Somewhat lighter sections are feasible depending on casting design and pattern equipment. This alloy permits designs involving intricate shapes. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 1/4 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the molding method and by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding DSS and SDSS castings can be welded with shielded metal-arc and inert-gas arc methods. Matched or overmatched filler metals may be used. Preheating is not required. Matched fillers have a composition which is similar to the base metal and will require post weld heat treatment in accordance with Table 1. Overmatched fillers have approximately 2% more nickel than the base metal to balance the ferrite content due to the high cooling rates of the weld metal. Overmatched rods are particularly suitable for conditions where postweld heat treatment may not be possible such as very large castings of field welds. Having said this it is not uncommon for foundries to carry out a post weld heat treatment on welds made with overmatching fillers. This requirements for post weld heat treatment is often made by customers and specifications.

Machining Most machining operations can be performed satisfactorily on DSS and SDSS castings. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface.

Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Because chips are tough and stringy, chip curler tools are recommended.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Castings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloys
The American Iron and Steel Institute wrought alloy designations are listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of casting

Cast (ASTM)	Wrought (UNS)
A890 - CD4MCu, CD4MCuN, A995 - CD4MCuN	S32550
A890 - CD3MCuN	
A890, A995 - CE8MN,	
A890, A995 - CD3MN,	S39205
A890, A995 - CE3MN	S32750
A890, A995 - CD3MWCuN	S32760

Table 1: Heat treatment Requirements

Grade	Heat Treatment
CD4MCu, CD4MCuN, CD3MCuN	Heat to 1900°F (1040°C) minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
CE8MN	Heat to 2050°F (1120°C) minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
CD6MN	Heat to 1950°F (1070°C) minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or rapid cool by other means.
CD3MN	Heat to 2050°F (1120°C) minimum, hold for sufficient time to heat casting uniformly to temperature and water quench, or the casting may be furnace cooled to 1850°F (1010°C) minimum, hold for 15 min minimum and then water quench. A rapid cool by other means may be employed in lieu of water quench.
CE3MN	Heat to 2050°F (1120°C) minimum, hold for sufficient time to heat casting to temperature, furnace cool to 1910°F (1045°C) minimum, quench in water or rapid cool by other means.
CD3MWCuN	Heat to 2010°F (1100°C) minimum, hold for sufficient time to heat casting uniformly to temperature, quench in water or cool rapidly by other means.

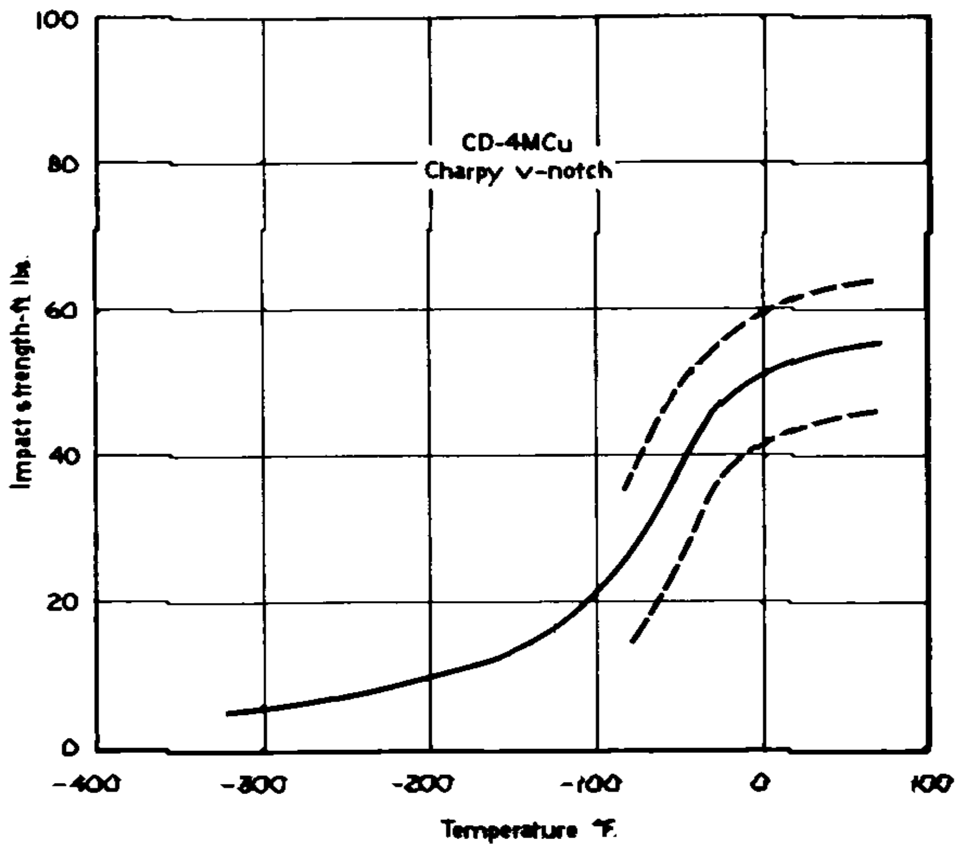


Fig. 1a . Room temperature and sub zero impact strength of solution annealed (2050°F., furnace cooled to 1900°F., water quenched) Type CD-4MCu. Dashed lines indicate probable spread of individual values.

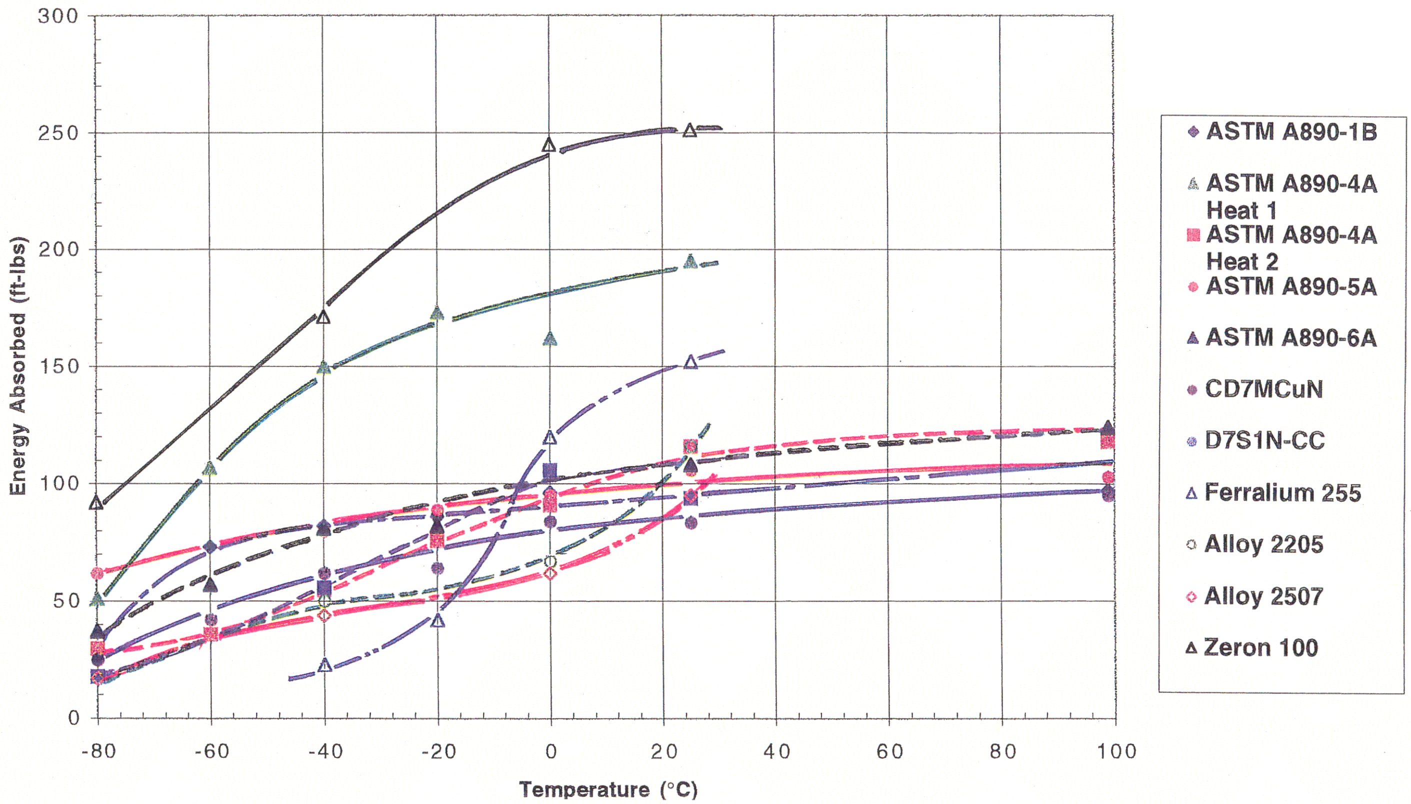


Figure 1b Toughness of Solution Annealed Duplex Stainless Steel Castings and Companion Wrought Alloys.

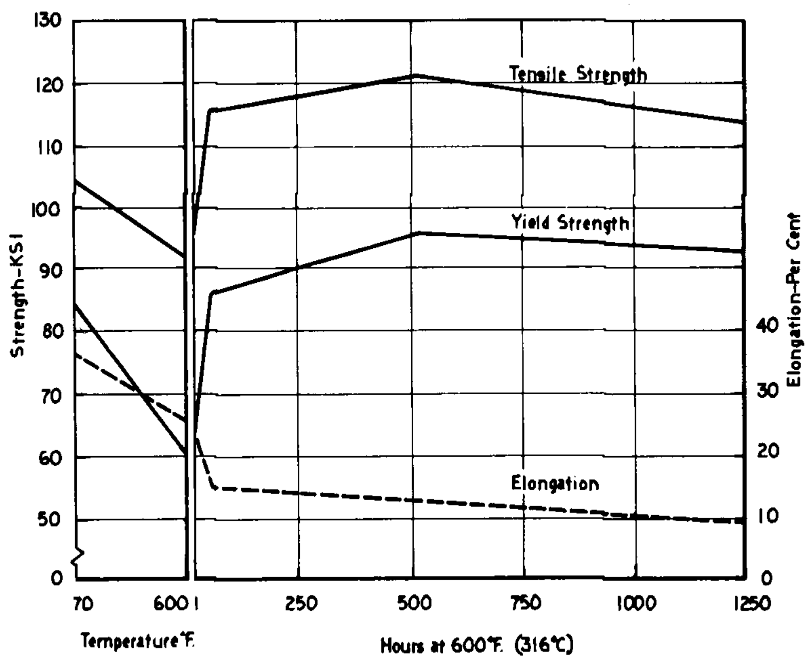


Fig. 2. Short-time tensile properties of solution annealed Type CD-4MCu alloy at 600°F. (316°C.), after holding a temperature for various times before testing, in comparison with room temperature properties.

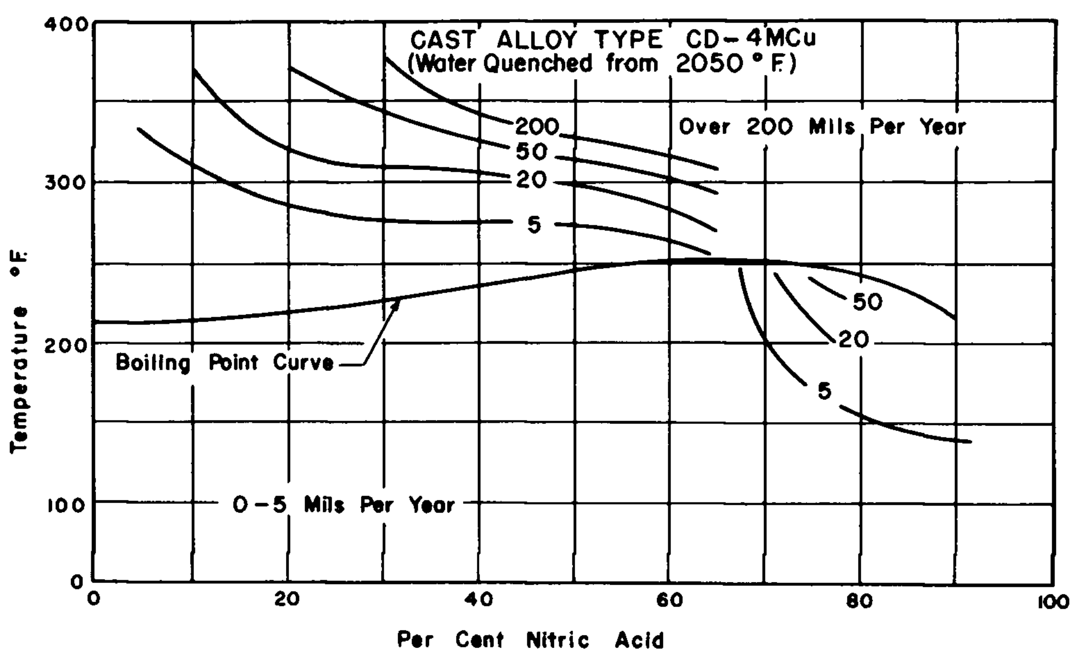


Fig. 3. Corrosion penetration rates in mils per year of Type CD-4MCu in nitric acid.

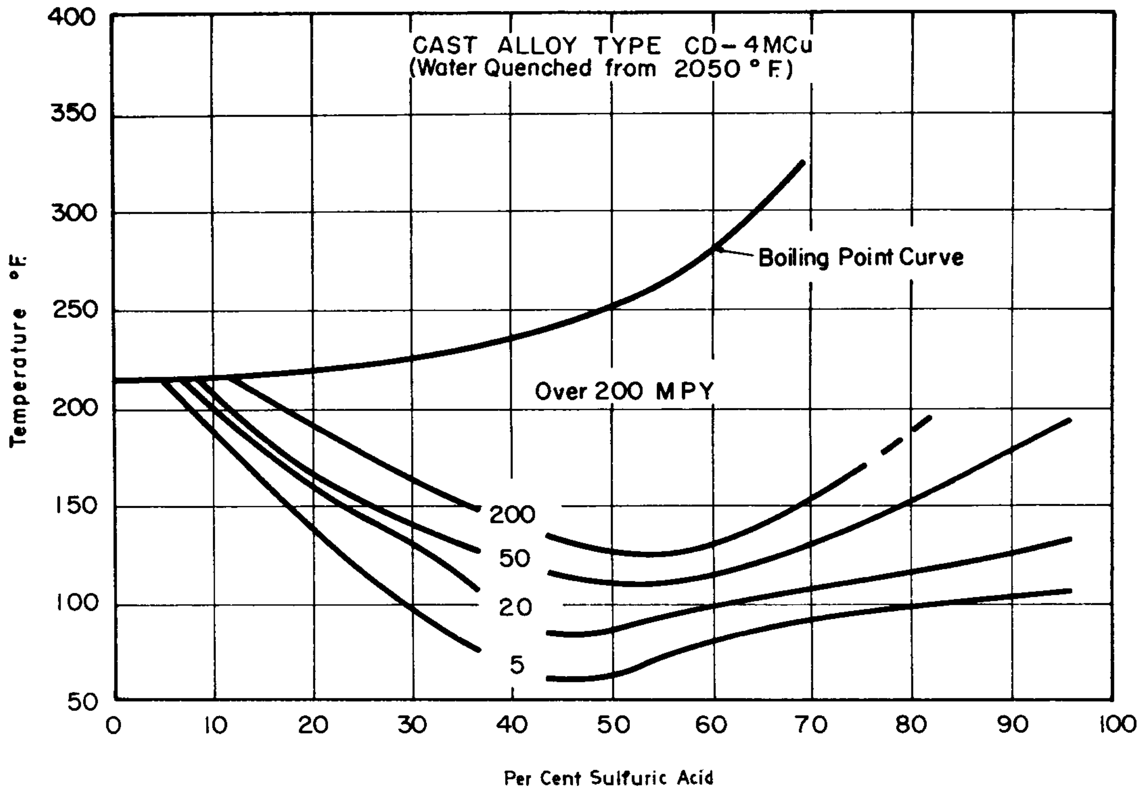


Fig. 4. Corrosion penetration rates in mils per year of Type CD-4MCu in sulfuric acid.

Corrosion Resistant Type CE30 (UNS J93423)

Description

Type CE30 is an iron-chromium-nickel alloy high in chromium but containing sufficient nickel to provide better strength and ductility than can be obtained with the high chromium CC50 type. The alloy is particularly resistant to sulfurous acid and sulfites in the paper industry, dilute sulfuric acid with sulfurous acid, and sulfuric with nitric acid.

(Please note that the composition of the heat resistant alloy, type HE, having a carbon content range of 0.20 percent to 0.50 percent and a manganese content of 2.00 percent max., overlaps that of corrosion resistant alloy, type CE30).

In the as-cast condition, the alloy has a two-phase, austenite plus ferrite structure containing carbides. The high chromium content and the duplex structure permit a fairly high carbon content without serious loss of corrosion resistance when the alloy is exposed to temperatures in the carbide precipitation range, 800 to 1600°F (427 to 871°C). For this reason, the alloy is useful where castings cannot be heat treated effectively, or where they must be welded without subsequent heat treatment.

Long exposure in the range 800-900°F (427-482°C) and 1500-1600°F (816-871°C), however, will result in a significant loss of toughness. This loss of toughness increases with increasing ferrite content. On the other hand, resistance to stress-corrosion cracking by chlorides and by polythionic acid increases with increasing ferrite content.

Type CE30 cannot be hardened by heat treatment, but the ductility and corrosion resistance can be improved somewhat by quenching the alloy from about 2000°F (1093°C).

A modification of the CE30 alloy having the composition balanced to obtain ferrite

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Fe
min.						26	8	
max.	0.30	1.50	2.00	0.04	0.04	30	11	bal

Physical properties

Modulus of elasticity, psi x 10^6	25.0
Density, lb/in^3	0.277
Sp. Heat, Btu/lb.°F, at 70 °F	0.14
Electrical resistivity, μΩ.m, at 70 °F	0.85
Melting point, approximate °F	2650
Magnetic permeability	> 1.5

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion μ in./(in. °F)	
At 212 °F	8.5	70 - 1000 °F	9.6
At 600 °F	10.5	70 - 1200 °F	9.9
At 1000 °F	12.4	70 - 1400 °F	10.2
At 1200 °F	13.5	70 - 1600 °F	10.5

Mechanical properties at room temperature

		Representative values As Cast	Representative values Water quench from 2000 °F to 2050 °F	Minimum tensile requirements ASTM A743
Tensile strength, ksi		95.0	97.0	80.0
Yield strength, 0.2% offset, ksi	65.0	45.0	63.0	40.0
Elongation, in 2in., %		15	18	10
Brinell hardness (HBW)		190	190	-
Charpy, Keyhole, ft. lbs		20	7	

Ratio of Yield and Tesile Strength at
Elevated Temperature to Room Temperature Strength

Temperature °C	°F	Ferrite # 6-8 Tensile Strength Ratio	Ferrite # 6-8 Yield Strength Ratio	Ferrite # 40-52 Tensile Strength Ratio	Ferrite # 40-52 Yield Strength Ratio
21	70	1.000	1.000	1.000	1.000
50	122	0.965	0.937	0.965	0.952
100	212	0.908	0.835	0.908	0.875
150	302	0.859	0.750	0.878	0.802
200	392	0.824	0.688	0.863	0.745
250	482	0.800	0.650	0.860	0.720
300	572	0.781	0.627	0.858	0.711
350	662	0.766	0.604	0.853	0.707
400	752	0.752	0.583	0.840	0.703
450	842	0.731	0.561	0.813	0.695
500	932	0.702	0.538	0.745	0.670
550	1022	0.655	0.511	0.635	0.597
600	1112	0.580	0.485	0.500	0.487

contents within the range of 5 to 20 percent is being used in oil refinery applications at temperatures around 825°F (440°C). This "controlled ferrite" grade is designated CE30A. This modified grade is more resistant to stress-corrosion cracking by polythionic acid and some chlorides.

Castings of the type CE30 alloy have good machining and welding properties. The alloy is magnetic, but not strongly so. Thermal expansion is about 50 percent greater than that of carbon steel or the iron-chromium, CA, CB, and CC types, and is comparable to the CF grades.

Heat Treatment

Type CE30 castings are used in the as-cast condition for many applications. For maximum corrosion resistance and improved ductility, however, castings should be heated in the range 2000-2050°F (1093-1121°C), and then quenched in water, oil or air to hold as great a portion of the carbides in solution as possible. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CE30 alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Chemical Processing, Mining, Oil Refining, Pulp and Paper, Synthetic Fibre Manufacturing.

Castings Digester necks and fittings, fittings, circulating systems, fractionating towers, piping, pump bodies and casings, valve bodies and parts.

Corrosives Acid mine water, caustic soda, hot nitric acid, hot oil products, organic acids, polythionic acid, sulfite liquors.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CE30 is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CE30. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CE30 alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Good castability of this alloy permits designs involving intricate shapes. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 5/16 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CE30 castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Preheating is not required, but after welding castings should be quenched from 2000 to 2050°F (1093 to 1121°C) to restore maximum corrosion resistance. Lime coated electrodes of similar composition (AWS E312-15) are recommended for arc welding.

Machining Most machining operations can be performed satisfactorily on castings of CE30 alloy. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface from rubbing or scraping. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Chips curlers are recommended.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy
The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A743 (CE30).

Wrought AISI 312.

Also, practices for estimating ferrite content in cast alloys are found in ASTM A799 and A800.

Corrosion Resistant Type CF3 (UNS J92500)

Description

Type CF3 is an iron-chromium-nickel alloy of the same family as types CF8 and CF20, but with the carbon content restricted to 0.03 percent maximum. Its corrosion resistance is equal to or better than type CF8 so it is used in similar applications, but particularly in those where post-weld heat treatment is inconvenient or impossible. Damaged ship propellers made of this ductile alloy, for example, can be straightened and repair welded without subsequent heat treatment with no impairment of corrosion resistance. Accordingly, type CF3 is widely used in riverboat service.

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Fe
min.						17	8	
max.	0.03	1.50	2.00	0.04	0.04	21	12	bal

Physical properties

Modulus of elasticity, psi x 10^6	25.0
Density, lb/in^3	0.277
Sp. Heat, Btu/lb.°F, at 70 °F	0.14
Electrical resistivity, μΩ.m, at 70 °F	0.85
Melting point, approximate °F	2650
Magnetic permeability	1.2 to 3.0

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion μ in./(in. °F)	
At 212 °F	9.2	70 - 212 °F	9.0
At 1000 °F	12.1	70 - 1000 °F	10.0

Mechanical properties at room temperature

	Representative values: Water quench from Above 1950 °F		Minimum tensile requirements ASTM A743	
	CF3	CF3A	CF3	CF3A
Tensile strength, ksi	77.0	87.0	70.0	77.0
Yield strength, 0.2% offset, ksi	36.0	42.0	30.0	35.0
Elongation, in 2in., %	60	50	35	35
Brinell hardness (HBW)	140	160	-	-
Charpy V-notch, ft.lbs	110	100	-	-

As cast, the alloy has an austenite structure containing about 5 to 20 percent ferrite in the form of discontinuous pools, but with virtually no chromium carbides. For this reason, the CF-3 grade is suitable for use in many corrodents without the necessity for heat treatment. To be sure of maximum corrosion resistance, however, a solution heat treatment is desirable. If the heat treated alloy is later exposed to temperatures around 1200°F (649°C) for relatively short times, as would occur in the heat-affected zone of a weld, any chromium carbides that are formed would precipitate in the ferrite pools, thereby avoiding any tendency toward intergranular corrosion in service and eliminating the need for further heat treatment. A "controlled ferrite" grade, CF3A, has its chemical composition balanced so as to obtain the minimum ferrite content necessary to ensure meeting the high mechanical properties specified for this grade, which has been used extensively in nuclear power plant construction. The CF3A alloy is not considered suitable for service temperatures above about 650°F (343°C). At sub-zero temperatures, impact strength of type CF3 is essentially the same as shown for the CF8 grade.

In general, the effect of ferrite on the room-temperature yield and tensile strengths of the type CF3 is the same as that shown for the type CF8. However, because of the lower carbon content of type CF3, the strength values of this type will fall in the lower part, or just below, the "band" of values shown for type CF8. At equal levels of ferrite content, additions of nitrogen result in a significant increase of yield and tensile strengths from room temperature to about 1200°F (649°C). Appropriate ASTM specifications for the CF3 alloy with nitrogen are being prepared.

Castings of the CF3 alloy types have good machining and welding characteristics. Thermal expansion is about 50 percent greater than carbon steel or iron-chromium alloy types CA, CB, and CC.

Below about 1600°F (871°C), heat conductivity is 30 to 50 percent less and, above about 1600°F (871°C), the heat conductivities of these materials are nearly equal. Conversely, the electrical resistance of CF3 is five times greater than that of carbon steel and of the iron-chromium alloys below about 1600°F (871°C), but, above this temperature, the electrical resistance of these materials is nearly the same.

The alloy is weakly magnetic, with magnetism most pronounced in the CF3A grade. Magnetic permeability of the as-cast alloy may change after heat treatment, depending on the thickness of section and casting configuration.

Heat Treatment

For maximum corrosion resistance, castings of CF3 alloy should be heated in the range 1900 to 2050°F (1038 to 1121°C), and then quenched in water, oil or air to ensure complete solution of carbides and sigma phase. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CF3 alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Beverage, Brewery, Distillery, Food, Heavy Water Manufacturing, Marine, Nuclear Power, Petroleum, Pipe Line, Soap and Detergent.

Castings Bowls, discharge cases, impellers, propellers, pump casings, retaining rings, suction manifolds, tubes, valve bodies and parts.

Corrosives Brackish water, phosphate solutions, pressurized water at 570°F., sea water, steam.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CF3 is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CF3. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CF3 alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Good castability of this alloy permits designs involving intricate shapes. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 5/16 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CF3 castings can be welded by shielded metal-arc, inert-gas arc, and oxyacetylene gas methods. Shielded metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Preheating is not required. Post-weld heat treatment usually is unnecessary for type CF3 castings, but, after welding, quenching from above 1900°F (1038°C) may be desirable for surfaces that will be exposed to severe corrosive attack. Lime coated electrodes of similar composition (AWS E308L-15) are recommended.

The welding procedures outlined for alloy CF8 are applicable to alloy CF3. Welding procedures utilizing SMAW, GMAW, and GTAW techniques are described in this section.

Machining Most machining operations can be performed satisfactorily on castings of CF3 alloy. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Because chips are tough and stringy, chip curler tools are recommended.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

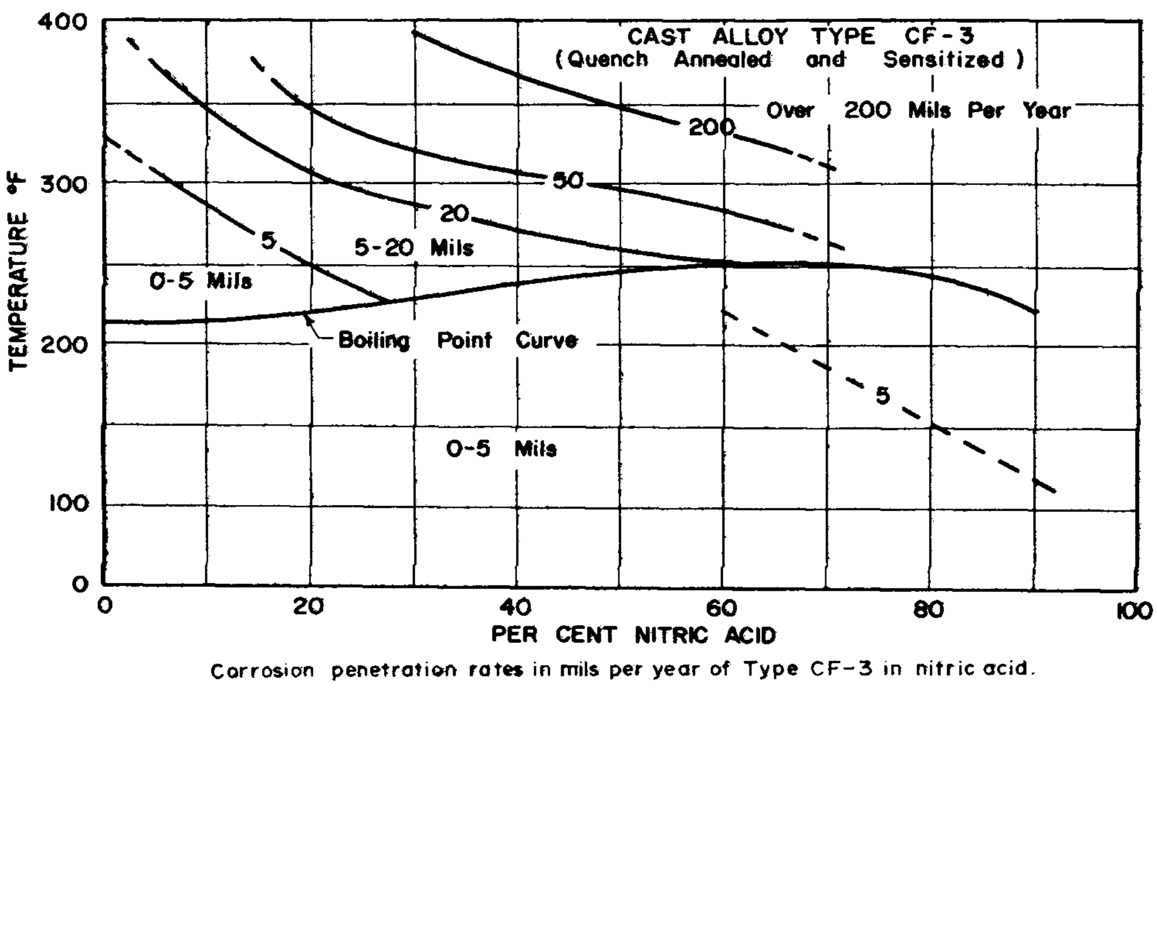
Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy
The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A351 (CF3, CF3A); A451 (CPF3, CPF3A); A743, A744 (CF3).

Wrought AISI 304L.

Also, practices for estimating ferrite content in cast alloys are found in ASTM A799 and A800.



Corrosion penetration rates in mils per year of Type CF-3 in nitric acid.

Corrosion Resistant Type CF3M (UNS J92800)

Description

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Mo	Fe
min.						17	9	2.0	
max.	0.03	1.50	1.50	0.04	0.04	21	13	3.0	bal

Physical properties

Modulus of elasticity, psi x 10^6	28.0
Density, lb/in^3	0.28
Sp. Heat, Btu/lb.°F, at 70 °F	0.12
Electrical resistivity, µΩ.m, at 70 °F	0.82
Melting point, approximate °F	2600
Magnetic permeability	1.5 - 3.0

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion µ in./(in. °F)	
At 212 °F	9.2	-325 - 70 °F	8.1
At 1000 °F	12.1	-260 - 70 °F	8.2
		-150 - 70 °F	8.6
		70 - 212 °F	9.0
		70 - 1000 °F	10.0
		70 - 1200 °F	10.2

Mechanical properties at room temperature

	Representative values Water quench from above 1900 °F		Minimum tensile requirements ASTM A743	
Tensile strength, ksi	80.0	90.0	70.0	80.0
Yield strength, 0.2% offset, ksi	38.0	45.0	30.0	30.0
Elongation, in 2in., %	55	45	30	30
Brinell hardness (HBW)	150	170	-	-
Charpy V-notch, ft lbs	120	100	-	-

Type CF3M is an iron-chromium-nickel-molybdenum alloy of the same family as type CF8M, but with the carbon content restricted to 0.03 percent maximum. This extra-low carbon limit makes the alloy useful in applications requiring field welding where post-weld heat treatment is inconvenient or impossible. Corrosion resistance of CF3M and general fields of application for the alloy are essentially the same as those of the CF8M grade, and equal to or better than that of the corresponding wrought grade.

As normally produced, the CF3M alloy has an austenitic microstructure containing discrete ferrite pools amounting to about 5 percent to 20 percent by volume. When exposed to welding temperatures, these ferrite pools provide a preferred location for precipitation of any carbides that may form, and thus reduce the sensitivity of the alloy by intergranular corrosion caused by grain boundary precipitates. Furthermore, the low carbon content of the alloy limits the formation of significant amounts of chromium carbide in any event, so post-weld heat treatment is not required.

The combination of molybdenum and low carbon content tends to unbalance the composition in the direction of high ferrite in the alloy microstructure unless the amounts of chromium and nickel are adjusted so as to maintain the ferrite at a low level. Because an increase in ferrite content is accompanied by an increase in mechanical strength, a "controlled ferrite" grade of CF3M is made, under the designation of CF3MA. In this grade, the chemical composition is balanced to obtain a ferrite content sufficiently high to meet minimum yield strength specifications that are about 25 percent higher than for the normal CF3M type. Thermal instability of the microstructure at these high ferrite levels makes the CF3MA alloy generally unsuitable for operation at temperatures above 800°F (427°C).

Castings of the CF3M alloy types have good machining and welding characteristics. Thermal expansion is about 50 percent greater than carbon steel or iron-chromium alloy types CA, CB, and CC.

Below about 1600°F (871°C), heat conductivity is 30 to 50 percent less and, above about 1600°F (871°C), the heat conductivities of these materials are nearly equal. Conversely, the electrical resistance of CF3M is five times greater than that of carbon steel and of the iron-chromium alloys below about 1600°F (871°C), but, above this temperature, the electrical resistance of these materials is nearly the same.

The alloy is weakly magnetic, with magnetism most pronounced in the CF3MA grade. Magnetic permeability of the as-cast alloy may change after heat treatment, depending on the thickness of section and casting configuration.

Heat Treatment

For maximum corrosion resistance, castings of CF3M alloy should be heated in the range 1900 to 2050°F (1038 to 1121°C), and then quenched in water, oil or air to ensure complete solution of carbides and sigma phase. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CF3M alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Chemical, Copper Mining, Food Processing, Paper Mill, Petroleum, Pipe Line, Power Plant (Fossil Fuel, Hydro, Nuclear), Water Supply.

Castings Mixer parts, pump casings and impellers, tubes, valve bodies and parts.

Corrosives Acetic acid, calcium carbonate, calcium lactate, potable water, sea water, steam, sulfites.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CF3M is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CF3M. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CF3M alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Good castability of this alloy permits designs involving intricate shapes. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 5/16 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding
Type CF3M castings can be welded by shielded metal-arc, inert-gas arc, and oxyacetylene gas methods. Shielded metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Preheating is not required. Post-weld heat treatment usually is unnecessary for type CF3M castings, but, after welding, quenching from above 1900°F (1038°C) may be desirable for surfaces that will be exposed to severe corrosive attack. Lime coated electrodes of similar composition (AWS E316L-15) are recommended.

The welding procedures outlined for alloy CF8M are applicable to alloy CF3M. Welding procedures utilizing SMAW, GMAW, and GTAW techniques are described in this section.

Machining Most machining operations can be performed satisfactorily on castings of CF3M alloy. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Because chips are tough and stringy, chip curler tools are recommended.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6^{th} Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy
The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A351 (CF3M, CF3MA); A451 (CPF3M); A743, A744 (CF3M).

Wrought AISI 316L.

Also, practices for estimating ferrite content in cast alloys are found in ASTM A799 and A800.

Corrosion Resistant Type CF8 (UNS J92600)

Description

Type CF8 is an iron-chromium-nickel alloy having good strength and ductility, and excellent resistance to a wide variety of corrodents. The alloy is especially useful in resisting attack by strongly oxidizing media such as boiling nitric acid. Castings of type CF8 alloy have excellent sub-zero properties, retaining high impact strength at temperatures below -400°F (-240°C), as shown in Fig. 2. Corrosion resistance of the cast alloy is equal to or better than the corresponding grade of wrought alloy.

As cast, the alloy has a predominantly austenitic structure containing chromium carbides and varying amounts of ferrite distributed throughout the matrix. The carbides must be put into solution by heat treatment to provide maximum corrosion resistance. If the heat treated material is later exposed to temperatures in the range 800 to 1600°F (427 to 871°C), carbides will be reprecipitated; this takes place quite rapidly around 1200°F (649°C). Castings thus "sensitized", as in welding, must be solution heat treated again to restore full corrosion resistance. Type CF8 alloy cannot be hardened by heat treatment, but ductility is improved.

The alloy, as normally produced, contains about 10 percent ferrite which takes the form of discrete pools in the microstructure. This ferrite is helpful in avoiding intergranular corrosion in castings exposed to temperatures in the sensitizing range, since carbides are precipitated in the discontinuous ferrite pools rather than in the grain boundaries. It also reduces the tendency for the cracking or microfissuring of welds that is experienced with wholly austenitic alloys. At higher ferrite contents, the strength of the alloy and its resistance to stress corrosion cracking are substantially increased. For this reason, the composition is balanced in the "controlled ferrite", CF8A, grade to obtain considerably higher minimum tensile properties at both room and elevated temperatures up to about 800°F (427°C) than the ordinary CF8 type. The CF8A alloy is not

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Fe
min.						18	8	
max.	0.08	1.50	2.00	0.04	0.04	21	11	bal

Physical properties

Modulus of elasticity, psi x 10^6	See Fig. 1
Density, lb/in^3	0.28
Sp. Heat, Btu/lb.°F, at 70 °F	0.12
Electrical resistivity, μΩ.m, at 70 °F	0.762
Melting point, approximate °F	2600
Magnetic permeability	1.0 - 1.3

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion μ in./(in. °F)	
At 212 °F	9.2	-325 - 70 °F	8.1
At 1000 °F	12.1	-260 - 70 °F	8.2
		-150 - 70 °F	8.6
		70 - 212 °F	9.0
		70 - 1000 °F	10.0
		70 - 1200 °F	10.2

Mechanical properties at room temperature

	Representative values Water quench from above 1900 to 2050 °F		Minimum tensile requirements ASTM A743	
	CF8	CF8A	CF8	CF8A
Tensile strength, ksi	77.0	95.0	70.0	77.0
Yield strength, 0.2% offset, ksi	37.0	45.0	35.0	35.0
Elongation, in 2in., %	55	50	30	35
Brinell hardness (HBW)	140	156	-	-
Impact	see fig 2			

Ratio of Yield and Tesile Strength at Elevated Temperature to Room Temperature Strength

Temperature		Ferrite # 2-4		Ferrite # 18-23		Ferrite # 33-38	
°C	°F	Tensile Strength Ratio	Yield Strength Ratio	Tensile Strength Ratio	Yield Strength Ratio	Tensile Strength Ratio	Yield Strength Ratio
-21	70	1.000	1.000	1.000	1.000	1.000	1.000
50	122	0.945	0.911	0.945	0.931	0.945	0.931
100	212	0.865	0.783	0.865	0.828	0.865	0.828
150	302	0.812	0.671	0.812	0.738	0.812	0.738
200	392	0.790	0.590	0.790	0.665	0.790	0.665
250	482	0.787	0.541	0.787	0.620	0.787	0.620
300	572	0.782	0.520	0.782	0.605	0.782	0.605
350	662	0.778	0.509	0.778	0.595	0.778	0.595
400	752	0.772	0.495	0.772	0.585	0.772	0.585
450	842	0.733	0.478	0.746	0.570	0.762	0.570
500	932	0.675	0.458	0.705	0.546	0.735	0.546
550	1022	0.588	0.430	0.640	0.512	0.687	0.512
600	1112	0.490	0.392	0.550	0.462	0.620	0.462

Creep - Rupture Properties

Temperature °F	Estimated Rupture stress, ksi 100h	Estimated Rupture stress, ksi 1000h	Estimated Limiting creep stress, ksi 0.01%/h	Estimated Limiting creep stress, ksi 0.001%/h
1000	38.4	31.3	36.4	31.6
1200	19.4	14.6	9.6	-

considered suitable for service temperatures above about 800°F (427°C). At sub-zero temperatures, alloy compositions balanced to have low ferrite contents have the best impact properties. When non-magnetic castings are needed for an application, compositions can be balanced to be wholly austenitic, *but the producer must be notified of this requirement.*

At equal levels of ferrite content, additions of nitrogen result in a significant increase of yield and tensile strengths from room temperature to about 1200°F (649°C). Appropriate ASTM specifications for the CF8 alloy with nitrogen are being prepared.

Castings of the CF8 type have good machining and welding characteristics. Thermal expansion is about 50 percent greater than carbon steel or iron-chromium alloy types CA, CB, and CC.

Thermal expansion is about 50 percent greater than that of carbon steel or iron-chromium alloy types CA, CB, and CC. Below about 1600°F (871°C), heat conductivity is 30 to 50 percent less; above about 1600°F (871°C), the thermal conductivity of these materials is nearly equal. Conversely, below about 1600°F (871°C), electrical resistivity is 30 to 50 percent greater than that of carbon steel or the iron-chromium alloys, but above about 1600°F (871°C), the electrical resistivity of these materials is about the same.

The alloy varies from non-magnetic to slightly magnetic depending on the composition. Magnetic permeability is not appreciably affected by heat treatment.

Heat Treatment

For maximum corrosion resistance, castings of CF8 alloy should be heated in the range 1900 to 2050°F (1038 to 1121°C), and then quenched in water, oil or air to ensure complete solution of carbides and sigma phase. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CF8 alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Aircraft, Aerospace, Architectural, Beverage and Brewing, Brass Mill, Chemical Processing, Electronic Food Processing, Marine, Military and Naval, Nuclear Power, Oil Refining, Oxygen Manufacturing, Pharmaceutical, Photographic, Plastics, Power Plant, Pulp and Paper, Sewage, Soap Manufacturing, Steel Mill, Synthetic Fibre, Textile.

Castings Architectural trim, Army kitchen fittings, autoclaves, blast furnace bushings, catapult parts, computer parts, cooling gauge, cryogenic valves and fittings, dye padder rolls, engine mountings, fan parts, filter press plates and frames, fittings, flanges, guide roller sleeves, hardware, headers, cream pasteurizer, heating coils, Kier and Kier lid, marine fittings, mixing agitators and propellers, mixing kettles, oil burner throat rings, packing rings, periscope tubes, pumps, pump sleeves, radar tubing, redlers, retaining rings, milk coolers, rotary strainers, sanitary fittings (dairy), scrubber castings, shaft sleeves, spray nozzles, stuffing boxes, valve bodies and trim.

Corrosives Adipic acid, antibiotics and drugs, bleaching compounds, copper sulfate 190°F (88°C), dye, fatty acids, film developer, fruit juices, gasoline, hot air, hot water, hydrocarbons, hypo, liquid oxygen, mixed H_2SO_4-HNO_3, nicotinic acid, nitric acid (hot and concentrated), organic liquids and acids, organic salts, potassium sulfate 1000°F (538°C), sea water, sewage, sodium carbonate, sodium sulfite, steam, sub-zero gases, sulfur dioxide at -20°F (-29°C) 60 psi, 50% sulfuric acid, vinegar, white liquor.

<u>NOTE</u>: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made

to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CF8 is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CF8. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CF8 alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Good castability of this alloy permits designs involving intricate shapes. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 5/16 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CF8 castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Preheating is not required, but after welding castings should be quenched from 1900 to 2050°F (1038 to 1121°C) to restore maximum corrosion resistance. Lime coated electrodes of similar composition (AWS E308-15) are recommended.

Welding procedures utilizing SMAW, GMAW, and GTAW techniques are described in this section.

Machining Most machining operations can be performed satisfactorily on castings of CF8 alloy. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Because chips are tough and stringy, chip curler tools are recommended.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy
The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A743 (CF8); A351, A743, A744 (CF8, CF8A); A451 (CPF8, CPF8A); SAE 60304; MIL-S-867 (Ships) Class I.

Wrought AISI 304.

Also, practices for estimating ferrite content in cast alloys are found in ASTM A799 and A800.

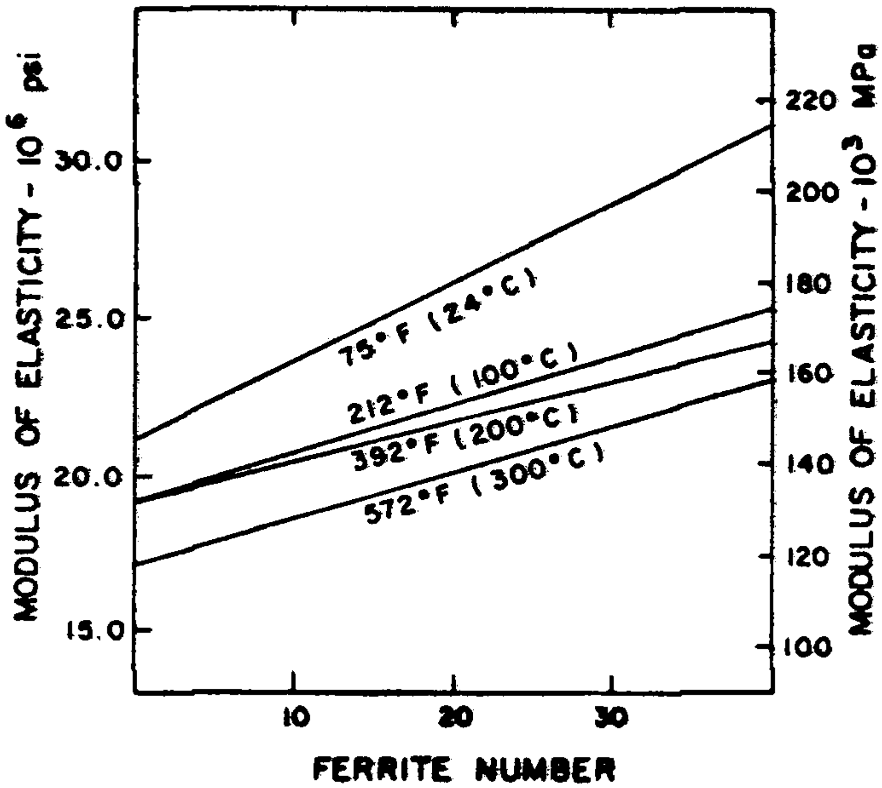


Fig. 1. Influence of ferrite content and temperature on modulus of elasticity of CF-8.

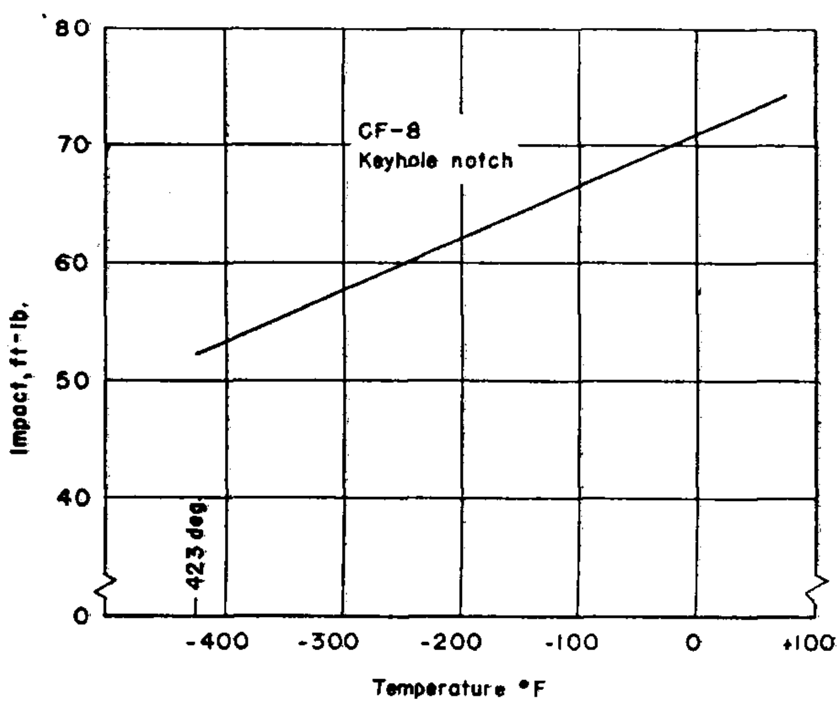


Fig. 2. Room temperature and sub-zero impact strength of Type CF-8.

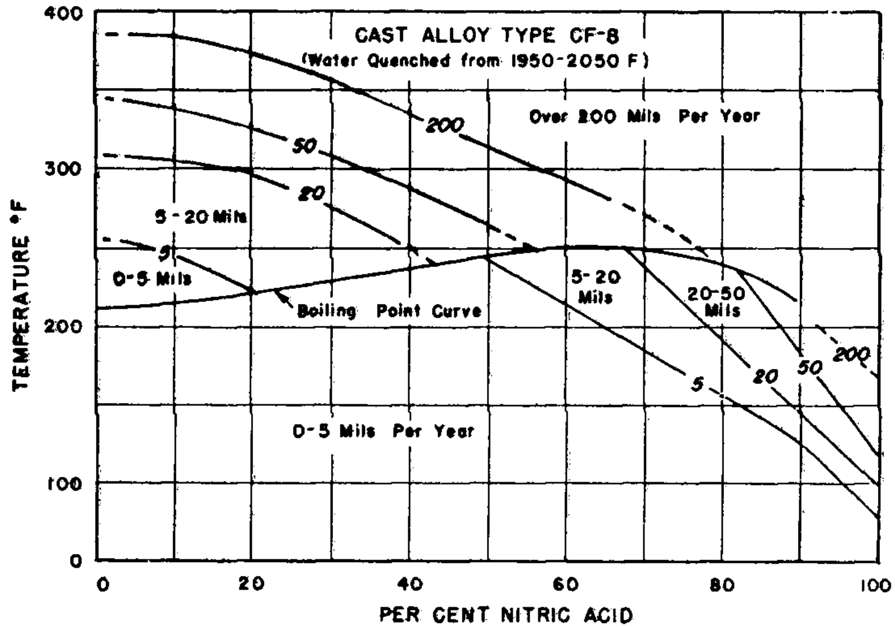


Fig. 3. Corrosion penetration rates in mils per year of Type CF-8 in nitric acid.

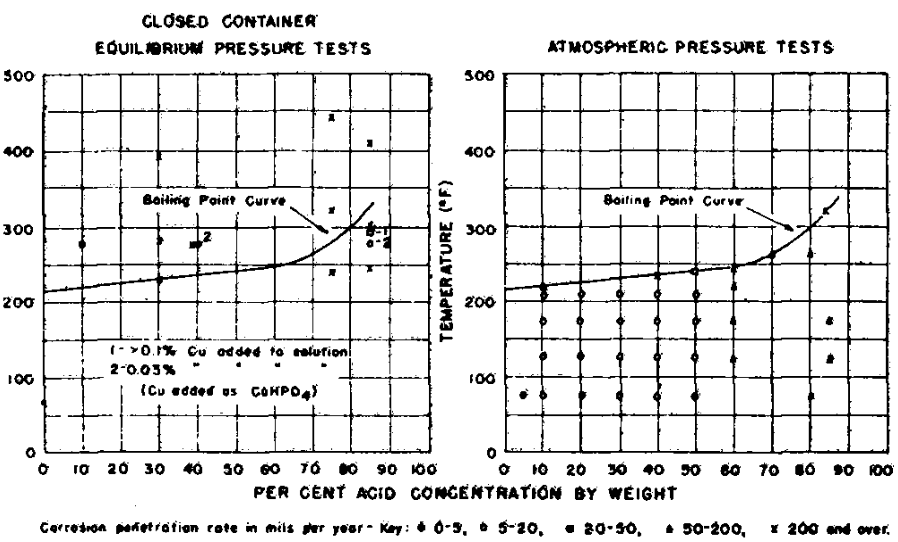


Fig. 4. Corrosion of Type CF-8 by phosphoric acid.

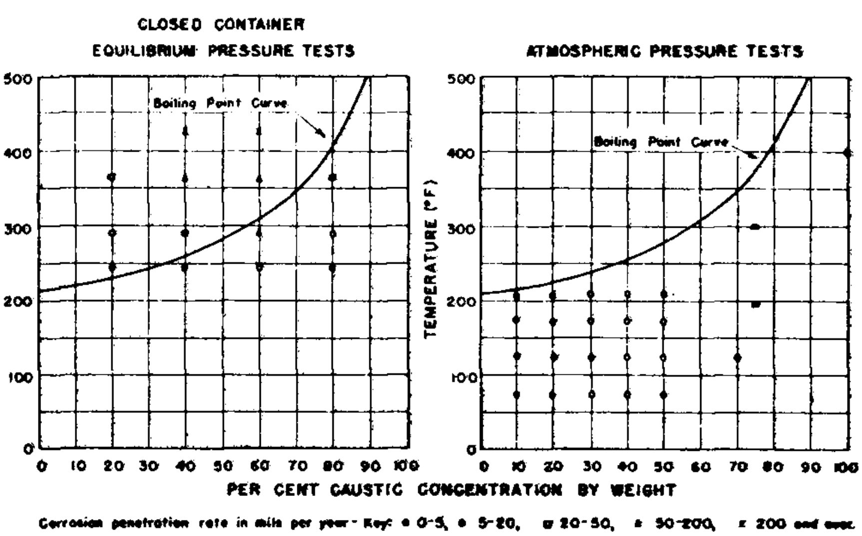


Fig. 5. Corrosion of Type CF-8 by sodium hydroxide.

Corrosion Resistant Type CF8C (UNS J92710)

Description

Type CF8C is an iron-chromium-nickel-columbium alloy especially useful for field welding, or for service involving long exposure to elevated temperatures. It is a modification of the CF8 type to which columbium (or columbium plus tantalum) is added to prevent grain boundary precipitation of chromium carbides when the material is heated in the range 800-1600°F (427-871°C). The alloy is normally used for the same types of service as type CF8, and provides approximately equivalent corrosion resistance.

In the heat treated condition, this alloy has an essentially austenitic structure with small amounts of ferrite (5-20%) distributed throughout the matrix in the form of discontinuous pools. When exposed to temperatures in the range 800-1600°F (427-871°C) for short times (as in welding), or for long times (as in elevated temperature service), precipitation of chromium carbides does not occur if the carbon has been intentionally combined in columbium carbides through prior heat treatment. This circumstance prevents the depletion of chromium along the grain boundary network, and the alloy, therefore, is protected against intergranular corrosion attack. There is no advantage in using this alloy instead of type CF8 if castings can be conveniently solution heat treated after welding, or where there is no danger of exposure to temperatures above 800°F (427°C) in service.

Castings of the CF8C type have good machining and excellent welding characteristics. Thermal expansion is about 50 percent greater than carbon steel or iron-chromium alloy types CA, CB, and CC.

Below about 1600°F (871°C), heat conductivity is 30 to 50 percent less and, above about 1600°F (871°C), the heat conductivities of these materials are nearly equal. Conversely, the electrical resistance of CF8C is five times greater

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Cb	Fe
min.						18	9	8 x C	
max.	0.08	1.50	2.00	0.04	0.04	21	12	1.0[1]	bal

Or Cb - Ta 9 x C min., 1.1 max.

Physical properties

Modulus of elasticity, psi x 10^6	28
Density, lb/in^3	0.28
Sp. Heat, Btu/lb.°F, at 70 °F	0.12
Electrical resistivity, μΩ.m, at 70 °F	0.71
Melting point, approximate °F	2600
Magnetic permeability	1.2 - 1.8

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion μ in./(in. °F)	
At 212 °F	9.3	70 - 212 °F	9.3
At 1000 °F	12.8	70 - 1000 °F	10.3

Mechanical properties at room temperature

	Representative values Water quench from above 1900 to 2050 °F	Minimum tensile requirements ASTM A743
Tensile strength, ksi	77.0	70.0
Yield strength, 0.2% offset, ksi	38.0	30.0
Elongation, in 2in., %	39	30
Brinell hardness (HBW)	149	-
Charpy, keyhole, ft lbs	30	

Ratio of Yield and Tesile Strength at
Elevated Temperature to Room Temperature Strength

Temperature °C	°F	Tensile Strength Ratio	Yield Strength Ratio
21	70	1.000	1.000
50	122	0.924	0.922
100	212	0.851	0.845
150	302	0.811	0.791
200	392	0.788	0.750
250	482	0.772	0.719
300	572	0.762	0.692
350	662	0.752	0.671
400	752	0.742	0.655
450	842	0.731	0.639
500	932	0.713	0.627
550	1022	0.680	0.614
600	1112	0.630	0.601

Creep - Rupture Properties

Temperature °F	Estimated Rupture stress, ksi 100h	1000h	Estimated Limiting creep stress, ksi 0.001%/h
1000	51.6	43.0	43.0
1200	27.0	19.5	19.5

than that of carbon steel and of the iron-chromium alloys below about 1600°F (871°C), but, above this temperature, the electrical resistance of these materials is nearly the same.

The alloy is slightly magnetic.

Heat Treatment

Type CF8C castings can be used as-cast, but they are normally supplied in the heat treated condition. Heat treatment consists of heating in the range 1950-2050°F (1066-1121°C) followed by quenching in water, oil or air to ensure complete solution of any chromium carbides that might have formed in the casting process. A "stabilizing" treatment at 1600 to 1650°F (871 to 899°C) following the solution treatment will cause the preferential precipitation of columbium carbides, and is desirable if castings are for service in the 800 to 1500°F (427 to 816°C) temperature range. Holding times at heat treatment temperatures will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CF8C alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Aircraft, Nuclear, Chemical Processing, Marine, Oil Refining, Plastics.

Castings Aircraft shroud assemblies, autoclaves, chemical tubing, digesters, engine exhaust fittings, filter press plates, fittings (welding), glands, inlet ring for tank exhaust, jet engine parts, marine fittings, port plates, pump parts, return bends for welding, rotors, tank parts, valve bodies.

Corrosives Hydrogen sulfide gas, petroleum products at high temperatures and pressures, plastics, products of combustion of high octane gasoline.

<u>NOTE</u>: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CF8C is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CF8C. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CF8C alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Good castability of this alloy permits designs involving intricate shapes. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 11/32 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CF8C castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Preheating is not required, but after welding castings may be quenched from 1950 to 2050°F (1066 to 1121°C) to restore maximum corrosion resistance. Postweld heat treatment usually is not necessary. Lime coated electrodes of similar composition (AWS E347-15) are recommended.

Machining Most machining operations can be performed satisfactorily on castings of CF8C alloy. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. This alloy is somewhat easier to machine than the CF8 type, but the chips are tough and chip curler tools are recommended.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy

The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A351, A743, A744 (CF8C); A451 (CPF8C); AMS 5363B; SAE 60347; MIL-S-867 (Ships) Class II.

Wrought AISI 347.

Also, practices for estimating ferrite content in cast alloys are found in ASTM A799 and A800.

Effect of Ferrite Content on 0.2% Yield--CF8C #1

Lower limit		Upper limit	
% Ferrite	ksi	% Ferrite	ksi
-	-	0	36.875
5	30.625	5	40.313
10	33.750	10	43.438
15	36.563	15	46.250
2	38.438	20	48.125
25	40.000	25	49.375
30	41.563	30	50.313

Effect of Ferrite Content on Tensile Strength of CF8C #2

Lower limit		Upper limit	
% Ferrite	ksi	% Ferrite	ksi
0	60.313	0	72.344
5	71.563	5	77.500
10	75.938	10	81.563
15	79.375	15	85.000
20	82.188	20	87.344
25	84.063	25	88.907
30	85.782	30	90.000

Corrosion Resistant Type CF8M (UNS J92900) and CF12M

Description

Type CF8M is an iron-chromium-nickel-molybdenum alloy differing only in carbon content. It is a modification of the CF8 type to which molybdenum is added to enhance general corrosion resistance and to provide greater strength at elevated temperatures. The alloy has good resistance to reducing corrosive media, and is substantially more resistant to pitting corrosion than the CF8 grade when exposed to chlorides as in sea water. Although not quite so resistant to strongly oxidizing corrodents such as boiling nitric acid, the molybdenum containing alloy is more stably passive than the CF8 type under weakly oxidizing conditions. Corrosion resistance of the cast alloy is approximately equal to, or better than, corresponding types of wrought alloys.

In the heat treated condition, this alloy has a predominantly austenitic structure with small amounts of ferrite (15-25%) distributed throughout the matrix in the form of discontinuous pools. When heated in the range 800 to 1600°F (427 to 871°C) (such as would occur in a welding operation), these pools provide a preferred location for carbides to precipitate, thus tending to reduce susceptibility of the alloy to intergranular corrosion caused by precipitation of carbides at austenite grain boundaries. The amount of ferrite present decreases as carbon content of the alloy is increased. By suitable balancing of the compositions, the alloy can be made wholly austenitic and non-magnetic. At operating temperatures of 1200°F (649°C) or higher, ferrite may transform to the brittle sigma phase. Maximum corrosion resistance, however, is associated with low carbon and high chromium contents, and for this reason, the partially ferritic CF8M type is usually employed at operating temperatures below 1000°F (538°C).

Castings of the CF8M type have good machining and welding characteristics. Thermal expansion is about 50 percent

Chemical composition - %

		C	Mn	Si	P	S	Cr	Ni	Mo	Fe
CF8M	min.						18	8	2.0	
	max.	0.08	1.50	2.00[1]	0.04	0.04	21	11	3.0	bal
CF12M	min.						18	8	2.0	
	max.	0.12	1.50	2.00	0.04	0.04	21	11	3.0	bal

[1] Si limited to 1.50 max for CF8M in ASTM A351

Physical properties

Modulus of elasticity, psi x 10^6	28
Density, lb/in^3	0.28
Sp. Heat, Btu/lb.°F, at 70 °F	0.12
Electrical resistivity, μΩ.m, at 70 °F	0.82
Melting point, approximate °F	2550
Magnetic permeability	1.5 - 2.5

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion μ in./(in. °F)	
At 212 °F	9.2	70 - 212 °F	8.9
At 1000 °F	12.1	70 - 1000 °F	9.7

Mechanical properties at room temperature

	Representative values Water quench from above 1950 to 2100 °F[2]	Minimum tensile requirements ASTM A743[3]
Tensile strength, ksi	80.0	70.0
Yield strength, 0.2% offset, ksi	42.0	30.0
Elongation, in 2in., %	50	30
Brinell hardness (HBW)	156 - 170	-
Charpy, keyhole, ft lbs	See fig 1	

[2] Type CF12M quenched from above 2000 °F
[3] Applies to type CF8M only; CF12M not covered by ASTM A743

Ratio of Yield and Tesile Strength at
Elevated Temperature to Room Temperature Strength

Temperature		Ferrite # 3-10		Ferrite # 16-20	
°C	°F	Tensile Strength Ratio	Yield Strength Ratio	Tensile Strength Ratio	Yield Strength Ratio
21	70	1.000	1.000	1.000	1.000
50	122	0.932	0.895	0.968	0.930
100	212	0.867	0.772	0.920	0.839
150	302	0.831	0.692	0.880	0.773
200	392	0.812	0.639	0.855	0.720
250	482	0.809	0.600	0.849	0.680
300	572	0.807	0.571	0.845	0.651
350	662	0.802	0.547	0.842	0.628
400	752	0.797	0.527	0.839	0.607
450	842	0.785	0.510	0.830	0.586
500	932	0.765	0.491	0.795	0.568
550	1022	0.728	0.475	0.740	0.548
600	1112	0.663	0.460	0.663	0.528

Creep - Rupture Properties

Temperature	Estimated Rupture stress, ksi		Estimated Limiting creep stress, ksi	
°F	100h	1000h	0.01%/h	0.001%/h
1000	47.2	42.5	45.2	41.2
1200	24.6	18.2	13.0	-

greater than carbon steel or iron-chromium alloy types CA, CB, and CC.

Below about 1600°F (871°C), heat conductivity is 30 to 50 percent less and, above about 1600°F (871°C), the heat conductivities of these materials are nearly equal. Conversely, the electrical resistance of CF8M is five times greater than that of carbon steel and of the iron-chromium alloys below about 1600°F (871°C), but, above this temperature, the electrical resistance of these materials is nearly the same.

The alloys are ductile and are the strongest of the 19 Cr, 9 Ni types.

Heat Treatment

For maximum corrosion resistance, castings of CF8M and CF12M alloys should be heated in the range 1950 to 2100°F (1066 to 1149°C) and then quenched in water, oil or air to ensure complete solution of carbides and sigma phase. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout. The low side of the range may be used for type CF8M castings.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CF8M alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Aircraft, A.E.C., Chemical Processing, Electronic, Fertilizer, Food Processing, Guided Missile, Marine, Mining, Oil Refining, Pharmaceutical, Photographic, Plastics, Power Plant, Soap, Synthetic Fibre, Synthetic Rubber, Textile.

Castings Agitators, blast plates, centrifuges, evaporator parts, filter press plates and frames, fittings, jet engine components, mixing propellers, pump parts, radar masts, rolls, spool heads, spray nozzles, high pressure steam valves, valve bodies and parts.

Corrosives Acetones, acetic acid, alkaline carbonate, amyl-acetate, ash-laden water, benzene, hexachloride, black liquor, bleaching compounds, blood plasma, chloride solutions, copper refining electrolyte, crude methacrylic acid, dyes (hot), fatty acids, high sulfur mine waters, hydrocarbon vapors, hydrogen peroxide, phosphoric acid [to 85%, to 200°F (93°C)], riboflavin syrup, salt water, slurries (phosphoric plus sulfuric and hydrofluoric acids), steam at high pressures and temperatures, sulfate and sulfite liquors, sulfuric acid (dilute or concentrated, oleum), sulfurous acid, vinyl alcohol.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CF8M is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CF8M. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CF8M alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Good castability of this alloy permits designs involving intricate shapes. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 5/16 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CF8M castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Preheating is not required, but after welding castings should be quenched from 1950 to 2100°F (1066 to 1149°C) to restore maximum corrosion resistance. Postweld heat treatment may be omitted provided castings will not be exposed to highly corrosive solutions. Lime coated electrodes of similar composition (AWS E316-15) are recommended.

Welding procedures utilizing SMAW, GMAW, and GTAW techniques are described in this section.

Machining Most machining operations can be performed satisfactorily on castings of CF8M and CF12M alloys. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Because chips are tough and stringy, chip curler tools are recommended.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy

The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A351, A743, A744 (CF8M); A451 (CPF8M); SAE 60316; MIL-S-867 (Ships) Class III.

Wrought AISI 316.

Also, practices for estimating ferrite content in cast alloys are found in ASTM A799 and A800.

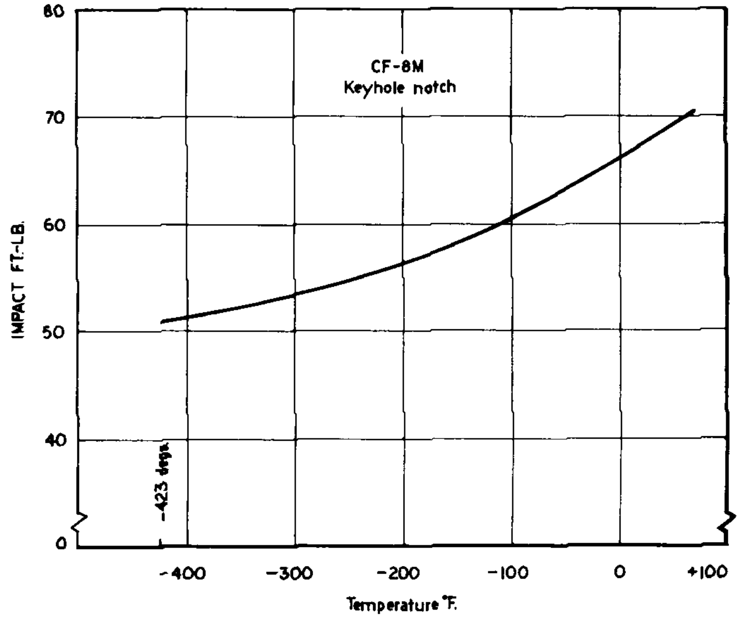


Fig. 1. Room temperature and sub-zero Charpy impact strength (keyhole notch) of Type CF-8M.

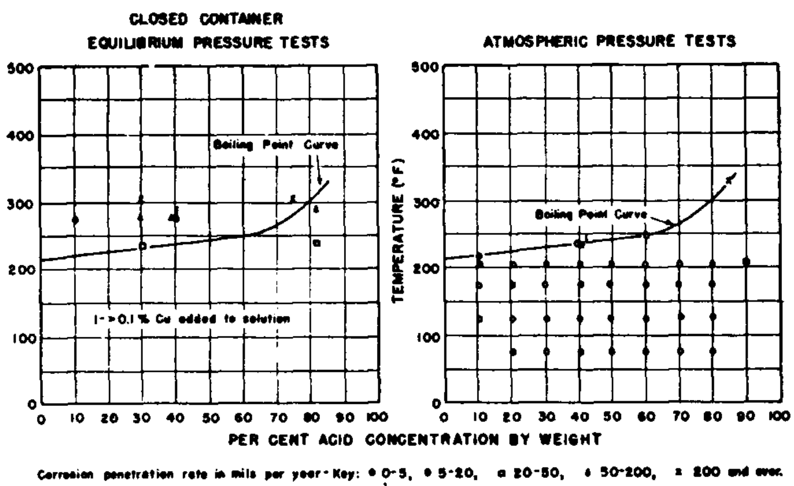


Fig. 2. Corrosion of Types CF-8M and CF-12M by phosphoric acid.

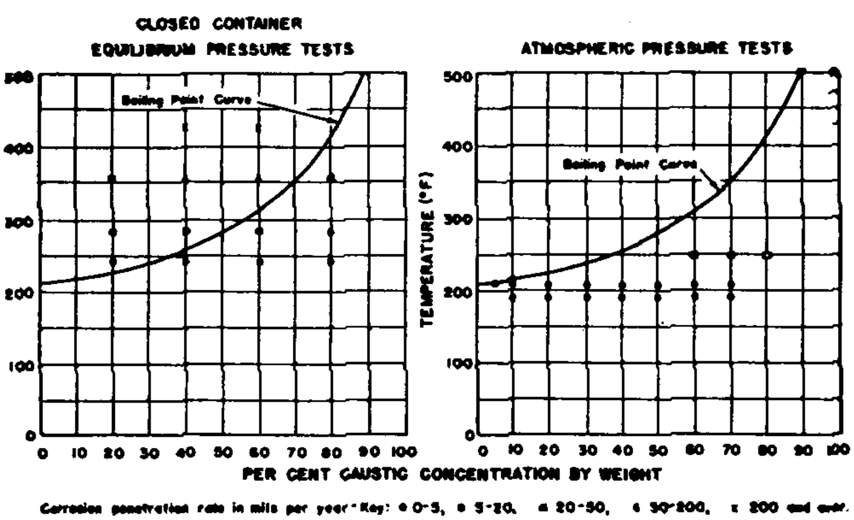


Fig. 3. Corrosion of Types CF-8M and CF-12M by sodium hydroxide.

Corrosion Resistant Type CF16F (UNS J92701)

Description

Type CF16F is an iron-chromium-nickel alloy similar to types CF8 and CF20, to which small amounts of selenium, either with or without molybdenum, and phosphorus have been added to improve machinability. Corrosion resistance of this alloy is somewhat inferior to the CF20 type, but it is adequate for many purposes.

As cast, this alloy has an austenitic structure containing chromium carbides and varying amounts of ferrite (0-15%) distributed throughout the matrix. The carbides must be put into solution by heat treatment to provide maximum corrosion resistance. Complex selenides, which are present in both the as-cast and heat treated material, contribute a free-machining quality to these alloys by serving as chip breakers. If the heat treated material is later exposed to temperatures in the range 800 to 1600°F (427 to 871°C), carbides will be reprecipitated; this takes place quite rapidly around 1200°F (649°C). Castings thus "sensitized", as in welding, must be solution heat treated again to restore full corrosion resistance. Type CF16F cannot be hardened by heat treatment, but ductility is improved.

Castings of the CF16F type have excellent machining and good welding characteristics. Thermal expansion and other physical properties are similar to the CF8 grade.

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Mo	Se	Fe
min.						18	9		0.20	
max.	0.16	1.50	2.00	0.04	0.04	21	12	1.50	0.35	bal

Physical properties

Modulus of elasticity, psi x 10^6	28
Density, lb/in^3	0.28
Sp. Heat, Btu/lb.°F, at 70 °F	0.12
Electrical resistivity, µΩ.m, at 70 °F	0.72
Melting point, approximate °F	2550
Magnetic permeability	1.0 - 2.0

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion µ in./(in. °F)	
At 212 °F	9.4	70 - 212 °F	9.0
At 1000 °F	12.1	70 - 1000 °F	9.9

Mechanical properties at room temperature

	Representative values Water quench from above 2000 °F	Minimum tensile requirements ASTM A743
Tensile strength, ksi	77.0	70.0
Yield strength, 0.2% offset, ksi	40.0	30.0
Elongation, in 2in., %	52	25
Brinell hardness (HBW)	150	-
Charpy, keyhole, ft lbs	75	

Heat Treatment

For maximum corrosion resistance, castings of CF16F alloy should be heated in the range 1950 to 2050°F (1066 to 1121°C) and then quenched in water, oil or air to ensure complete solution of carbides. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CF16F alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Architectural, Chemical Processing, Explosives Manufacturing, Food and Dairy, Marine, Oil Refinery, Pharmaceutical, Power Plants, Pulp and Paper, Textile.

Castings Bearings, bushings, fittings, flanges, machinery parts, pump casings, valves.

Corrosives Atmosphere, bleaching compounds, caustic salts, food products, hydrocarbon vapors, sulfite liquor, sulfurous acid.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CF16F is generally recommended for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CF16F. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CF16F alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Good castability of this alloy permits designs involving intricate shapes. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 5/16 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding

Type CF16F castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Preheating is not required, but after welding castings should be quenched from 2000 to 2100°F (1093 to 1149°C) to restore maximum corrosion resistance. Lime coated electrodes of similar composition (AWS E308-15 or E308L-15) are recommended.

The welding procedures outlined for alloy CF8 are applicable to alloy CF16F. Welding procedures utilizing SMAW, GMAW, and GTAW techniques are described in this section.

Machining Most machining operations can be performed readily on castings of CF16F alloy. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Chips tend to free themselves more readily from the tool and break more easily than is the case with other CF grades.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur without a fatty base oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy

The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A743 (CF16F); SAE 60303 and 60303a.

Wrought AISI 303.

Also, practices for estimating ferrite content in cast alloys are found in ASTM A799 and A800.

Corrosion Resistant Type CF20 (UNS J92602)

Description

Type CF20 is an iron-chromium-nickel alloy containing a maximum of 0.20 percent carbon. The alloy serves satisfactorily in many types of oxidizing corrosion service where its superior ductility and impact strength make it more useful than the iron-chromium type CB30. Providing considerably better corrosion resistance than the iron-chromium type CA15, the CF20 alloy is, in general, similar to the low carbon CF8 grade except that it is used for less severe operating conditions.

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Fe
min.						18	8	
max.	0.20	1.50	2.00	0.04	0.04	21	11	bal

Physical properties

Modulus of elasticity, psi x 10^6	28
Density, lb/in^3	0.28
Sp. Heat, Btu/lb.°F, at 70 °F	0.12
Electrical resistivity, μΩ.m, at 70 °F	0.779
Melting point, approximate °F	2575
Magnetic permeability	1.01

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion μ in./(in. °F)	
At 212 °F	9.2	70 - 212 °F	9.6
At 1000 °F	12.1	70 - 1000 °F	10.4

Mechanical properties at room temperature

	Representative values Water quench from above 2000 °F	Minimum tensile requirements ASTM A743
Tensile strength, ksi	77.0	70.0
Yield strength, 0.2% offset, ksi	36.0	30.0
Elongation, in 2in., %	50	30
Brinell hardness (HBW)	163	-
Charpy, keyhole, ft lbs	60	-

As cast, the alloy has an austenitic structure containing chromium carbides. The carbides must be put into solution by heat treatment to provide maximum corrosion resistance. If the heat treated material is later exposed to temperatures in the range 800 to 1600°F (427 to 871°C), carbides will be reprecipitated; this takes place quite rapidly around 1200°F (649°C). Castings thus "sensitized", as in welding, must be solution heat treated again to restore full corrosion resistance. Type CF20 alloy cannot be hardened by heat treatment.

Castings of the CF20 type have good machining and welding characteristics. Thermal expansion is about 50 percent greater than carbon steel or iron-chromium alloy types CA, CB, and CC.

Below about 1600°F (871°C), heat conductivity is 30 to 50 percent less and, above about 1600°F (871°C), the heat conductivities of these materials are nearly equal. Conversely, the electrical resistance of CF-20 is five times greater than that of carbon steel and of the iron-chromium alloys below about 1600°F (871°C), but, above this temperature, the electrical resistance of these materials is nearly the same.

In contrast to the CF8 type, the higher carbon content of the CF20 alloy makes it virtually non-magnetic.

Heat Treatment

For maximum corrosion resistance, castings of CF20 alloy should be heated in the range 2000 to 2100°F (1093 to 1149°C) and then quenched in water, oil or air to ensure complete solution of carbides. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CF20 alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Architectural, Chemical Processing, Explosives Manufacturing, Food and Dairy, Marine, Oil Refinery, Pharmaceutical, Power Plants, Pulp and Paper, Textile.

Castings Circuit breaker parts, cylinder liners and sleeves, pumps, return bends, rolls, street markers, valve bodies and parts.

Corrosives Atmosphere, bleaching compounds, caustic salts, food products, hydrocarbon vapors, sulfite liquor, sulfurous acid.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CF20 is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CF20. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CF20 alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Good castability of this alloy permits designs involving intricate shapes. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 11/16 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding

Type CF20 castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Preheating is not required, but after welding castings should be quenched from 2000 to 2100°F (1093 to 1149°C) to restore maximum corrosion resistance. Lime coated electrodes of similar composition (AWS E308-15) are recommended.

The welding procedures outlined for alloy CF8 are applicable to alloy CF20. Welding procedures utilizing SMAW, GMAW, and GTAW techniques are described in this section.

Machining Most machining operations can be performed satisfactorily on castings of CF20 alloy. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Because chips are tough and stringy, chip curler tools are recommended.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy

The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A743 (CF20); SAE 60302.
Wrought AISI 302.

Corrosion Resistant Type CG8M (UNS J93000)

Description

Type CG8M is an iron-chromium-nickel-molybdenum alloy with excellent resistance to corrosion by reducing media. Except for its higher molybdenum content, the CG8M alloy is similar to the widely used CF8M grade. The addition of approximately one percent more molybdenum, however, increases the resistance of the alloy to sulfurous and sulfuric acid solutions, and to the pitting action of halogen compounds. Thus, it is preferred to CF8M in applications where improved resistance to such corrodents is required. It is not suitable for use in nitric acid or other strongly oxidizing environments.

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Mo	Fe
min.						18	9	3.0	
max.	0.08	1.50	1.50	0.04	0.04	21	13	4.0	bal

Physical properties

Modulus of elasticity, psi x 10^6	28
Density, lb/in^3	0.28
Sp. Heat, Btu/lb.°F, at 70 °F	0.12
Electrical resistivity, µΩ.m, at 70 °F	0.82
Melting point, approximate °F	2550
Magnetic permeability	1.5 - 3.0

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion µ in./(in. °F)	
At 212 °F	9.4	70 - 212 °F	8.9
At 1000 °F	12.1	70 - 1000 °F	9.7

Mechanical properties at room temperature

	Representative values Water quench from above 1900 °F	Minimum tensile requirements ASTM A743
Tensile strength, ksi	82.5	75.0
Yield strength, 0.2% offset, ksi	44.0	35.0
Elongation, in 2in., %	45	30
Brinell hardness (HBW)	176	-
Charpy V-notch, ft lbs	80	-

After heat treatment, the normal microstructure of the alloy consists of an austenitic matrix in which 15 to 35 percent of ferrite is distributed in the form of discontinuous pools. This ferrite content gives the alloy considerable resistance to stress corrosion cracking, and high strength at room and elevated temperatures. It should be noted that long exposure to temperatures above 1200°F (649°C) may cause the alloy to become embrittled from transformation of some ferrite to the sigma phase.

Castings of the CG8M alloy type have good machining and welding characteristics. Thermal expansion is about 50 percent greater than carbon steel or the iron-chromium alloy types CA, CB, and CC.

Below about 1600°F (871°C), heat conductivity is about 30 percent less and, above about 1600°F (871°C), the heat conductivities of these materials are nearly equal. Conversely, the electrical resistance of CG8M is five times greater than that of carbon steel and of the iron-chromium alloys below about 1600°F (871°C), but, above this temperature, the electrical resistance of these materials is nearly the same.

The alloy is ductile and retains good strength at temperatures in the 600 to 800°F (316 to 427°C) range.

Heat Treatment

For maximum corrosion resistance, castings of CG8M alloy should be heated in the range 1950 to 2050°F (1065 to 1121°C) and then quenched in water, oil or air to ensure complete solution of carbides and sigma phase. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CG8M alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Heavy Water Manufacturing, Nuclear, Petroleum, Pipe Line, Power, Pulp and Paper, Printing, Textile.

Castings Dyeing equipment, flow meter components, propellers, pump parts, valve bodies and parts.

Corrosives Dye solutions, ink, Mississippi River water, sulfite liquor.

<u>NOTE</u>: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CG8M is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CG8M. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CG-8M alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Good castability of this alloy permits designs involving intricate shapes. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 5/16 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CG-8M castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Shielded metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Preheating is not required, but after welding castings should be quenched from above 1950°F (1065°C) to restore maximum corrosion resistance. Lime coated electrodes of similar composition (AWS E317-15) are recommended.

The welding procedures outlined for alloy CF8M are applicable to alloy CG8M. Welding procedures utilizing SMAW, GMAW, and GTAW techniques are described in this section.

Machining Most machining operations can be performed satisfactorily on castings of CG8M alloy. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Because chips are tough and stringy, chip curler tools are recommended.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6^{th} Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy

The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A743, A744 (CG8M).

Wrought AISI 317.

Corrosion Resistant Type CH20 (UNS J93402)

Description

Type CH20 is an iron-chromium-nickel alloy similar to type CE30, but with somewhat higher nickel and lower chromium and carbon contents. Mechanical properties of this alloy lie between those of the CE30 and the CF8 types: it is more ductile than CE30 but not as strong; stronger than CF8 but not as ductile. The higher nickel and chromium contents impart to this alloy considerably better resistance to certain corrosive media than is available with the CF8 type.

It is used most frequently in applications involving contact with hot dilute sulfuric acid. This grade is sometimes made with carbon limited to 0.10 percent maximum (CH10), and with a molybdenum addition (CH10M) to provide further improvement over the resistance of the CF8 and CF8M grades.

As cast, the alloy has an essentially austenitic structure containing chromium carbides and small amounts of ferrite distributed throughout the matrix. The carbides must be put into solution by heat treatment to provide maximum corrosion resistance. If the heat treated material is later exposed to temperatures in the range 800 to 1600°F (427 to 871°C), carbides will be reprecipitated.

Type CH alloys are not hardened by heat treatment, but ductility and strength are improved.

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Fe
min.						22	12	
max.	0.20	1.50	2.00	0.04	0.04	26	15	bal

Physical properties

Modulus of elasticity, psi x 10^6	28
Density, lb/in^3	0.279
Sp. Heat, Btu/lb.°F, at 70 °F	0.12
Electrical resistivity, µΩ.m, at 70 °F	0.84
Melting point, approximate °F	2600
Magnetic permeability	1.71

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion µ in./(in. °F)	
At 212 °F	8.2	70 - 212 °F	8.6
At 600 °F	10.1	70 - 600 °F	8.7
At 1000 °F	12.0	70 - 1000 °F	9.5

Mechanical properties at room temperature

	Representative values Water quench from above 2000 °F	Minimum tensile requirements ASTM A743
Tensile strength, ksi	88.0	70.0
Yield strength, 0.2% offset, ksi	50.0	30.0
Elongation, in 2in., %	38	30
Brinell hardness (HBW)	190	-
Charpy, keyhole, ft lbs	30	-

Castings of the type CH20 alloy have fair machinability and good weldability. Thermal expansion is about 50 percent greater than carbon steel, but slightly less than the CF alloy types.

Below about 1600°F (871°C), the heat conductivity is lower than for the CF grades, and the electrical resistance is about 10 percent higher; above about 1600°F (871°C), the thermal and electrical properties of these materials are nearly equal.

The alloy is slightly magnetic.

Heat Treatment

For maximum corrosion resistance, castings of CH20 alloy should be heated in the range 2000 to 2100°F (1093 to 1149°C) and then quenched in water, oil or air to ensure complete solution of carbides. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CH20 alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Chemical Processing, Power Plant, Pulp and Paper.

Castings Digester fittings, pumps and parts, roasting equipment, valves, water strainers.

Corrosives Sulfite liquor, sulfuric acid (hot, dilute).

<u>NOTE</u>: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CH20 is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CH20. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CH20 alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Good castability of this alloy permits designs involving intricate shapes. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 5/16 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CH20 castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Preheating is not required, but after welding castings should be quenched from 2000 to 2100°F (1093 to 1149°C) to restore maximum corrosion resistance. Postweld heat treatment may be omitted provided castings will not be exposed to highly corrosive solutions. Lime coated electrodes of similar composition (AWS E309-15) are recommended.

Machining Most machining operations can be performed satisfactorily on castings of CH20 alloy. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Because chips are tough and stringy, chip curler tools are recommended.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6^{th} Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy

The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A351, A743 (CH20); A451 (CPH20); SAE 60309.

Wrought AISI 309.

Corrosion Resistant Type CK3MCuN (UNS J93254) and CN3MN (UNS J94651)

Description

Types CK3MCuN and CN3MN8 are iron-chromium-nickel-molybdenum alloys. They are commonly referred to as the “6% Mo Superaustenitics”. They have slightly higher strength and ductility levels than CF8M. They have excellent resistance to a wide variety of corrosive media. The primary corrosion environments for these alloys are chloride containing media. The critical crevice temperature is much higher than the 19 chromium, 10 nickel, molybdenum bearing alloys. It has been reported that the toughness of the wrought forms of these alloys compares favorably with the “300" series alloys.

Chemical composition - %

		C	Mn	Si	P	S	Cr	Ni	Mo	Cu	N
CK3MCuN	min.						19.5	17.5	6	0.5	0.18
	max.	0.025	1.20	1	0.045	0.010	20.5	19.5	7	1	0.24
CN3MN	min.						20	23.5	6	-	0.18
	max.	0.03	2	1	0.040	0.010	22	25.5	7	-	0.26

Physical properties

Modulus of elasticity, psi x 10^6	
Density, lb/in^3	0.291
Sp. Heat, Btu/lb.°F, at 70 °F	0.11
Electrical resistivity, μΩ.m, at 70 °F	0.89
Melting point, approximate °F	2450

Thermal conductivity Btu/(ft.h. °F)	68- 212 °F	6.8

Mechanical properties at room temperature

	Minimum tensile requirements ASTM A743	
	CK3MCuN	CN3MN
Tensile strength, ksi	80	80
Yield strength, 0.2% offset, ksi	38	38
Elongation, in 2in., %	35	35

As cast, the alloy has a predominantly austenitic structure containing chromium carbides, sigma and varying amounts of ferrite distributed throughout the matrix. The carbides and sigma`must be put into solution by heat treatment to provide maximum corrosion resistance. If the heat treated material is later exposed to temperatures in the range 800 to 1600°F (427 to 871°C), carbides will be reprecipitated; this takes place quite rapidly around 1200°F (649°C). Sigma can also form above 1000°F (538°C) these temperatures. Castings thus "sensitized", as in welding, must be solution heat treated again to restore full corrosion resistance. These alloys cannot be hardened by heat treatment.

The alloys, as normally produced, are fully austenitic although small pools of ferrite have been observed in CK3MCuN in the microstructure.

Heat Treatment

ASTM A744 specifies a minimum solution heat treatment temperature of 2100°Ffollowed by quenching in water or rapid cooling by other means. It has been observed that the higher the solution treatment temperature the higher the Critical Pitting Temperature and the lower the intergranular corrosion rate. This treatment should ensure the complete solution of carbides and sigma phase. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where the "6 Mo superaustenitc" grades have been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Aerospace, Beverage, Biopharmaceutical, Brewing, Brine Concentrators, Chemical Processing, Desalination, Distillation, Flue Gas Desulfurization, Food Processing, Heating Furnaces, Marine, Military and Naval, Nuclear Power, Oil and Gas Production, Offshore Platforms, Pharmaceutical, Pulp and Paper, Seawater Handling Equipment, Semi-conductor, Steam Surface Condensers.

Castings Cryogenic valves and fittings, fittings, flanges, headers, marine fittings, mixing agitators and propellers, pumps, pump sleeves, milk coolers, rotary strainers, sanitary fittings (dairy), scrubber castings, shaft sleeves, spray nozzles, stuffing boxes, valve bodies and trim.

Corrosives Acetic acid, antibiotics and drugs, bleaching compounds, formic acid, fruit juices, hot air, hot water, hydrocarbons, hydrochloric acid, organic liquids and acids, nitric acid, organic salts, oxalic acid, phosphoric acid, sea water, sewage, sodium bisulfate, sodium hydroxide, steam, sulfamic acid, 10% sulfuric acid, vinegar, white liquor.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether "6% Mo superaustentic" grades are suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular form are representative for alloys CK3MCuN and CN3MN. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in these alloys. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 5/16 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CK3MCuN and CN3MN castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Preheating is not required, but after welding castings should be quenched from a minimum of 2100°F (1121°C) to restore maximum corrosion resistance.

Machining Most machining operations can be performed satisfactorily on castings of CK3MCuN and CN3MN alloys. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Because chips are tough and stringy, chip curler tools are recommended.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy

Cast ASTM: A743, A744 (CK3MCuN, CN3MN)

Wrought 254 SMO (UNS S31254), AL6XN (UNS N08367)

Corrosion Resistant Type CK20 (UNS J94202)

Description

Type CK20 is an iron-chromium-nickel alloy containing slightly more chromium and considerably more nickel than the CH20 grade. It is used for special service conditions at high temperatures, handling about the same corrodents as CH20. The alloy provides good resistance to dilute sulfuric acid and resists many corrodents more effectively than the CF8 type. Because of its high alloy content, it is usually employed only where specific requirements warrant the cost.

As cast, the alloy has an austenitic structure containing chromium carbides distributed throughout the matrix. The carbides must be put into solution by heat treatment to provide maximum corrosion resistance. If the heat treated material is later exposed to temperatures in the range 800 to 1600°F (427 to 871°C), carbides will be reprecipitated.

Type CK alloy is not hardened by heat treatment, but ductility and strength are improved.

Castings of the type CK20 alloy have good machining and welding characteristics. Thermal expansion is about 50 percent greater than carbon steel, but slightly less than the CF alloy types.

Below about 1600°F (871°C), the heat conductivity is lower than for the CF grades, and the electrical resistance is about 15 percent higher than that of CF8; above about 1600°F (871°C), the thermal and electrical properties of these materials are nearly equal.

The alloy is virtually non-magnetic.

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Fe
min.						23	19	
max.	0.20	2.00[1]	2.00[1]	0.04	0.04	27	22	bal

[1]Limits in ASTM A743. Limits in A351 are: Mn 1.50 max., Si 1.75 max.

Physical properties	
Modulus of elasticity, psi x 10^6	29
Density, lb/in^3	0.28
Sp. Heat, Btu/lb.°F, at 70 °F	0.12
Electrical resistivity, µΩ.m, at 70 °F	0.9
Melting point, approximate °F	2600
Magnetic permeability	1.02

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion µ in./(in. °F)	
At 212 °F	7.9	70 - 212 °F	8.3
At 600 °F	9.8	70 - 600 °F	8.9
At 1000 °F	11.8	70 - 1000 °F	9.4

Mechanical properties at room temperature

	Representative values Water quench from above 2100 °F	Minimum tensile requirements ASTM A743
Tensile strength, ksi	76.0	65.0
Yield strength, 0.2% offset, ksi	38.0	28.0
Elongation, in 2in., %	37	30
Brinell hardness (HBW)	190	-
Charpy V-notch, ft lbs	See Fig. 1	-

Heat Treatment

For maximum corrosion resistance, castings of CK20 alloy should be heated in the range 2000 to 2150°F (1093 to 1177°C) and then quenched in water, oil or air to ensure complete solution of carbides. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CK20 alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Aircraft, Chemical Processing, Oil Refining, Pulp and Paper.

Castings Digesters, filter press plates and frames, fittings, jet engine parts, mixing kettles, pumps, return bends, tar still fittings, valves.

Corrosives Hot oil products around 1200°F (649°C), sulfite liquor, sulfuric acid (dilute).

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CK20 is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CK20. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CK20 alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Good castability of this alloy permits designs involving intricate shapes. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 5/16 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CK20 castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Preheating is not required, but after welding castings should be quenched from 2000 to 2150°F (1093 to 1177°C) to restore maximum corrosion resistance. Postweld heat treatment may be omitted provided castings will not be exposed to highly corrosive solutions. Lime coated electrodes of similar composition (AWS E310-15) are recommended.

Welding procedures utilizing SMAW, and GTAW techniques are described in this section.

Machining Most machining operations can be performed satisfactorily on castings of CK20 alloy. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface from rubbing or scraping. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy

The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A351, A743 (CK20); A451 (CPK20); AMS 5365A; SAE 60310.

Wrought AISI 310.

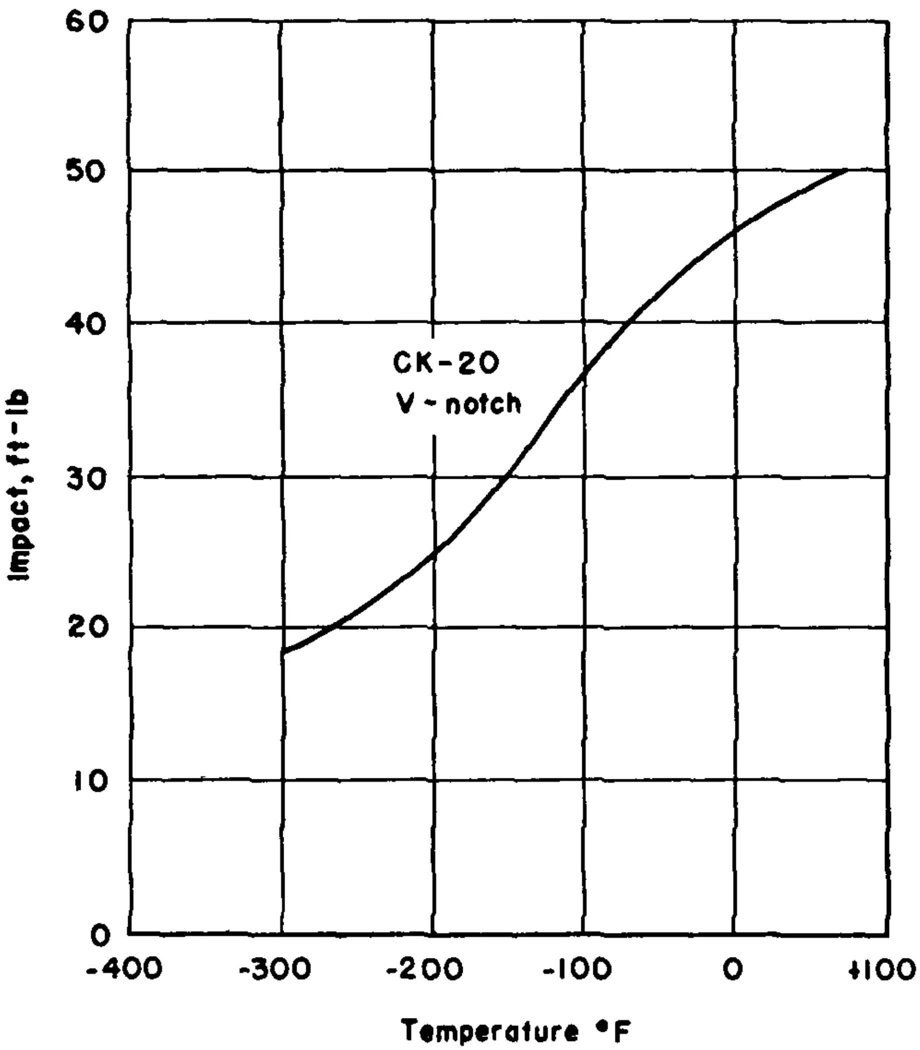


Fig. 1. Room temperature and sub-zero impact strength of Type CK-20. (Izod V-notch)

Corrosion Resistant Type CN7M (UNS N80020) formerly (UNS J95150)

Description

Type CN7M covers a group of related complex iron-nickel-chromium-molybdenum-copper alloys that contain more nickel than chromium. The high nickel content, together with the added elements molybdenum and copper, give these alloys especially good resistance to sulfuric acid and many reducing chemicals. Among the alloys included in this type designation, the so-called "20" alloy is produced in greatest quantity. Data for this grade are given in the "Summary of Properties". Whereas the chromium predominant alloys have poor or no resistance to hydrochloric acid, type CN7M has good resistance to dilute acid and hot chloride salt solutions. The alloy also will resist nitric acid satisfactorily.

In the heat treated condition, type CN7M has an austenitic structure. As in the iron-chromium-nickel grades, carbides must be put into solution by heat treatment to provide maximum corrosion resistance and to eliminate susceptibility to intergranular attack. Castings later exposed to temperatures in the range 800 to 1600°F (427 to 871°C) must be heat treated again to restore full corrosion resistance. Type CN7M cannot be hardened by heat treatment.

Castings of the CN7M type have excellent machining and fair welding characteristics. Thermal expansion and other physical properties are comparable to the CF grades. The alloy is virtually non-magnetic.

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Mo	Cu	Fe
min.						19	27.5	2.0	3.0	
max.	0.07	1.50	1.50	0.04	0.04	22	30.5	3.0	4.0	bal

Physical properties

Modulus of elasticity, psi x 10^6	24
Density, lb/in^3	0.289
Sp. Heat, Btu/lb.°F, at 70 °F	0.11
Electrical resistivity, μΩ.m, at 70 °F	0.896
Melting point, approximate °F	2650
Magnetic permeability	1.01- 1.1

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion μ in./in./ °F	
At 212 °F	12.1	70 - 212 °F	8.6
		70 - 1000 °F	9.7

Mechanical properties at room temperature

	Representative values Water quench from above 2050 °F	Minimum tensile requirements ASTM A743
Tensile strength, ksi	69.0	62.0
Yield strength, 0.2% offset, ksi	31.5	25.0
Elongation, in 2in., %	48	35
Brinell hardness (HBW)	130	-
Charpy, keyhole, ft lbs	70	-

Heat Treatment

For maximum corrosion resistance, castings of CN7M alloy should be heated to 2050°F (1121°C) minimum, and then quenched in water, oil or air to ensure complete solution of carbides. Holding time at temperature will vary with the thickness of casting sections involved, but should be sufficiently long to heat all sections to a uniform temperature throughout.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CN7M alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Chemical Processing, Food Processing, Metal Cleaning and Plating, Mining, Munitions Manufacturing, Oil Refining, Paint and Pigment, Pharmaceutical, Plastics, Pulp and Paper, Soap and Detergent, Steel Mill, Synthetic Rubber, Textile and Dye.

Castings Filter parts, fittings, heat exchanger parts, industrial mixer components, pickling rolls, pickling hooks and racks, pump parts, steam jets, tanks and towers, valve bodies and parts, ventilating fans.

Corrosives Acetic acid (hot), brines, caustic solutions (strong, hot), hydrochloric acid (dilute), hydrofluoric and hydrofluosilicic acids (dilute), nitric acid (strong, hot), nitric-hydrofluoric pickling acids, sulfates and sulfites, sulfuric acid [all concentrations to 150°F (65.6°C), many to 176°F (80°C)], sulfurous acid, phosphoric acid, plating solutions.

<u>NOTE</u>: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CN7M is suitable for the particular corrosive involved, and the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property data presented in tabular and graphical form are representative for alloy CN7M. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Specification and/or design information may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CN7M alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 5/16 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CN7M castings can be welded by metal-arc, inert-gas arc, and oxyacetylene gas methods. Metal-arc is most frequently used. Oxyacetylene welding is not advisable because of possible impairment of corrosion resistance caused by carbon pick-up. Castings normally are not preheated, but may be heated to 400 to 600°F (204 to 316°C) if the extent of the weld is substantial. This is most important in restrained sections since the weld metal is susceptible to cracking. After welding, the castings should be slowly cooled and then reheated to 2050°F (1121°C) and water quenched. Lime coated electrodes of similar composition (AWS E320-15) are recommended.

Welding procedures utilizing SMAW, GMAW, and GTAW techniques are described in this section.

Machining Most machining operations can be performed readily on castings of CN7M alloy. It is important in all cases that the tool be kept continually entering into the metal in order to avoid work-hardening the surface. Slow feeds, deep cuts, and powerful, rigid machines are necessary for best results. Work should be firmly mounted and supported, and tool mountings should provide maximum stiffness. Both high speed steel and carbide tools may be used successfully. Chips are short and brittle. Characteristic large grains of this alloy may tend to cause uneven machined surfaces.

Good lubrication and cooling are essential. The low thermal conductivity of the alloy makes it most important to have the cutting fluid flood both the tool and the work. Sulfo-chlorinated petroleum oil containing active sulfur and about 8 to 10 percent fatty oil is recommended for high speed steel tools. Water-soluble cutting fluids are primarily coolants and are most useful for high speed operation with carbide tools.

Information on the procedures for specific machining operations is contained in SFSA Steel Casings Handbook, 6th Edition, Chapter 26.

Casting designations, specifications, and corresponding wrought alloy

The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A351, A743, A744 (CN7M).

Wrought None.

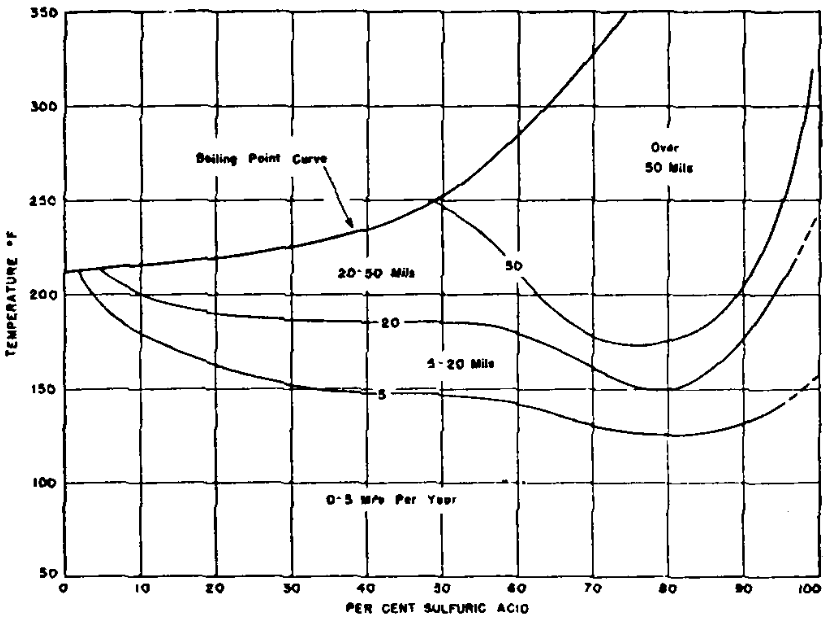


Fig. 1. Corrosion penetration rates in mils per year of Type CN-7M in sulfuric acid.

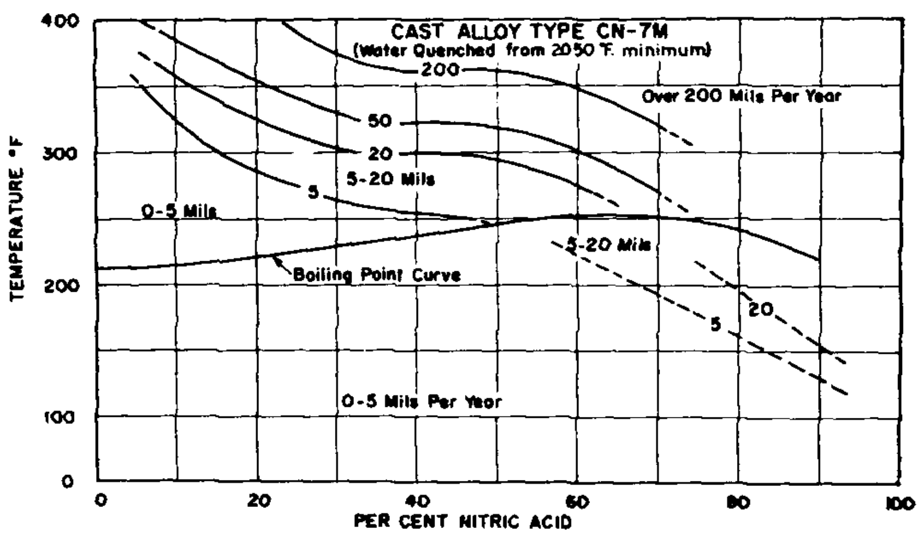


Fig. 2. Corrosion penetration rates in mils per year of type CN-7M in nitric acid.

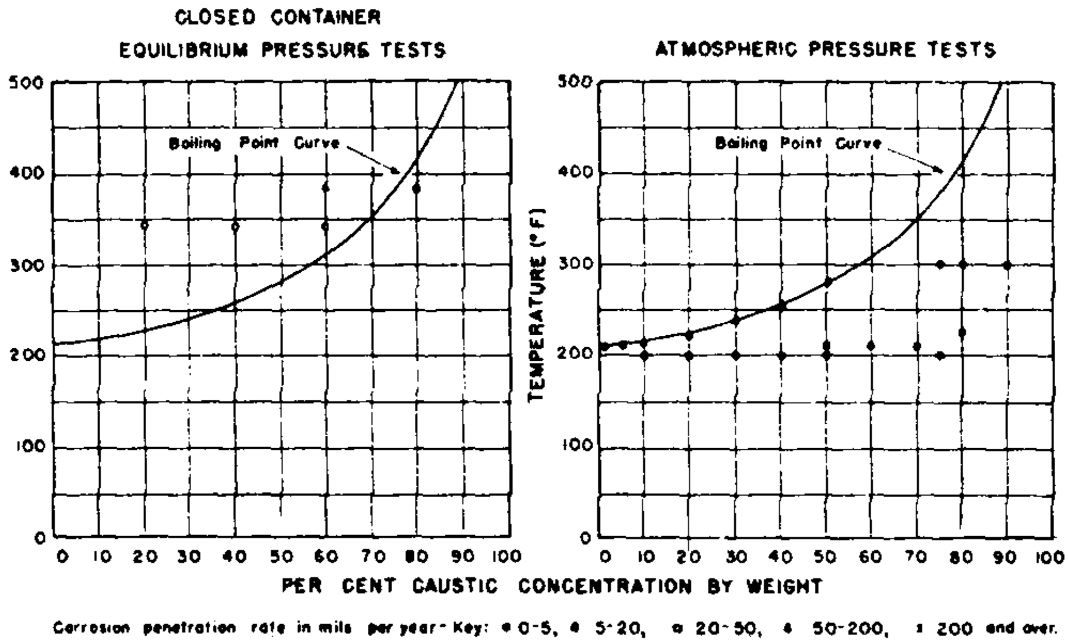


Fig. 3. Corrosion of Type CN-7M by sodium hydroxide.

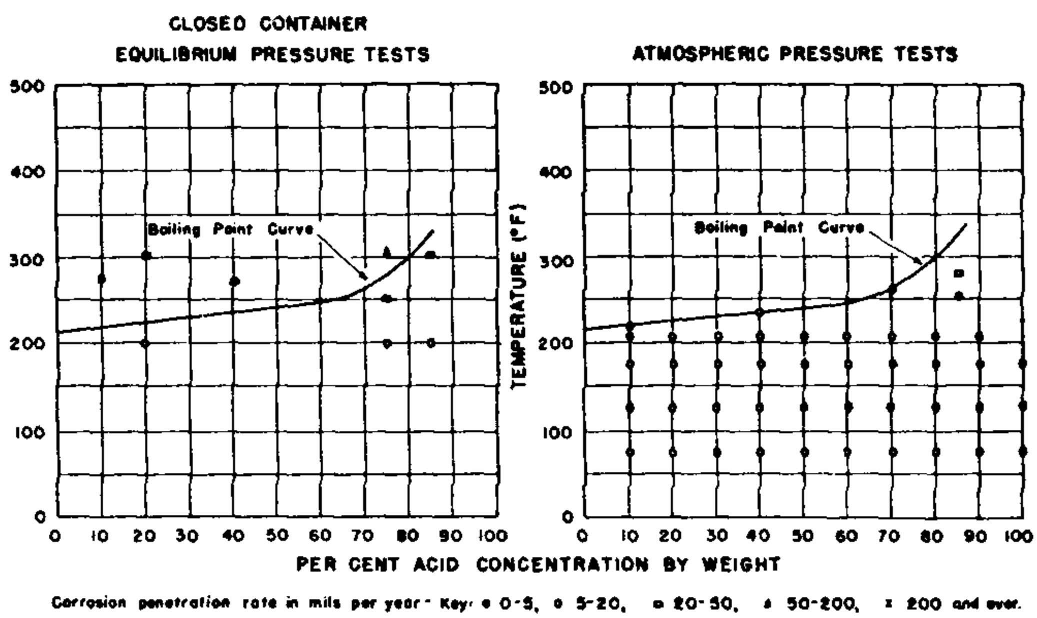


Fig. 4. Corrosion of Type CN-7M by phosphoric acid.

Corrosion Resistant Type CX2MW (UNS N26022)

Description

Type CX2MW is a cast nickel-chromium-molybdenum-tungsten alloy widely used alone or in conjunction with wrought nickel-chromium -molybdenum-tungsten alloys. The alloy has good strength and toughness at cryogenic temperatures. Its microstructure consists of an austenitic matrix with some grain boundary precipitates.

The alloy is resistant to pitting, crevice corrosion, stress corrosion cracking, and oxidizing conditions, including wet chlorine, and mixtures containing nitric or oxidizing acids.

Wrought and cast alloys differ in the amount of the minor elements because of the different requirements for processing by rolling and processing by casting. However, these differences in chemical composition are minor and do not interfere with wrought-to-cast fabrication.

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Fe	Mo	W
min.						20.0		2	12.5	2.5
max.	0.02	1.00	0.80	0.025	0.025	22.5	bal.	6	14.5	3.5

Physical properties

Modulus of elasticity, psi x 10^6	29.9
Density, lb/in^3	0.314
Sp. Heat, Btu/lb.°F, at 70 °F	0.99
Electrical resistivity, µΩ.m, at 70 °F	44.8
Melting point, approximate °F	2475-2550

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion µ in./in./ °F	
At 212 °F	77	75 - 212 °F	6.9
		70 - 1000 °F	7.7

Mechanical properties at room temperature

	Minimum tensile requirements ASTM A494
Tensile strength, ksi	80
Yield strength, 0.2% offset, ksi	45
Elongation, in 2in., %	30
Brinell hardness (HBW)	-

Heat Treatment

Heat treatment consists of a solution treatment at 2200°F minimum followed by water quenching or rapid cooling by other means.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CX2MW alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Chemical Processing, Cellophane Manufacturing, Chlorination Systems, Flue Gas Scrubbers, Geothermal Wells, Heat Exchangers, HF Furnace Scrubbers, Incineration Scrubbers, Nuclear Fuel Reprocessing, Pesticide Production, Phosphoric Acid Production, Pickling Systems, Refining, SO_2 Cooling Towers, Sulfonation Systems.

Castings Fittings, heat exchanger parts, pump parts, valve bodies and parts.

Corrosives Acetic acid/acetic anhydride, acid etching, hydrofluoric acid, 2%HF/20%HCl at 170°F,salt air.
NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial

operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CX2MW is suitable. Also, the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

Information on specification and/or design may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CX2MW alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 9/32 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding CX2MW castings can be repair welded or fabrication welded to matching wrought alloys by all of the usual welding processes. Rod and wire of matching nickel-chromium-molybdenum-tungsten contents are available. Post-weld heat treatment may be required after repair welding or fabrication.

Machining Machinability of CX2MW requires heavy cuts at slow cutting speeds because of the tendency of the alloy to work harden.

Casting designations, specifications, and corresponding wrought alloy

Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A494 (CX2MW (UNS N26022)).

Wrought Hastelloy C-22 (UNS 06022).

Corrosion Resistant Type CY40 (UNS N06040)

Description

Type CY40 is a cast nickel-chromium alloy widely used alone or in conjunction with wrought nickel-chromium alloys. The alloy has good strength and toughness from cryogenic to elevated temperatures. Its microstructure consists of an austenitic matrix with a uniform distribution of carbide particles.

The alloy is resistant to oxidizing conditions, and is used to handle hot corrosives or corrosive vapors under conditions where the austenitic stainless steels might be subject to intergranular attack or stress corrosion cracking.

The nickel content of CY40 is high enough so that its behavior is similar to that of CZ100 in resistance to hot caustic or alkaline solutions. Where cast-to-wrought fabrication is required for handling hot concentrated alkalies, CY40 usually can be substituted for low carbon CZ100. Generally, sound castings are more easily produced with type CY40 than with CZ100.

Wrought and cast alloys differ in the amount of the minor elements because of the different requirements for processing by rolling and processing by casting. However, these differences in chemical composition are minor and do not interfere with wrought-to-cast fabrication. The somewhat lower mechanical properties for cast products are compensated for by heavier cast sections in cast-to-wrought fabrication.

Chemical composition - %

	C	Mn	Si	P	S	Cr	Ni	Fe
min.						14.0		
max.	0.40	1.50	3.00	0.03	0.03	17.5	bal.	11.0

Physical properties

Modulus of elasticity, psi x 10^6	
Density, lb/in^3	
Sp. Heat, Btu/lb.°F, at 70 °F	
Electrical resistivity, μΩ.m, at 70 °F	
Melting point, approximate °F	
Magnetic permeability	

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion μ in./(in. °F)	
At 212 °F		70 - 212 °F	
		70 - 1000 °F	

Mechanical properties at room temperature

	Representative values Water quench from above 2050 °F	Minimum tensile requirements ASTM A494
Tensile strength, ksi		70.0
Yield strength, 0.2% offset, ksi		28.0
Elongation, in 2in., %		30
Brinell hardness (HBW)		-

In elevated temperature service, CY40 is usually produced with a minimum carbon content of 0.20% to improve elevated temperature properties. Typical elevated temperature properties are shown in the accompanying tables.

CY40 is less susceptible to intergranular corrosion than the cast stainless steels. The reason for this improved behavior is a less pronounced chromium depletion in the grain boundary areas, and the high nickel content which provides a more corrosion resistant matrix than can be provided in the iron-based stainless steels.

Heat Treatment

Because CY40 is less susceptible to intergranular corrosion, following sensitizing treatments, than the austenitic stainless steel, it is used in the as-cast condition for most applications. However, for nuclear applications and for applications where very severe corrosive conditions are anticipated, CY40 is cast with a low carbon content and solution treated at 1900°F (1038°C) minimum.

Unless residual stresses pose a problem, post-weld heat treatment is not required.

Applications

The following lists of consuming industries, cast parts, and corrosive materials are useful as examples of typical applications where type CY40 alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Chemical Processing, Power Plant, Nuclear.

Castings Fittings.

Corrosives Hot boiler feed water, hot caustics, hot concentrated alkalines, elevated temperature oxidizing conditions.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CY40 is suitable. Also, the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical property, physical property, and corrosion data presented here are representative for alloy CY-40. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Information on specification and/or design may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 3/16 inch up can be cast satisfactorily in CY40 alloy. Somewhat lighter sections are feasible depending on casting design and pattern equipment. Drastic changes in section should be avoided, however, and uniform thickness should be maintained as far as possible. This applies to the casting *as cast;* i.e., including finish allowance of 1/8 inch or more on surfaces to be machined. Normally used patternmakers' shrinkage allowance for this alloy is 9/32 inch per foot.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding CY40 castings can be repair welded or fabrication welded to matching nickel-chromium wrought alloys by all of the usual welding processes. Rod and wire of matching nickel-chromium contents are available. Post-weld heat treatment is not required after repair welding or fabrication because the heat affected zone is not sensitized by the weld heat.

Welding procedures utilizing SMAW, and GTAW techniques are described in this section.

Machining Machinability of CY40 is somewhat better than that of cast stainless steels. Heavy cuts at slow cutting speeds are recommended because of the tendency of the alloy to work harden.

Recommended machining speeds are shown in the accompanying table.

Casting designations, specifications, and corresponding wrought alloy

The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A743 (CY40); A744 (CY40); A494 (CY40).

Wrought An 0.08% max. C alloy would be similar to Inconel 600.

Elevated-Temperature Tensile Properties of CY40

Temp °F	0.2% Yield Strength, ksi	Tensile Strength, ksi	Elongation, %
Room	42	70.5	16
900	-	62	20
1200	-	54.5	21
1350	-	45.5	25
1500	-	27	34

100 Hour Rupture Strength of CY-40

Temp °F	Rupture Strength, ksi
1200	24
1350	15
1500	9
1700	5.5

Corrosion Resistant Type CZ100 (UNS N02100)

Description

Type CZ100 is commercially pure nickel with a minimum of added elements to provide the casting and solidification characteristics necessary for the production of good castings. Although used in a variety of applications, the most common use of type CZ100 is in the handling of anhydrous caustic and hot concentrated caustic in caustic manufacture, and in caustic processing.

Type CZ100, in comparison to stainless steels, has high thermal and electrical conductivity and a low coefficient of expansion. Type CZ100 retains strength and toughness over a wide range of temperatures - cryogenic to 1000°F+. The alloy is magnetic.

Chemical composition - %

	C	Mn	Si	P	S	Ni	Cu	Fe
min.								
max.	1.00	1.50	2.00	0.03	0.03	95	1.25	3.0

Physical properties

Modulus of elasticity, psi x 10^6	
Density, lb/in^3	
Sp. Heat, Btu/lb.°F, at 70 °F	
Electrical resistivity, μΩ.m, at 70 °F	
Melting point, approximate °F	
Magnetic permeability	

Thermal conductivity Btu/(ft.h. °F)		Mean coefficient of Linear thermal expansion μ in./(in. °F)	
At 212 °F		70 - 212 °F	
		70 - 1000 °F	

Mechanical properties at room temperature

	Representative values Water quench from above 2050 °F	Minimum tensile requirements ASTM A494
Tensile strength, ksi		50.0
Yield strength, 0.2% offset, ksi		18.0
Elongation, in 2in., %		10
Brinell hardness (HBW)		-

Heat Treatment

Type CZ100 is used in the as-cast condition. The alloy cannot be hardened by heat treatment, nor is behavior under corrosive conditions altered by heat treatment.

Applications

Type CZ100 is most commonly used in handling hot concentrated, caustic solutions. The 3% maximum limit for iron is based on corrosion testing results in hot concentrated and anhydrous caustic. Type CZ100 is most commonly cast with 0.6, 0.7 to 0.9% carbon which is present in the cast product as graphite spheroids. The graphite does not interfere with corrosion resistance of the alloy in any of its applications. The exception where a low carbon nickel should be specified is for applications involving cast-to-wrought welded sections where the welding operation results in grain boundary graphitization and consequent loss in strength and ductility.

Graphite has no known detrimental effects on the corrosion resistance of CZ100; moreover, the graphite has a highly beneficial effect on casting quality. Castability is greatly improved because the metal is cleaner, can be poured at lower temperature, and solidification shrinkage is substantially reduced. The net result is a cleaner, sounder casting.

Although the hardness of cast nickel is relatively low, the material has excellent resistance to erosion by hot caustic slurries. Nickel in pure alkaline solutions develops a passive layer which is apparently responsible for the good erosion resistance.

In processing with hot alkaline or caustic solutions where halides may be present, pitting attack can occur. Similarly, the presence of increasing amounts of halide in alkaline or caustic slurries results in measurable rates of erosion.

The following lists of consuming industries, cast parts, and corrosive environments are useful as examples of typical applications where cast nickel (type CZ100) alloy has been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Chemical Processing, Mineral Processing, Food Processing.

Castings Filter parts, fittings, heat exchanger parts, industrial mixer components, pump casings and parts, valve bodies and trim.

Corrosives Nickel is useful in handling hot concentrated alkaline or caustic solutions, reducing acids, certain food products, organic acids under certain conditions, dry chlorine, and anhydrous ammonia. Cast nickel is not applicable in oxidizing acids and alkaline perchlorite. The high thermal conductivity of cast nickel is a useful property where heat transfer is important.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type CZ100 is suitable. Also, the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical property, physical property, and corrosion data presented here are representative for alloy CZ100. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Information on specification and/or design may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Thin sections are readily cast in type CZ100 and, particularly with carbon in the 0.6%/0.9% range, the castability of type CZ100 approaches that of high strength cast irons. Normal pattern shrinkage allowance for type CZ100 is 1/8" per foot. Because, in many cases, type CZ100 is specified as an upgraded material from stainless steel, pattern equipment, particularly for larger castings, must be altered for lower pattern shrinkage allowance and rerigged for differences in solidification behavior.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding Type CZ100 is readily weldable with nickel electrodes and filler wire. AWS A5.11 Class ENi-1 covers coated electrodes, and AWS A5.14 Class ERNi-3 covers wire for GMAW and GTAW welding. No preheat is necessary, nor is postweld heat treatment required. Where cast nickel is to be joined to wrought nickel for high temperature service, a low carbon (.10 maximum) cast nickel should be specified.

Welding procedure utilizing SMAW technique is described in this section.

Machining Type CZ-100 with spheroidal graphite has excellent machinability compared to stainless steels. Most machining operations can be performed at a rate that is at least twice that of stainless steels. Speeds and feeds can be varied over a much wider range than those of stainless steel. The relatively high thermal conductivity of type CZ-100 and the lubricating and chip breaking effect of graphite in the microstructure make the need for cutting fluids minimal. Excellent surface finish can be obtained.

Casting designations, specifications, and corresponding wrought alloy

The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A743 (CZ100); A744 (CZ100); A494 (CZ100).

Wrought ASTM:

- B-160 Bar & Rod
- B-161 Pipe & Tube
- B-162 Plate, Sheet & Strip
- B-163 Seamless Tubes

Corrosion Resistant Type M-35 (M35-1 UNS N24135, M35-2 N04020)

Description

The nickel-copper alloys represented by type M-35, grades 1 and 2, and QQ-N-288, grades A through E, contain approximately 30% copper, 67% nickel, and small amounts of iron and manganese are impurities. Silicon in amounts up to 4.5% is added to improve strength and resistance to wear and galling. With the exception of those grades containing over about 3.5% silicon, which are age-hardenable, this alloy system has a single phase, face-centered-cubic microstructure.

This alloy system is widely used in marine environments, mineral acids, organic acids, and strong alkalies.

Heat Treatment

M-35, 1 and 2, and QQ-N-288, compositions A and E, are employed in the as-cast condition. Homogenization at 1500 to 1700°F (816 to 927°C) may enhance corrosion resistance where iron is near the specified maximum in heavy section castings. However, under most corrosive conditions where the alloy is commonly applied, performance is not noticeably affected by the minor segregation occurring in the as-cast alloy.

Beginning at about 3.5% minimum silicon, a silicide aging effect occurs in the high silicon grade composition D. Aging can occur during cooling from casting to room temperature, and is increasingly evident as cooling rate decreased with increasing section size. The combination of aging plus massive silicides which appear in the microstructure above about 3.8% silicon greatly reduces machinability.

Chemical composition - %

M35-1	C	Mn	Si	P	S	Ni	Mo	Cu	Fe	Cb
min.							2.0	26		
max.	0.35	1.50	1.25	0.03	0.03	bal.	3.0	33	3.5	0.5

M35-2	C	Mn	Si	P	S	Ni	Mo	Cu	Fe	Cb
min.							2.0	26		
max.	0.35	1.50	2.00	0.03	0.03	bal.	3.0	33	3.5	0.5

Physical properties

Modulus of elasticity, psi x 10^6
Density, lb/in^3
Sp. Heat, Btu/lb.°F, at 70 °F
Electrical resistivity, μΩ.m, at 70 °F
Melting point, approximate °F
Magnetic permeability

Thermal conductivity Btu/(ft.h. °F)	Mean coefficient of Linear thermal expansion μ in./(in. °F)
At 212 °F	70 - 212 °F
	70 - 1000 °F

Mechanical properties at room temperature

	Representative values Water quench from above 2050 °F	Minimum tensile requirements ASTM A494 M35-1	M35-2
Tensile strength, ksi		65.0	65.0
Yield strength, 0.2% offset, ksi		25.0	30.0
Elongation, in 2in., %		25	25
Brinell hardness (HBW)		-	

Composition D can be softened for machining by solution heat treating at 1650°F (899°C), and air cooling or oil quenching. Maximum softening is attained by oil quenching, but may result in quench cracking in complex, variable section, and heavy section castings. In solution heat treating complex, variable section, and heavy section castings, it is advisable to charge into a furnace below 600°F (316°C), and heat to 1650°F (899°C) at a rate that will limit the maximum temperature difference within the casting to about 100°F (38°C). After soaking, castings that will not permit direct oil quenching should be transferred to a furnace held at 1350°F (732°C), allowed to equalize, then oil quenched.

Applications

The following lists of consuming industries, cast parts, and corrosive environments are useful as examples of typical applications where nickel-copper alloys have been employed successfully; they are not comprehensive, nor are they intended as guides to alloy selection for specific end uses.

Industries Marine, Chemical Processing, Food Processing, Metal Cleaning and Plating, Oil Refining, Soap and Detergent.

Castings Filter parts, fittings, pump casings and parts, valve bodies and trim.

Corrosives Boiler water and steam condensate, sea water, unaerated sulfuric acid, hydrochloric acid, hydrofluoric acid, unaerated phosphoric acid, organic acids, halogens, alkalies, anhydrous ammonia, neutral and alkaline sales, acid salts.

NOTE: Corrosion rate data obtained in carefully controlled laboratory tests using chemically pure reagents are helpful in screening alloys for further consideration, but the difference between such tests and commercial operation should not be overlooked. Concentration, temperature, pressure, contamination, and velocity of corrosives all influence the rate of attack, as do surface finish and casting design. Reference should be made to the extensive alphabetical lists of corrodents published by many alloy foundries and to corrosion data surveys published by the NACE to determine whether type M-35 is suitable. Also, the designer should provide the foundry with as much pertinent information as possible on operating conditions before reaching a definite decision to use this alloy.

The mechanical and physical property and corrosion data presented here are representative for alloy M-35. These data are neither average nor minimum values, and should not be used for either specification or design purposes. Information on specification and/or design may be obtained from appropriate technical associations such as ASTM, ASME, API, NACE, and SAE.

Design Considerations

Section thicknesses from 1/8" upwards can be cast satisfactorily in the nickel-copper alloys. In designing for castings, uniform sections should be maintained, avoiding drastic changes in section. Isolated or internal heavy sections should be avoided if possible. Normal pattern shrinkage allowance for the nickel-copper alloys is 1/8" per foot. Because nickel-copper alloys are frequently specified as an alternative to steel or stainless steel, pattern equipment for heavy section or extensive castings may have to be altered because of the lower pattern shrinkage allowance and differences in solidification behavior.

Fabricating Considerations

Dimensional tolerances for rough castings are influenced by the quality of pattern equipment provided. In general, overall dimensions and locations of cored holes can be held to 1/16 inch per foot.

Welding M-35, 1 and 2, and QQ-N-288, composition A and E, are readily weldable using matching nickel-copper content rod and wire. QQ-N-288, composition B, C, and D, are not weldable. Coated electrodes for arc welding are covered by AWS A5.11 Class E NiCu-2, and wire for GMAW and GTAW welding are covered by AWS A5.14 Class ER NiCu-7.

In general, increasing silicon content reduces weldability of the nickel-copper alloys. Silicon, in addition to deoxidizing nickel-copper, acts as a solid solution hardener to improve strength. Where design considerations do not require high strength, the M-35, 1 and 2 grades, should be specified because of their good weldability. Columbium containing QQ-N-288, composition E, in the past, has been designated as "weldable grade nickel copper"; but with higher purity raw materials, the presence of columbium in castings is not needed to obtain good weldability.

Welding procedures utilizing SMAW, and GTAW techniques are described in this section.

Machining Nickel-copper alloy M-35, 1 and 2, and compositions A and E can be machined in the cast condition at the speeds shown in the accompanying table.

When only a limited amount of machining is necessary, nickel-copper composition D can be machined in the as-cast or aged conditions. However, because of the high hardness of composition D in these conditions, it should be annealed before machining, particularly if extensive machining is done on a production basis. Hardening can be accomplished after machining.

High speed steel, cemented carbide or cast non-ferrous cutting tools may be used.

Casting designations, specifications, and corresponding wrought alloy

The American Iron and Steel Institute wrought alloy designation is listed only for the convenience of those who want to determine corresponding wrought and cast grades. Because the cast chemical composition ranges *are not the same* as the wrought composition ranges, buyers should use cast alloy designations for proper identification of castings.

Cast ASTM: A494

Wrought ASTM: None