ACMECAST®

Steel, Stainless Steel, High Alloy & Super Alloy-
Castings, Spares, Replacement Parts & Custom Made Components
Manufacturer - Supplier to OEM's, Plants and Process Industry
Heat, Wear, Abrasion, Pressure and Corrosion Resistant Alloys for Specific End Applications
Conversion to an Integrated Casting from Fabrications, Forgings and Welded Assemblies
Fabricated and Welded-Parts, Components & Assemblies in Steels and Stainless Steels
Engineering & Metallurgical Consulting

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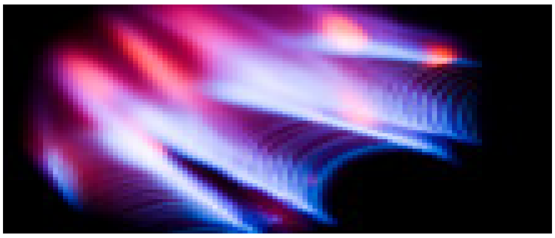
ACME® Cast Heat Resistant Alloy Solutions for High Temperature - Boilers, Heat Treatment, Industrial & Steel Plant Furnaces



Definition and Alloy Classification

Cast heat-resistant alloys are primarily used in applications where service temperature exceeds 650°C (1200°F) and may reach as high as 1315°C (2400°F). Strength at elevated temperatures is often key consideration in alloy selection however the resistance of an alloy to attack by the environment, present of aggressive corrodants, and the imposition of cyclic stresses and temperatures are some other important factors that may need equal consideration.

Several cast heat-resistant alloys are in composition related to the wrought stainless steels and to the cast corrosion-resistance stainless steels as shown in Table 1.0. Reference to wrought corrosion resistant stainless steels and heat resistance stainless steels most often made by purchasers, and end users; owing to ease of availability and identification.

Table 1.0 Similar Cast Heat-Resistant, Cast Corrosion-Resistant, and Wrought Stainless Steel Grades

Cast Heat-Resistant Grade	Wrought Corrosion-Resistant Stainless Grade	Cast Corrosion-Resistant Stainless Grade
HC	446	CC50
HD	327	
HE	312	
HF	302B	CF20
HH II	309	CH20
HK	310	CK20
HT	330	

The major difference between these materials is their carbon content. With a few exceptions, carbon in the heat-resistant alloys lie in range of 0.30 to 0.60% compared with 0.01 to 0.25% carbon normally associated with the wrought- and cast-corrosion resistant grades. In addition, there is difference in percentage of manganese and silicon, with cast heat-resistant alloys possessing higher percentage compared to wrought- and cast- corrosion resistant grades. Such key difference in percentage of carbon, manganese and silicon results in significant changes in the alloy properties. For example, the higher rupture strength of the cast alloys, which are compared with those of wrought alloys in Table 2.0. It is therefore, important to recognise these distinctions, because each group of alloys has its own appropriate application and related specifications.

Table 2.0 Rupture Strength of Cast Heat Resistant and Wrought Stainless Steel Grades

Form	Alloy	10,000 hour rupture strength ksi 871°C (1600°F)	10,000 hour rupture strength ksi 983°C (1800°F)
Wrought	309	1.5	0.5
Cast	HH II	4.4	1.7
Wrought	310	1.5	0.5
Cast	HK 40	4.0	1.6
Wrought	330	1.7	0.6
Cast	HT	4.7	1.7

A wide range of cast heat-resistant alloys have been developed to meet varied industrial needs. The composition of these alloys is mentioned in Table 3.0. The standard grades, which are recognized by ASTM specifications, fall in a range from 0 to 68% nickel with 8 to 32% chromium and the balance primarily iron plus up to 2.5% silicon and 2% manganese.

Table 3.0 ASTM Standard Designations and Compositions of Cast Heat-Resistant Stainless Steels-Composition (% w/w)

Alloy Grade	ASTM Specification	C	Mn	Si	P	S	Cr	Ni	Mo*	Nb/Cb
HA	1,2,3	0.20	0.35-0.65	1.0	0.04	0.04	8-10	-	0.9-1.2	-
HC	1,3	0.50	1.0	2.0	0.04	0.04	26-30	4	0.50*	-
HD	1,3	0.50	1.5	2.0	0.04	0.04	26-30	4-7	0.50*	-
HE	1,3	0.2-0.5	2.0	2.0	0.04	0.04	26-30	8-11	0.50*	-
HF	1,3	0.2-0.4	2.0	2.0	0.04	0.04	18-23	8-12	0.50*	-
HH	1,3,4	0.2-0.5	2.0	2.0	0.04	0.04	24-28	11-14	0.50*	-
HI	1,3	0.2-0.5	2.0	2.0	0.04	0.04	26-30	14-18	0.50*	-
HK	1,3,5	0.2-0.6	2.0	2.0	0.04	0.04	24-28	18-22	0.50*	-

HL	1,3	0.2-0.6	2.0	2.0	0.04	0.04	28-32	18-22	0.50*	-
HN	1,3	0.2-0.5	2.0	2.0	0.04	0.04	19-23	23-27	0.50*	-
HP	1	0.35-0.75	2.0	2.5	0.04	0.04	24-28	33-37	0.50*	-
HT	1,3,5	0.35-0.75	2.0	2.5	0.04	0.04	15-19	33-37	0.50*	-
HU	1,3	0.35-0.75	2.0	2.5	0.04	0.04	17-21	37-41	0.50*	-
HW	1,3	0.35-0.75	2.0	2.5	0.04	0.04	10-14	58-62	0.50*	-
HX	1,3	0.35-0.75	2.0	2.5	0.04	0.04	15-19	64-68	0.50*	-
CT15	5	0.05-0.15	1.5	1.5	0.03	0.03	19-21	31-34	0.50*	0.5-1.5
50-50-Nb	6	0.10	0.3	0.5	0.02	0.02	47-52	Bal	-	1.4-1.7

Key to ASTM Specifications: 1. A297, 2. A743, 3. A608, 4. A447, 5. A351, 6. A560
*Mo optional

Alternate Classification

An alternative method of classification is based on the order of the diminishing quantity of major elements. It comprises of following four groups:

1.	Iron-Chromium (Fe-Cr)	HA, HC, HD
2.	Iron-Chromium-Nickel (Fe-Cr-Ni)	HE, HF, HH, HI, HK, HL
3.	Iron-Nickel-Chromium (Fe-Ni-Cr)	HN, HP, HT, HU
4.	Nickel-Iron-Chromium	HX, HW

Proprietary and Semi-Proprietary Grades

Many of the proprietary alloys or proprietary compositions that are now in public domain can be classified broadly into three groups, with the following base compositions:

- 20Ni-25Cr
- 35Ni-25Cr
- 45Ni-30Cr

ACME® Modified & Proprietary Grades

Fundamental requirements in increasing high temperature capability include increase in strength at elevated temperature and increase in environmental resistance. Thus, in many cases the overall design requirement cannot be satisfied by a single material. Coatings are commonly required. Depending on the complexity of the component duty it may be necessary and in extreme cases, to apply multiple coatings to protect against different environmental factors, for example- corrosion, abrasion, impact and wear.

The various complementary mechanisms which strengthen metallic materials and increase temperature capability include solid solution strengthening and dispersion strengthening. They all operate by making dislocation movement more difficult. Solid solution strengthening is applicable to all base metals. Precipitation hardening is a potent strengthening mechanism but is limited to certain alloy types. Dispersion strengthening using fine dispersion of stable particles can be effective in developing strength at very high temperatures.

Grain boundaries play a very significant role in relation to material strength. Depending upon temperature, they can be beneficial and play a role in increasing strength or can be detrimental and reduce strength. Thus, the grain size may be controlled within specified limits, the behaviour of grain boundaries may be modified and the boundaries themselves may be eliminated through the use of components in the form of single crystals.

Solid Solution Strengthening

When atoms of one metal are substituted into the crystal lattice of another metal, internal strains are generated, resulting in strengthening. The extent of strengthening produced depends on the atoms involved. Atoms with similar crystal structures and lattice parameters will have high mutual solubility and with generate relatively little strengthening. Atoms of different size may have limited solubility but could potentially generate significant strengthening.

The effect of various alloying elements-tungsten, molybdenum, vanadium on the proof stress of gamma iron is buttressed by considerable research and as in case with alpha iron, the interstitial atoms N and C are more effective than the substitutional atoms.

Tungsten and molybdenum have long been recognized as strong solid solution strengthening elements in nickel super alloys. Recently, rhenium has been found to be a particularly effective element, partitioning mainly to the matrix, reducing diffusion rates and therefore retarding coarsening of the gamma precipitate. It also forms short range ordering with very small clusters of atoms in the matrix, which act as effective obstacles to dislocation movement.

Grain Size and Grain Boundary Effects

A grain boundary is a region of mismatch between the lattices of adjacent grains. The effect of the grain boundary on properties varies with temperature. At temperatures up to around 50% of the melting temperature the boundary impedes dislocation movement and thus provides a strength-mechanism. At higher temperatures, diffusion becomes increasing important and is much more rapid in the grain boundaries than within the grain. Grain boundaries are therefore sources of weakness in high temperature creep processes. Depending on the service temperature of the component, the grain size and shape can be controlled, and the grain boundary structure can be modified, to optimize properties.

ACME® offers proprietary alloys and modifications of standard alloy grades, that involve strengthening of the alloy solid solution with single or multiple additions of the elements aluminium, molybdenum, niobium, rare earth metals (REM)-Ce, La, Ta, Re, Y, titanium, tungsten and zirconium are added to improve specific properties; such as high-temperature strength, carburization resistance, and resistance to thermal cycling and fatigue.

Research reveals that in Fe-Ni-Cr and Nickel Base Alloys following objectives can be achieved with element alloying additions:

Solid solution strengthening	Mo, Ta, W, Re
Precipitation strengthening	Al, Ti, Ta
Grain boundary strengthening	B, C, Zr, Hf
Surface protection	Al, Cr

Heat Resistant Materials for Furnace-Parts, Tubes, Trays, Fittings, and Fixtures

Furnace application products can be divided into two broad categories. The first consists of parts that go through the furnaces and are therefore, subjected to thermal and/ or mechanical shock; these include trays, fixtures, conveyor chains, chain links, chain belts, and quenching fixtures. The second comprises parts that remain in the furnace with less thermal or mechanical shock; these include support beams, hearth plates, combustion tubes, radiant tubes, burners, thermo-wells, roller and skid rails, conveyor rolls, walking beams, rotary retorts, pit-type retorts, muffles, re-cuperators, fans, and drive and idler drums.

Product Form

The heat resistant alloys are supplied in either wrought or cast forms. In some situations, they may be combination of the two- weld integrated fabricated assemblies and components.

We use compatible welding electrodes/ welding filler wires of make ESAB Sweden/ESAB India Limited, Deloro Stellite, Böhler, Speciality Metals Corporation and alike; adhering to ASTM A 488/ A 488M or equivalent welding procedures and welding practices. If necessary, for in situ fabrication and product integration at client's plants, we provide compatible welding electrodes and fillers along with our product to ensure quality welding of our products with process equipment at customer end. In addition, on request we also provide welding practice data sheets to enable plant and operations team to follow correct welding practice required for an alloy, thereby helping them to service/maintain their equipment with our replacement parts, spares and consumables. Acme this contributes to achieving reduced plant down time and lowering overall plant product manufacturing /processing costs.

Basic Metallurgy of Furnace Parts

In general, these materials contain iron, nickel, and chromium as major alloying elements. Carbon, silicon and manganese also are present and affect the foundry pouring and rolling characteristics of these alloys, as well as their properties. Nickel influences primarily high-temperature strength and toughness. Chromium increases oxidation resistance by the formation of a protective scale of chromium oxide on the surface. An increase in carbon content increases strength.

Sigma phase embrittlement

All the alloys commonly used in castings for furnace parts have essentially austenitic structure. The Fr-Cr-Ni alloys (HF, HH, HI, HK and HL) may contain some ferrite, depending on composition balance. If exposed to a temperature in the range of 540-900°C (1000 -1650°F), these compositions may phase transform to embrittling sigma phase. Sigma phase embrittlement can be mitigated and in cases, avoided using proper percentage proportions of nickel, chromium, carbon and associated minor elements. Chromium and silicon promote ferrite, whereas nickel, carbon and manganese promote austenite. Use of the Fe-Cr-Ni types should be limited to applications in which temperatures are steady and are not within the sigma phase forming range. Phase transformation from ferrite to sigma phase at elevated temperature is accompanied by a change from ferromagnetic material and from a soft to a very hard, brittle material. All heat-resistant alloys of Fe-Ni-Cr group are wholly austenitic and not as sensitive to composition balance as is the Fe-Cr-Ni group. Also, the Fe-Ni-Cr alloys contain large primary chromium carbides in the austenitic matrix that after exposure to service temperature, show fine, precipitated carbides. The Fe-Ni-Cr alloys are considerably stronger than Fe-Cr-Ni alloys offering lower life cycle cost of the parts which offsets its initial higher price at the outset.

Table 4.0 Recommended cast materials for furnace parts and fixtures for hardening, annealing, normalizing, brazing and stress relieving

Working temperature range	Retorts, muffles, radiant tubes	Chain Links	Sprockets, rolls, guides, trays
595-675°C (1100-1250°F)	HF	HF	HF
675-760°C (1250-1400°F)	HF, HH	HF, HH	HF, HH
760-925°C (1400-1700°F)	HF, HK, HT, HL, HW	HH, HL, HT	HH, HK, HL, HT
925-1010°C (1700-1850°F)	HK, HL, HW, HX	HL, HT, HX	HL, HT, HX
1010-1095°C (1850-2000°F)	HK, HL, HW, HX, NA22H	HL, HT, HX	HL, HX
1095-1205°C (2000-2200°F)	HL, HU, HX	HX	HL, HX

Table 5.0 Recommended cast materials for furnace parts and fixtures for carburizing and carbo-nitriding furnaces

Working temperature range	Retorts, muffles, radiant tubes, structural parts	Pier caps, rails	Trays, baskets, fixtures
815-1010°C (1500-1850°F)	HK, HT, HU, HX	HT	HT, HT (Nb), HU, HU (Nb), HX

A factor that must be considered in evaluating castings and fabrications is the importance of good welding techniques, particularly parts that are used in case-hardening atmospheres. Castings have replaced fabricated products because of weld failures in multi-weld fabrications. Although cast alloys exhibit greater higher temperature strength, it is possible to place much emphasis on this characteristic in materials selection. Strength is rarely the only requisite and frequently is not the major one. More failures are attributed to brittle fracture from thermal fatigue than from stress rupture or creep. Nonetheless, higher temperature strength in important where severe thermal cycling is required.

Talk to us of your industry specific, end application needs.

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