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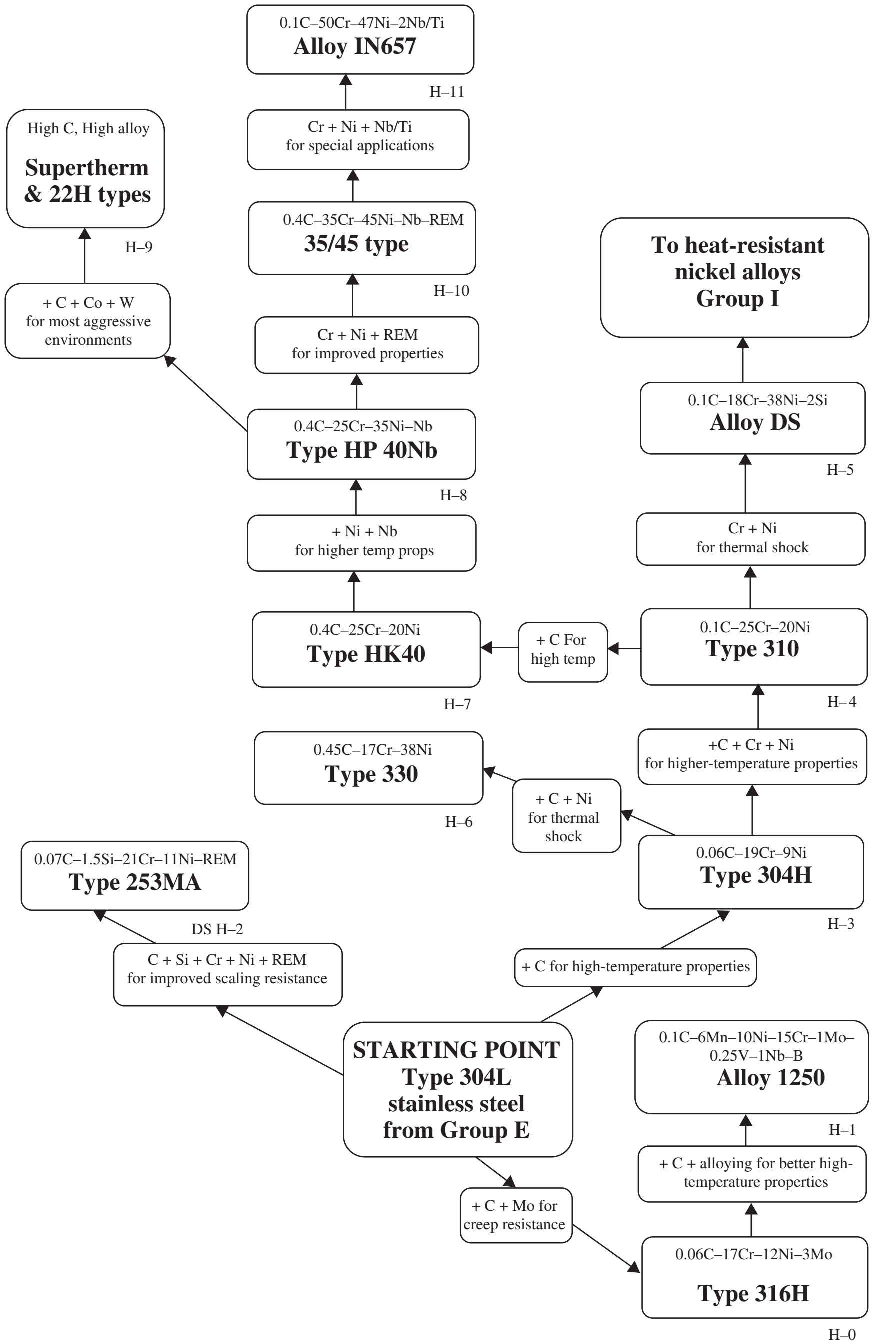
Group H

Heat-resistant stainless steels



Group H: Heat-resistant stainless steels.

Introduction

Group H starts with type 304L stainless steel from Group E and is a rather complex group with several branches and sub-branches reflecting a number of different design philosophies adopted to achieve specific high-temperature properties for particular applications. The main branch shows the evolution of controlled carbon austenitic stainless steels with increasing alloy content. When the nickel and iron contents are approximately the same at around 40%, the distinction between stainless steels and nickel alloys becomes blurred. This is exactly analogous to the corrosion side of the alloy tree. In the case of high-temperature alloys, alloy DS represents the transition point and the link to Group I heat-resistant nickel alloys.

A major branch is that which shows the development of high carbon, typically 0.4%, austenitic stainless steels. Some of the more highly alloyed types contain significantly more nickel than iron and strictly should be classified as nickel alloys. However, they have evolved progressively from stainless steels, are used for similar applications and are generally available only as castings. For these reasons they are properly included in Group H. In fact, the most highly alloyed material described is approximately 50% chromium and 50% nickel with no iron content at all!

There are two sub-branches. One deals with molybdenum-bearing high-temperature alloys and the other with alloys that make use of rare earth metal (REM) additions to improve oxidation and scaling resistance in high-temperature gaseous environments.

H–0

Controlled carbon, 17% chromium, 12% nickel, 2.5% molybdenum austenitic stainless steel

Also known generically as type 316H

Description

This steel is the high-temperature version of type 316 with a similar composition, but with carbon content controlled in the range 0.04 to 0.08% to give improved high-temperature properties, particularly creep resistance. A typical composition is:

	C	Mn	Si	S	P	Cr	Ni	Mo
Weight %	~0.06	2	0.5	<0.01	<0.02	17	12	2.5

The steel is normally supplied in accordance within one of the following specifications:

UNS	ASTM
S31609	Gr. 316H CF10M (castings)

This steel is always solution treated followed by quenching to give a fully austenitic structure.

Background

Stainless steels have always been of interest as high-temperature alloys since they combine long-term thermal stability with good corrosion resistance, particularly high-temperature oxidation and scaling resistance, helped by the high chromium content. However, they also have a number of disadvantages, not least of which is their high cost compared with low-alloy creep-resisting steels. They also have high coefficients of expansion, which can cause problems when used with other steels and they have low coefficients of thermal conductivity, which can limit their use in thick sections. Nevertheless, 316H is quite widely used for a number of high-temperature applications.

Performance

This steel combines good corrosion resistance with long-term creep resistance and thermal stability. However, 316H is not a particularly strong alloy and a number of related alloys have been developed to improve creep strength, particularly at higher temperatures. A typical operating temperature range for 316H would be 500–800 °C.

Corrosion resistance is reasonable and similar to type 316L. However, the higher carbon content, combined with the absence of stabilisation, increases the risk of weld HAZ attack under certain conditions.

Applications

Type 316H is mainly used for high-temperature plant and components in thermal and nuclear power stations and in the chemical and petrochemical industries. It tends to be used for plant and components operating at higher temperatures where the additional cost can be justified. It also tends to be used in thinner sections if thermal expansion and conductivity issues are important. Specific applications include steam piping, superheater headers, furnace parts and some gas and steam turbine components.

H–1

15% chromium, 10% nickel, 1% molybdenum, 6% manganese, austenitic stainless steel with vanadium, niobium and boron additions

Also known generically as alloy 1250

Description

This steel is a complex austenitic creep-resisting steel with a composition designed to optimise long-term high-temperature creep performance. The steel has a moderate carbon content and additions of vanadium, niobium and boron to give stable carbides as long-term ageing takes place within an austenitic structure stabilised with both nickel and about 6% manganese. A typical composition is:

	C	Mn	Si	S	P	Cr	Ni	Mo	V	Nb	B
Weight %	0.1	6	0.5	<0.01	<0.02	15	10	1	0.25	1	0.005

The steel is normally supplied in accordance with:

UNS
S21500

The steel is usually solution treated, followed by quenching, to give a fully austenitic structure. Tubes are often supplied in the warm worked condition.

Background

The then private steel company Samuel Fox Ltd, based near Sheffield, developed this steel in the 1960s. The company became part of the English Steel group and the steel was designated Esshete 1250. It was one of a number of complex austenitic creep-resisting alloys developed at the time to provide enhanced performance in supercritical thermal power stations then being built in large numbers.

Performance

This steel is designed for long-term continuous service at temperatures up to 675 °C. It combines a high level of rupture strength with reasonable ductility and good weldability. It also has excellent structural stability and good oxidation resistance because of the high chromium content. At the time it was designed for use in the most advanced power stations operating with high steam temperatures at about 600 °C.

Applications

This steel is used almost exclusively in fossil-fuelled power stations. It finds application in pressure parts, superheaters and steam pipes. It is also used for turbine blades, valve covers and high-temperature bolting.

Its high resistance to oxidation and high-temperature scaling is exploited in coaxial tubing. It is used as the outer layer of co-extruded tubing and piping, in conjunction with low-alloy creep-resisting steels, which are much cheaper and have better thermal conductivity. However, they do not have sufficient oxidation resistance at the higher temperatures and are therefore 'protected' by an outer layer of alloy 1250.

H–2

21% chromium, 11% nickel, austenitic stainless steel with controlled carbon content, silicon, nitrogen and REM

Also known generically as type 253MA

Description

This steel is the most widely used of a group of austenitic stainless steels specifically designed to combine good high-temperature properties and scaling resistance with economy of alloy content. A slightly enriched type 304H composition is further enhanced by the addition of somewhat more carbon plus silicon, nitrogen and REMs. A typical composition is:

		C	Mn	Si	S	P	Cr	Ni	N	REM
Weight %	**Type 253MA**	0.08	1	2	<0.01	<0.02	21	11	0.15	~0.01

The steel is normally supplied in accordance within one of the following specifications:

UNS/ASTM	EN	Proprietary alloy
S30815	1.4835 1.4893	Avesta Polarit 253MA

This steel is always solution treated followed by quenching to give a fully austenitic structure.

Background

This is one of a series of steels introduced by Avesta Steel (now Avesta Polarit) since about 1970. The leanest alloyed is 153MA and this is essentially a type 304 with additions of nitrogen to increase strength and a higher silicon content plus REM additions to improve high-temperature oxidation resistance. Type 253MA, the most well-known and widely used grade, has slightly higher carbon, chromium and nickel contents to improve overall performance. The highest alloyed grade, type 353MA, is based on the 25% chromium, 35% nickel system and provides further improvements in performance, albeit at a significantly higher cost. All three alloys contain high silicon with nitrogen and REM additions.

Performance

This steel is designed to give creep strength and resist serious oxidation at temperatures in the range 900–1100 °C. The addition of nitrogen improves strength. The high silicon content and the REM additions act synergistically to stabilise the oxide film and so prevent oxide spalling and long-term progressive degradation.

Resistance to sulphidation under oxidising conditions is superior to many higher nickel heat-resisting alloys. In addition, resistance to carburisation and nitriding is reasonable, except under reducing conditions where higher nickel alloys are superior.

These alloys are not primarily designed to provide good corrosion resistance under aggressive aqueous conditions.

Applications

Alloy 253MA has found worldwide use in a wide range of industries. Components manufactured from the steel include burner tubes, hot gas cyclones, hot gas recuperators, calcining and muffle furnaces, hot gas ducting and fans. These are used extensively in plant manufacturing cement, iron and steel and other metals and ceramics.

In recent years the alloy has been used in modern power generation plant for piping, ducting and cyclones that are in direct exposure to hot exhaust gases. It can also be used to manufacture refractory anchor bolts, where its high resistance to oxide formation reduces the risk of damage to and cracking of the heat-resistant refractory lining.

It is not generally found in the chemical and petrochemical industries, where conditions tend to require the use of more highly alloyed materials than 253MA.

H–3

18% chromium, 8% nickel, austenitic stainless steel with controlled carbon content

Also known generically as type 304H

Description

This steel is the same as the ubiquitous type 304L with the exception that is has a higher controlled carbon content and is specifically designed for high-temperature operation. A typical composition is:

	C	Mn	Si	S	P	Cr	Ni
Weight %	~0.06	2	0.5	<0.01	<0.02	19	9

The steel is normally supplied in accordance within one of the following specifications:

UNS	ASTM	EN
S30409	Gr. 304H Gr. CF8 (cast) Gr. CF10 (cast)	1.4948

This steel is always solution treated followed by quenching to give a fully austenitic structure.

Background

Now that the standard grades of type 304 are all essentially low or even very low carbon, it is necessary to produce grades with the carefully controlled carbon contents required to give long-term high-temperature performance.

Performance

These steels tend to be used for their high-temperature scaling resistance and long-term thermal stability and creep rupture strength rather than their corrosion resistance. In fact the corrosion resistance is not particularly good and precautions have to be taken to avoid corrosive acid condensates, which may form at low temperatures during shut down of catalytic cracking processes and could cause pitting attack.

Applications

The main application for 304H type stainless steels is in petrochemical and chemical process plant operating at relatively high temperatures. They are widely used in the construction of parts of oil refinery catalytic crackers (cat crackers), which produce light gasoline and diesel fuels from heavier residues remaining from the primary distillation process. These plants operate continuously for long periods and therefore reliability of material performance is essential. Items made from 304H include catalyst recovery cyclones, hot gas and catalyst transfer lines and support grids.

This grade of stainless steel has also been used to fabricate silencers for jet engine testing rigs where the steel has to withstand the eroding effects of the high-temperature exhaust gases.

H–4

Medium carbon, 25% chromium, 20% nickel, austenitic stainless steels

Also known generically as type 310

Description

These steels are a simple alloy of 25% chromium and 20% nickel with a carbon content usually in the range 0.1–0.25%. They should not be confused with the cast 0.4% carbon versions known as HK40 (H–7), nor with the very low-carbon versions that are designed for corrosion resistance (F–1). They can be supplied as both wrought and cast products. A typical composition is:

		C	Mn	Si	S	P	Cr	Ni
Weight %	**Type 310**	~0.15	1	0.5	<0.01	<0.02	25	20

The steels are normally supplied in accordance within one of the following specifications:

UNS/ASTM	EN	Proprietary alloys
S31000	1.4840, 1.4841	Firth Vickers Immaculate 5
Gr. 310 CK20 (cast)	1.4842, 1.4845	CLI Sirius 3
		Sandvik 15RE10

These steels are always solution treated followed by quenching to give a stable fully austenitic structure.

Background

These steels were some of the first generation industrial stainless steels and their origin can be traced back to the early 18/8 austenitic steels. The design philosophy was simple: the carbon was increased to improve hot strength, and the chromium was raised to 25% to provide good high-temperature scaling resistance. In order to maintain a fully austenitic microstructure and avoid ferrite, which would transform to sigma during long-term service, the nickel content was increased to 20%.

Performance

Type 310 provides good scaling resistance in clean air or oxygen at temperatures up to about 1100 °C. However, prolonged exposure above 1000 °C, particularly if thermal cycling or fatigue is also present, will result in breakdown and spalling of the oxide film, resulting in premature failure. Nevertheless, iron–nickel–chromium alloys are a common choice for many high-temperature applications because of their relatively low cost, good mechanical properties, moderate oxidation resistance and ready availability in a wide range of product forms.

Applications

Type 310 alloys are invariably used for heat-resistant applications such as furnace parts, heat shields, hot gas ducting and cyclones. The main industrial users are iron and steel, cement, ceramic and metal producers. While this is still an important alloy, many of its uses have been substituted by more modern alloys such as Avesta 253MA (H–2), which tend to be much lower in nickel content and hence lower in price and, with their higher silicon content plus REM additions, offer better long-term oxidation resistance.

H–5

Low carbon, 18% chromium, 38% nickel, 2% silicon, austenitic stainless steels

Also known generically as alloy DS

Description

This alloy is closely related to alloy 330 (H–6). However, the high-carbon version of alloy 330 is only available as castings and has a carbon content of about 0.45%, similar to HK40 (H–7). This is a simple, low-carbon alloy with about 18% chromium, 38% nickel, 2% silicon and an iron content of 40%. For the purposes of grouping, this alloy is included with the high-temperature austenitic stainless steels. However, the iron and nickel contents are similar and this alloy represents the transition point between high-temperature stainless steels and nickel alloys, and is the starting point for Group I. A typical composition is:

		C	Mn	Si	S	P	Cr	Ni	Fe
Weight %	**Alloy DS**	0.05	1	2.2	<0.01	<0.02	18	38	40

The alloy is normally supplied in accordance within one of the following specifications, but it should be noted that different proprietary alloys might have slightly different compositions:

ASTM/UNS	EN	Proprietary alloys
N08330	1.4862	Special Metals Incoloy DS Rolled Alloys RA330

This alloy is always solution treated followed by quenching to give a stable fully austenitic structure.

Background

These type 330 alloys (H–6) were first developed as high-carbon castings about the middle of the 20th century. However, wrought versions were later developed to widen the available range of product forms and hence the scope of applications. In order to facilitate the hot working of these alloys to produce plate, sheet and wire, etc., the carbon level is reduced to levels below 0.1%. In fact, alloy DS was specifically developed by Inco for woven wire furnace conveyor belts.

Performance

Alloy DS is designed as a high-temperature alloy with good mechanical strength up to 1050–1100 °C and reasonable scaling resistance, being achieved with the combination of 18% chromium and about 2% silicon. It is also resistant to 'green rot', which can occur in nickel–chromium alloys when furnace atmospheres vary between reducing and oxidising, and in some cases where there is a carburising atmosphere. Under these conditions, chromium carbides can form along the grain boundaries and preferential oxidation of the chromium-depleted matrix, then takes place. Alloy DS is also resistant to sigma formation, and consequent embrittlement, and can be heated in the critical 600–900 °C range, for indefinite periods of time.

Applications

Apart from its original use for woven wire furnace conveyor belts, alloy DS is widely used for a range of heat treatment applications where its strength and corrosion resistance at high temperature enable it to be used in light sections. Major uses include high-temperature process equipment and fittings, furnace retorts and heat treatment jigs. It is also used for some high-temperature components in general industrial and domestic equipment.

H–6

High carbon 17% chromium, 38% nickel, austenitic stainless steel

Also known generically as type 330 or HT

Description

These steels are quite closely related to the HK40 alloys (H–7), in that the cast version has a carbon content of about 0.45%, similar to HK40. These are simple alloys with about 17% chromium and 38% nickel. They are variously described by different users as 17/38 or 38/17 alloys, depending on which of the two major alloying elements is considered the more important. The low carbon wrought version, often known as alloy DS, is described in H–5. A typical composition is:

		C	Mn	Si	S	P	Cr	Ni
Weight %	**Type 330**	0.45	1	1.5	<0.01	<0.02	17	35

Note: HT has typical carbon content of 0.45%, whereas HT30 has about 0.3%.

The steels are normally supplied in accordance within one of the following specifications:

UNS/ASTM		EN	Proprietary alloys
N08605	A297 HT	1.4865	Doncasters Paralloy H38, H40, H33 & H35
N08030	A351 HT30		Duraloy Thermalloy T50 & T58
			Rolled Alloys RA330-HC

These steels are always solution treated followed by quenching to give a stable fully austenitic structure. However, castings may contain pockets of ferrite, which may transform to sigma.

Background

These alloys were first developed as high-carbon castings about the middle of the 20th century. However, wrought versions were later developed to widen the available range of product forms and hence the scope of applications. In order to facilitate the hot working of these alloys to produce forgings, etc.. the carbon level is reduced to below 0.1% (H–5). Both cast and wrought versions contain significant amounts of silicon, sometimes in excess of 2%, and this improves oxidation resistance in certain environments.

Performance

Type 330 alloys are designed as high-temperature alloys with good mechanical strength up to 1050–1100 °C and reasonable scaling resistance, being achieved with the combination of 18% chromium and up to 2% silicon. However, the combination of the relatively high nickel content and the low coefficient of thermal expansion make these alloys particularly resistant to thermal shock.

The alloy is also highly resistant to carburisation and nitriding but is not suitable for use in high sulphur-bearing furnace atmospheres.

Applications

These alloys are used for heat treatment trays and baskets, furnace rollers, moulds and hearth plates and similar components that are subjected to repeated rapid heating and cooling cycles. A particular application is the manufacture of quench baskets that contain engineering components, which are heat treated above 1000 °C, and then the basket and contents are subject to rapid quenching. Type 330 alloy is one of the few materials that can withstand the repeated thermal shock imposed by this process.

H–7

0.4% carbon, 25% chromium, 20% nickel, cast austenitic stainless steels

Also known generically as type HK40

Description

These steels are like other 310 types in that they contain 25% chromium and 20% nickel, with the balance iron. However, unlike the plain 310 and the very low-carbon 310L types, they have a high carbon content of 0.4% and are generally only available as castings. A typical composition is:

		C	Mn	Si	S	P	Cr	Ni
Weight %	**Type HK40**	0.4	2	1	<0.01	<0.02	25	20

The steels are normally supplied in accordance within one of the following specifications:

UNS/ASTM		EN	Proprietary alloys
J94204	A351 A608 Gr. HK40	1.4846	Doncasters Paralloy H20
J94224	A297 Gr. HK	1.4848	Duraloy Thermalloy 47
			Cronite HR6

These steels are always solution treated followed by quenching to give a stable austenitic structure.

Background

This alloy was developed about 1950, to meet the needs of the rapidly developing chemical and petrochemical industries and other users who required an economic high-temperature steel. For many years it was the workhorse alloy, but since 1975 better-performing alloys have been developed to meet increasingly arduous conditions. The combination of 25% chromium and 20% nickel with a high carbon level provides excellent high-temperature performance at a reasonable cost. These alloys were not developed for, and are not intended for, use in corrosive conditions.

Performance

Alloy HK40 is designed to operate for continuous long periods at temperatures of about 1000 °C. At almost 1100 °C it has a 100 000-hour (more than 10 years) rupture stress of about 4 MPa, combined with good oxidation resistance and reasonable carburisation resistance. These high-carbon cast alloys do not have good room temperature ductility, and after long periods of high-temperature service, further deterioration takes place as sigma and other intermetallic phases form. While the steel is readily weldable in the original as-cast condition, special precautions have to be taken when welding service-aged material.

Applications

The most well-known use of this alloy is in the manufacture of pyrolysis coils for use in high-temperature ethylene reformer and steam cracker plants. The coils consist of centrifugally cast tubes joined to conventionally cast bends and headers. The complete assemblies operate in a fired furnace at temperatures around 1000 °C at reasonably high pressures, often for many months continuously. With hydrocarbon feedstocks, carburisation of the alloy and coking of the tubes are recognised problems. Creep and creep fatigue are also causes of failure, and the need to improve service life has led to the development of improved alloys (H–8 and H–10).

The other important application is in the manufacture of billet skids, calcinating tubes, kiln nose segments, conveyor rolls and other furnace structural items in the cement, ceramic and steel industries.

H–8

0.4% carbon, 25% chromium, 35% nickel, cast austenitic stainless alloys

Also known generically as type HP40Nb

Description

These steels are an evolutionary development of alloy HK40 (H–7) with the nickel content increased from 20% to 35% and an addition of about 1.5% niobium. They have a high carbon content of more than 0.4% and are generally only available as castings. A typical composition is:

		C	Mn	Si	S	P	Cr	Ni	Nb
Weight %	**Type HP40Nb**	0.45	2	1	<0.01	<0.02	25	35	1.5

These steels are usually purchased as proprietary alloys rather than in accordance with the UNS, ASTM or EN specifications.

UNS/ASTM		EN	Proprietary alloys
N08705	A297 Gr. 'HP40Cb'	1.4857	Doncasters Paralloy H39W Duraloy Thermalloy 64 Manoir Manurite 36X &36XM

The steels are always solution treated followed by quenching to give a stable austenitic structure.

Background

This alloy was first developed about 40 years ago to provide improvements on alloy HK40, particularly by increased creep performance and resistance to carburisation. These improvements are achieved by increasing the nickel content and by adding niobium to provide a network of stable carbides. Developments have continued and, in recent years, further improvements have been made by the use of microalloying elements such as titanium and zirconium, which form secondary networks of fine carbides. Some grades are supplied with a lower carbon content of about 0.15%, which results in better resistance to thermal shock but at the expense of high-temperature creep rupture strength.

Performance

Alloy HP40Nb is designed to operate for continuous long periods at temperatures up to about 1100 °C and to provide benefits over HK40, which justify the additional cost. Resistance to oxidation is improved and resistance to carburisation is twice that of HK40. At temperatures of about 1100 °C only a modest gain in 100 000-hour rupture life is achieved, but at 1000 °C this alloy provides a 50% improvement, with the microalloyed versions giving a further 5–10%.

At all but the highest temperatures, the lower carbon (0.15%) version offers significant improvements over HK40 with the added benefit of much better resistance to thermal shock. These high-carbon cast alloys do not have good room temperature ductility but HP40Nb is reasonably resistant to sigma formation. However, after long periods of high-temperature service, further deterioration of ductility takes place as carbides grow. While the steel is readily weldable in its original condition, special precautions have to be taken when welding service-aged material.

Applications

These alloys are used almost exclusively in the manufacture of catalytic steam reformer coils and pyrolysis coils for ethylene cracking. The key components in hydrogen, ammonia and methanol plants are the primary reformer furnaces which operate at high pressures in the temperature range 750–1050 °C. The use of HP40Nb allows the tube wall thickness to be reduced, with a consequent increase in catalyst capacity and improvements in heat transfer.

In ethylene production, hydrocarbon feeds (ethane, propane, naphtha, etc.) are thermally cracked in the presence of steam at low pressures and at temperatures up to about 900 °C. HP40Nb's good resistance to carburisation from the hydrocarbon feedstock is a key benefit for this application.

H–9

0.5% carbon, 25–28% chromium, 35–50% nickel, 0–15% cobalt, 5% tungsten, cast austenitic alloys

Also known generically as alloy 22H and Supertherm

Description

These are a pair of related proprietary alloys based on the 25% chromium, 35% nickel system and designed for use in the most aggressive high-temperature environments. Cobalt and tungsten are used in significant quantities, albeit at a cost penalty, to maintain matrix strength at temperatures where carbides begin to dissolve. The carbon content is held at the high level of 0.5% and for this reason these alloys are only available as castings. Higher-silicon versions (~2%) are sometimes produced to improve castability and oxidation resistance. Typical compositions are:

		C	Mn	Si	S	P	Cr	Ni	Co	W	Fe
Weight %	**Alloy 22H**	0.5	0.6	1	<0.01	<0.02	28	50	–	5	15
	Supertherm	0.5	0.6	1	<0.01	<0.02	25	35	15	5	20

The alloys are produced as castings from one of the following proprietary brands:

Alloy 22H	EN	Proprietary alloys
	2.8479	Doncasters Paralloy H48T
		Duraloy 22H & Super 22H (22H + 3%Co)
		Schmidt & Clements Centralloy 8479
		Manoir Manaurite 50W
Supertherm		Duraloy Supertherm
		Schmidt & Clements ET35Co
		Manoir Manaurite 35K

These alloys are always solution treated followed by rapid quenching to give a complex structure with austenite and networks of eutectic carbides.

Background

These alloys were developed in the USA in the 1950s, with the intention of producing alloys superior to anything then available for operation at temperatures up to as high as 1250 °C. Supertherm was a trade name of the Abex Corporation and 22H was designed by the Blaw Knox Corporation.

Performance

Supertherm and 22H provide excellent combinations of very high-temperature creep strength, oxidation and carburisation resistance. Alloy 22H with its higher chromium content provides useful resistance to sulphidation under high-temperature oxidising conditions. While the long-term rupture strengths are not quite as high as for the most modern microalloyed 35/45 types (H–10), they offer unrivalled resistance to hot abrasion without the high cost penalty of cobalt-based superalloys (Stellites). They also have good dimensional stability and high resistance to thermal shock.

Applications

These cast alloys are used primarily in furnaces, kilns and equipment operating at temperatures in the range 950–1250 °C, where a variety of atmospheres may be present and hot abrasive wear is a problem. Typical applications are highly stressed furnace parts, sintering and calcining muffle furnaces, radiant tubes and pyrolysis coils used in the metallurgical ore processing, cement and ceramic industries. Cast parts are often incorporated in areas subjected to hot abrasive products such as cement clinker.

H–10

0.4% carbon, 35% chromium, 45% nickel, cast austenitic alloys

Also known generically as type 35/45

Description

This alloy is a further evolutionary development of alloy HK40 (H–7) with the chromium content increased from 25% to 35% and the nickel content from 20% to 45%, plus an addition of about 1.5% niobium and some micro-alloying. It has a high carbon content of more than 0.4% and is generally only available as castings. A typical composition is:

		C	Mn	Si	S	P	Cr	Ni	Nb
Weight %	**Type 35/45**	0.45	2	1	<0.01	<0.02	35	45	1.5

This is a comparatively new alloy that has not yet been incorporated into national codes or standards. There are, however, a number of proprietary producers and some of these are listed:

Proprietary alloys
Doncasters Paralloy H46M
Duraloy Thermalloy 80
Manoir Manaurite XT & XTM

This alloy is always solution treated followed by quenching to give a complex austenitic structure with eutectic and secondary carbides.

Background

This alloy was first developed about 1990 to provide further improvements on alloy HP40Nb (H–8), particularly in increased high-temperature creep performance and resistance to oxidation and carburisation. These are achieved by increasing both the chromium and nickel contents. Most suppliers offer alloys microalloyed versions containing titanium and zirconium, which form secondary networks of fine carbides. Some grades are supplied with small REM additions (e.g. cerium), which it is claimed help stabilise the surface oxide film and further reduce oxidation and carburisation.

Performance

Alloy 35/45 is designed to operate for continuous long periods at temperatures up to about 1150 °C, which is about the practical upper limit for most of the heat-resistant alloys that can be reasonably easily fabricated. It is also intended to provide benefits over HP40Nb that justify the additional cost. Resistance to oxidation is improved and resistance to carburisation is about 50% better than that of HP40Nb. At temperatures below about 1000 °C this alloy offers no real improvement in 100 000-hour rupture life, but at 1100 °C an improvement of about 30% in rupture stress can be expected.

Applications

This alloy is used almost exclusively in the manufacture of coils for ethylene cracking, in which hydrocarbon feeds (ethane, propane, naphtha, etc.) are thermally cracked in the presence of steam at low pressures and at temperatures up to about 900 °C. However, the radiant sections of some modern cracking furnaces operate at ‘end-of-run’ tube metal temperatures of up to 1150 °C. The good resistance to carburisation from the hydrocarbon feedstock is also a key incentive for the use of alloy 35/45 in this application.

H–11

50% chromium, 50% nickel, 2% niobium, cast austenitic alloy

Also known generically as alloy IN-657

Description

This is a special high-temperature alloy developed for a specific application and represents the ultimate in this type of alloy composition in that it consists entirely of approximately equal quantities of chromium and nickel with a relatively small addition of either niobium or titanium. The alloy is sometimes described as 50Ni–50Cr–Nb, even though this composition would technically exceed 100%!

The most common form of the alloy is as castings with niobium, designated IN-657, but a wrought version with titanium in place of the niobium is available as IN-671. A typical composition is:

		C	Mn	Si	S	P	Cr	Ni	Nb
Weight %	**IN-657**	0.07	0.5	1	<0.01	<0.02	50	47	1.8

This alloy is generally supplied to one of the following specifications or as proprietary brands;

ASTM	EN	Proprietary alloys
Gr. 50Cr–50Ni-Cb	2.4678	Inco IN-657 & IN-671
	2.4813	Doncasters Paralloy N50W
	2.4680	Duraloy 50/50Cb

The alloy is always solution treated followed by quenching to give an austenitic structure with some carbides.

Background

This alloy was first developed about 1970 by Inco in the UK to provide an alloy that would resist fuel ash corrosion at high temperatures. The alloy was patented and licensed to foundries worldwide. Since the expiration of the patent a number of foundries have introduced their own versions of the alloy. The overall design philosophy was to increase both chromium and nickel to the highest possible levels and so provide maximum resistance to oxidation and carburisation in a wide range of environments.

Performance

Alloy IN-657 is designed to operate for continuous long periods at temperatures in the range 650–950 °C, and be resistant to hot corrosion by fuel ash containing vanadium pentoxide and alkali metal sulphates arising from the combustion of low-grade heavy fuel oils. The melting point of such compounds can be as low as 630 °C and corrosion of less highly alloyed materials can be rapid and catastrophic. It is not a particularly strong alloy with a fairly low carbon content and only limited strengthening results from the chromium and niobium contents.

Applications

This alloy is the only one that can be used for hangers, tubesheets and tube supports in oil-fired furnaces and boilers where the fuel is dirty, heavy low-grade fuel oil. Typical applications are ships, power stations, oil refineries and petrochemical plants. However, such fuels are not used in reformers and ethylene furnaces because of the catastrophic corrosion that would occur at their high operating temperatures. The use of this high-cost alloy for all the high-temperature components in these furnaces would not be efficient, practicable or cost effective.