INCOLOY® alloy DS (W. Nr. 1.4862), first developed for woven wire furnace conveyor belts, is now widely used for a range of heat-treatment applications where its strength and corrosion resistance at high temperatures enable its use in light section.

Alloys for use in high-temperature processes must be able to withstand exposure to hot combustion gases and operating atmospheres for a considerable period oftime without the loss of effective section that can be caused by corrosion.

INCOLOY alloy DS, in common with other Special Metals Corporation heat-resisting alloys, develops a tightly adherent oxide film that protects its surface against corrosion processes. It is also resistant to 'green rot' which can occur in nickel-chromium alloys when atmospheres vary between reducing and oxidizing, and in some cases where the reducing atmosphere is of a carburizing nature. In these conditions chromium carbide can form along the grain boundaries and preferential oxidation of the depleted chromium matrix follows, a form distinct from ordinary oxidation which produces a passive oxide film.

INCOLOY alloy DS is also resistant to 'sigma' phase, a hard, brittle, complex intermetallic compound, basically iron-chromium, which precipitates in the 600-900°C range from structures that are either ferritic, mixed ferrite and austenite, or marginally austenitic. Nickel, an austenite former, suppresses the tendency to 'sigma' phase formation and INCOLOY alloy DS, with a nominal 37% nickel content, may be heated indefinitely within the 600-900°C range without fear of 'sigma' phase embrittlement.

Thus, the corrosion resistance and strength of INCOLOY alloy DS account for its use in a wide variety of high temperature process equipment ranging from furnace retorts and heat treatment jigs to components used in domestic appliances.

Table 1 - Composition, % (max. unless stated)

Ni + Co	C	Mn	Fe	Si	Cr	Cu	Ti	S
34.5-41.0	0.10	0.8-1.5	Balance*	1.9-2.6	17.0-19.0	0.50	0.20	0.03

To B.S. 3073 : NA17

*Reference to the 'balance' of an alloy's composition does not guarantee this is exclusively of the element mentioned, but that it predominates and others are present only in minimal quantities.

Table 2 - Density

g/cm³	7.86
lb/in³	0.284

Table 3 - Melting Range

°C	1330-1400

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INCOLOY® alloy DS

Table 4 - Mean Coefficient of Linear Thermal Expansion

°C	10^{-6}/°C
20-100	15.0
20-200	15.5
20-300	15.9
20-400	16.2
20-500	16.5
20-600	17.0
20-700	17.5
20-800	17.8
20-900	18.2
20-1000	18.7

Average of 5 casts. Hot-rolled plate 11 mm thick. Heat treated 11 min/1020°C/AC

Table 5 - Specific Heat

°C	J/kg °C
20	452
100	473
200	502
300	528
400	557
500	582
600	611
700	636
800	662
900	691
1000	716

Table 6 - Electrical Resistivity

°C	Relative Resistance
20	1.000
100	1.029
200	1.061
300	1.094
400	1.123
500	1.141
600	1.160
700	1.176
800	1.191
900	1.206
1000	1.220

Electrical resistivity at 20°C = 108 microhm cm.
Average of 5 casts. Hot-rolled plate 11 mm thick. Heat treated 11 min/1020°C/AC

Table 7 - Magnetic Properties

Field strength (*H,oersted*)	Permeability (μ)
200	1.038
300	1.031
500	1.024
1000	1.017
1500	1.014
2000	1.014
3000	1.013

Mass susceptibility at 1000 oersted = 1.72 x 10^{-4} cm^3/g.
Volume susceptibility at 1000 oersted = 1.36 x 10^{-3}
Hot-rolled plate. Heat treated 10 min/1020°C/AC

Table 8 - Dynamic Young's Modulus

°C	Hot rolled plate (GPa)	Sheet (GPa)
20	194	197
100	191	193
200	184	188
300	178	181
400	171	174
500	164	168
600	157	159
700	149	151
800	142	144
900	132	134
1000	118	119

Average of 5 casts. Hot-rolled plate, 11 mm thick. Heat treated 11 min/1020°C/AC
Average of 4 casts. Sheet 0.7-2.0 mm thick. Heat treated 6 min/1020°C/AC

Table 9 - Dynamic Torsional Modulus

°C	GPa
20	51.7
100	51.7
200	49.6
300	47.6
400	45.5
500	43.4
600	40.7
700	37.9
800	35.9
900	33.8
1000	29.6

Average of 4 casts. Sheet 0.7-2.0 mm thick. Heat treated 6 min/1020°C/AC

Table 10 - Tensile Properties (sheet, cold-rolled, heat treated)

°C	0.1% proof stress (MPa)	0.2% proof stress (MPa)	Tensile strength (MPa)	Elongation on 50 mm %
20	327	363	687	37.1
100	310	329	629	36.3
200	284	303	616	32.7
300	292	304	607	36.7
400	286	297	602	35.2
500	269	283	578	35.4
600	239	253	482	40.1
700	195	208	335	48.8
800	107	116	181	75.7
900	63	66	105	79.9
1000	31	36	65	74.6

Average of 5 casts. Cold-rolled sheet 0.7-2.0 mm thick. Heat treated 6 min/1020°C/AC

Table 11 - Tensile Properties (plate, hot-rolled, heat treated 10 min/1020°C/AC)

°C	0.1% proof stress (MPa)	0.2% proof stress (MPa)	Tensile strength (MPa)	Elongation on 5.65 √ So %	Reduction of area %
-196	473	485	914	54.5	68.1
20	298	301	670	47.6	71.5
100	263	269	618	44.1	69.0
200	242	247	581	41.1	64.0
300	219	222	593	41.5	62.1
400	213	219	593	46.7	60.8
500	196	202	568	43.6	57.3
600	196	201	490	45.3	45.0
700	179	185	351	56.7	44.9
800	136	142	208	74.0	60.7
900	63	71	119	90.9	75.1
1000	37	42	73	111.3	82.2

Average of 5 casts. Hot-rolled plate 11 mm thick.

Table 12 - Tensile Properties (plate, hot-rolled, heat treated 1h/1150°C/AC)

°C	0.1% proof stress (MPa)	0.2% proof stress (MPa)	Tensile strength (MPa)	Elongation on 5.65 √ So %	Reduction of area %
-196	391	406	798	61.1	75.5
20	210	219	602	61.1	77.0
100	188	196	551	55.0	70.9
200	164	168	528	55.6	71.4
300	133	136	505	55.6	68.0
400	133	136	511	62.2	64.3
500	119	124	493	64.4	67.8
600	113	116	440	55.5	44.6
700	117	124	334	31.1	37.3
800	137	145	232	35.6	32.0
900	66	74	122	86.7	61.9
1000	37	42	73	97.8	66.3

Data from one cast. Hot-rolled plate 11 mm thick.

Table 13 - Tensile Properties (plate, hot-rolled, heat treated and welded)

°C	0.1% proof stress (MPa)	0.2% proof stress (MPa)	Tensile strength (MPa)	Elongation on 5.65 √ So %	Reduction of area %
-196	558	579	951	31.1	41.6
20	360	380	672	38.9	71.1
100	290	314	468	13.3	22.3
200	303	317	595	33.3	66.7
300	300	306	588	38.9	58.6
400	280	297	582	37.8	63.9
500	276	300	562	36.7	48.0
600	252	266	513	36.7	56.5
700	221	233	408	32.2	47.8
800	159	171	235	35.6	65.9
900	82	88	124	52.2	81.2
1000	46	48	76	42.2	88.7

Data from one cast. Hot-rolled plate 11 mm thick. Heat treated 10 min/1020°C /AC prior to welding. Metal arc welded in 4 runs using INCO-WELD® 'A' elec- trode.

Table 14 - Charpy Impact Properties (plate, hot-rolled, heat treated 10 min/1020°C/AC)

°C	J
-196	141
-100	156
20	180
100	199
200	197
300	201
400	178
500	171
600	174
700	156
800	148
900	156
1000	203

Average of 5 casts. Hot-rolled plate 11 mm thick. Charpy test specimen has square cross section 10 mm, test area 80 mm², V-notch 45° included angle.

Table 15 - Charpy Impact Properties (plate, hot-rolled, heat treated 1h/1150°C/AC)

°C	J
-196	217
-100	247
20	270
100	288
200	285
300	290
400	260
500	266
600	260
700	236
800	157
900	184
1000	184

Data from one cast. Hot-rolled plate 11 mm thick. Charpy test specimen has square cross section 10 mm, test area 80 mm², V-notch 45° included angle.

Table 16 - Charpy Impact Properties, J, at Room Temperature

Soaking time, h	Soaking temperature, °C				
	800	850	900	950	1000
30	137	153	142	171	216
100	142	136	156	151	134
300	136	136	156	170	298
1000	163	142	176	155	292
3000	140	151	176	279	266
10 000	123	174	199	243	89

Data from one cast. Hot-rolled plate 11 mm thick. Heat treated 10 min/1020°C/AC
Charpy test specimen has square cross section 10 mm, test area 80 mm², V-notch 45° included angle.

Table 17 - Charpy Impact Properties, J, at High Temperatures

Soaking time, h	Soaking and test temperature, °C				
	800	850	900	950	1000
30	190	176	180	209	216
100	152	189	231	170	201
300	203	136	155	178	202
1000	144	—	168	168	208
3000	160	155	161	194	208
10 000	153	186	161	217	71

Data from one cast. Hot-rolled plate 11 mm thick. Heat treated 10 min/1020°C/AC
Charpy test specimen has square cross section 10 mm, test area 80 mm², V-notch 45° included angle.

Table 18 - Creep Rupture Properties, MPa, (plate, hot-rolled)

°C	Heat treated 15 min/1020°C/AC			Heat treated 1 h/1150°C/AC		
	100 h	1000 h	10 000 h	100 h	1000 h	10 000 h
750	67.3	44.5	29.5	72.3	48.8	32.9
850	34.9	20.4	11.9	45.6	26.3	15.2
950	18.1	9.4	4.9	29.2	15.4	8.1
1050	—	—	—	11.4	6.7	3.9

Data from one cast. Hot-rolled plate 3.2 mm thick.

Table 19 - Cyclic Oxidation Resistance

°C	Time to break-away (h)	Rate of spalling (mg/cm²/h)	Weight change in 1000 h (mg/cm²)
890	>1000	—	2.08
910	>1000	—	3.19
990	400	0.112	-50.4
1010	375	0.174	-87.8
1090	50	0.5	-541
1110	50	0.5	-487

Working instructions

INCOLOY alloy DS is readily fabricated hot and cold and can be joined by standard welding processes.

Hot and cold working

The usual hot working range is 900-1200°C with heavy working being carried out between 1000 and 1200°C. Normal forging operations are usually started from 1200°C and light forging is possible down to 900°C.

The rate of cooling does not affect the alloy's hardness and air cooling or quenching are satisfactory. Quenching forgings should be avoided where the variation in the cross-sectional area of the forging is high.

Cold working procedures are similar to those for carbon and stainless steels. The alloy's rate of work hardening is greater than that of low carbon steel but less than that of 18/8 stainless steel.

Machining

INCOLOY alloy DS is best machined in the annealed condition, with hot-rolled, as-rolled and hot-forged material showing the next best results.

It is best machined on heavy duty equipment using tools large and heavy enough to withstand the loads and dissipate heat quickly.

Annealing

The alloy should be annealed within the range 1000-1150°C, the temperature and holding time depending on the thickness of the material and the proposed application. Cooling rate does not affect hardness.

Furnace fuel should preferable be sulfur-free. Town's gas, natural gas, distillate fuel oils and electricity are suitable. For most heat treatments and heating processes, atmosphere should be adjusted to maintain slight oxidizing conditions.

Bright annealing can be carried out in dry hydrogen or cracked ammonia.

Pickling

A fused caustic soda mixture is a suitable pre-treatment to be followed by a cold water rinse before acid pickling (HNO_3/$FeCl_3$) at 65°C for 5-20 minutes, and a final rinse in cold water.

Joining

INCOLOY alloy DS is readily joined to itself or to other metals by standard processes. It is important that material to be welded is in the annealed condition. Removal of welding slag residue is essential to avoid subsequent corrosion in service.

Welding materials to be used are:

For shielded metal arc	..	INCO-WELD® 'A' electrode
For inert-gas shielded arc	..	NC 80/20 filler metal

Available Products and Specifications

INCOLOY alloy DS is available in pipe, tube, sheet, strip, plate, round bar, forging stock, hexagon and wire. The alloy is designated Werkstoff Number 1.4862.

Sheet and plate:	BS 3072
Strip:	BS 3073
Seamless tube:	BS 3074
Wire:	BS 3075
Bar:	BS 3076