

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 of time 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

| | | | | | | | | | 4 | Stell | | ST | -Steel. | Stal |
|-------|-----------|---------------|-----------|-------|-----------|---------------|-----------|----------------|-------|----------------|-----|----|---------------|------------|
| See. | Steelinge | Sterne | | g/cm | 3 Starter | Stefas | Sterrer | and the second | - Sel | are staff | 7. | 86 | Straffing | A CONTRACT |
| , end | -steelese | of collection | at states | lb/in | 3 Julio | and a testing | C. Martin | of a feature | | a for a sector | 0.2 | 84 | and the first | |
| Ì | 1 | d a | n a | A | è. | ê s | | | 8 | 1 | 0 | | | |

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| 3 | 3 | - S | - S ^r | - S ^V | 3 | S | - S | S | - S | 3 ^v | - 3 |
|-----|-------------|-----|------------------|------------------|-----|---------|---------------|-----|------|----------------|-------|
| | See Instant | °C | tellar | tertion | | testing | and a section | 13 | 30-1 | 400 | 1 |
| 2.9 | 2.9 | 2.9 | 100 | 201 | 104 | 100 | 2.9 | 2.9 | 2.2 | | |

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GOLOV® AILOV DS

| and the section of th | °C | after after and | and suffering suffering suffering | 10 ⁻⁶ /°C | ALANTA |
|--|---------|--|-----------------------------------|----------------------|----------------|
| and and and a | 20-100 | and a second and a second and a second | and the second second | 15.0 | and the second |
| | 20-200 | ren oren oren | | 15.5 | |
| | 20-300 | teaters aternet ater | | 15.9 | |
| | 20-400 | testing and a testing and a test | | 16.2 | |
| | 20-500 | and and a | | 16.5 | |
| | 20-600 | ten sten sten | | 17.0 | |
| | 20-700 | here's cherry cher | | 17.5 | |
| | 20-800 | information stationers start | | 17.8 | |
| | 20-900 | Treasured Treasured D | | 18.2 | |
| | 20-1000 | feet offeet offeet | | 18.7 | |

Table 4 - Mean Coefficient of Linear Thermal Expansion

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

| | AT STATE STATE STATE | Star and | | |
|-------------------------|----------------------|------------------------|---------|-------------|
| and advantage advantage | °C | | J/kg °C | and the set |
| and and and | 20 | and and and | 452 | |
| | 100 | Steel Steel Steel | 473 | |
| | 200 | State State State . | 502 | |
| | 300 | | 528 | |
| and the second | 400 | | 557 | |
| | 500 | | 582 | |
| | 600 | Sector Sector Sector : | 611 | |
| | 700 | Automa Automa Automa | 636 | |
| | 800 | the second second | 662 | |
| 5 5 | 900 | Star Star Star (| 691 | |

716

Table 5 - Specific Heat

res!

Table 6 - Electrical Resistivity

| °C | Relative Resistance |
|---|---------------------|
| 20 | 1.000 |
| ో ో 100 ో | 1.029 |
| 200 | 1.061 |
| 300 | 1.094 |
| 400 | 1.123 |
| <u>ن 500 کې کې او کې </u> | 1.141 |
| 600 | 1.160 |
| 700 | 1.176 |
| 800 | 1.191 |
| 900 | 1.206 |
| 1000 | 1.220 |
| | |

Table 7 - Magnetic Properties

| Field str | ength (H | H,oers | ted |) | P ermeability (μ) | | | | | | |
|-----------------|----------|----------------|----------------|-------|--------------------------|---------|---------|------|--------|--|--|
| | 200 | and the second | and the second | C. A. | and the second | and the | 1.038 | , °, | el and | | |
| | 300 | | | | Stra c | | ້ 1.031 | | | | |
| are atom of | 500 | | | | Stefast 2 | | 1.024 | | | | |
| And Andrew | 1000 | | | | Telligent | | 1.017 | | | | |
| traffic traffic | 1500 | | | | Traffer C | | 1.014 | | | | |
| | 2000 | | | | Star o | | 1.014 | | | | |
| | 3000 | | | | Sterno 2 | | 1.013 | | | | |

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

1000

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

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| | °C | Hot rolled plate | Sheet |
|----------------------|----------|------------------|---------------------|
| | Stat Sat | (GPa) | ් (GPa) ් ් |
| Stated Stated Stated | 20 | 194 | / / / / 197 |
| | 100 | 191 | 193 |
| | 200 | 184 | 188 |
| | 300 | 178 | i81 کې کې |
| | 400 | 171 5 | 174 |
| | 500 | 164 | 168 |
| | 600 | 157 | 159 |
| | 700 | 149 | 151 |
| | 800 | 142 | 144 |
| | 900 | 132 | 134 |
| | 1000 | 118 | 119 |

Table 8 - Dynamic Young's Modulus

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

| | | | | | | - | 1 | 1 St 1 St 1 St | | 1. St. 1. St. 1. |
|---|------|-----------|---------|--------------------|---|----------|----------------|-----------------|-----------|------------------|
| Steel Steel Str | °C | Ster | Ster | Ster | Street | 4 | Star . | frei Steit | Star S | G Pa |
| Station Station Str | 20 | Station | Station | N.C. | Staffer | 3 Fred | | Station Station | Stallar . | 51.7 |
| | 100 | | | t al mars | | | | | | 51.7 |
| | 200 | | | | 14. Juni | | | | | 49.6 |
| | 300 | | ST. | 3th | Ste | Street . | | | | 47.6 |
| | 400 | | Steffer | | Steelins | | Station | | Stell 3 | 45.5 |
| and a starting of the starting of the start | 500 | | | | | | | | A COMPANY | 43.4 |
| | 600 | | | r ^o las | 100 - | | | | | 40.7 |
| Star Star | 700 | St. | Stel | | Steel | | , 6 | Jean Star | | 37.9 |
| Store V | 800 | St. Car | | States | States. | 34 | States 2 | | | 35.9 |
| A state of the state | 900 | Testinger | | | | a | And and a | | | 33.8 |
| | 1000 | | | | | e di | n and a second | a Go | A CART | 29.6 |

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

| States | °C | 0.1% proof stress (MPa) | 0.2% proof stress (MPa) | Tensile strength (MPa) | Elongation on 50 mm % |
|---------|------|-------------------------------|-------------------------------|------------------------------|-----------------------------|
| | 20 | 327 | 363 | 687 | 37.1 |
| Stell | 100 | 310 | 329 | 629 | 36.3 |
| Testing | 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 | i 105 i i | 79.9 |
| | 1000 | 31 | 36 | 65 | 74.6 |

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

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

| Internet Statement St | °C | 0.1% proof stress (MPa) | 0.2% proof stress (MPa) | Tensile strength (MPa) | Elongation on 5.65 √ So | Reduction of area |
|-----------------------|-------------------------|-------------------------------|-------------------------------|-------------------------------|----------------------------|----------------------|
| | Start Start Start Start | a strand strand strand strand | Strater States Strates States | Start Start Start Start Start | % | % |
| | -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 | a 219 a a | 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 |

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

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

| | 8 a - 6 | ಷ್ಟೆ ನಿ. | | e | . 3 | | 100 | S 5 | . 3 | 1 di 🔹 . | | 1 | |
|-------|---------|----------|-------|-------|-----|-------|-----|------------|-----|--------------|------|------|---------------------|
| Table | 12 - | lensi | le Pi | opert | les | (plat | te, | hot-rolled | d, | heat treated | 1h/1 | 150° | C/AC) |
| | | | | 110 1 | | 100 | | | | | | | 11 ¹⁰ 11 |

| and Statement Statement Statement Statement St | °C | 0.1% proof stress (MPa) | 0.2% proof stress (MPa) | Tensile strength (MPa) | Elongation on 5.65 √ So | Reduction of a rea |
|--|----------|----------------------------|----------------------------|-----------------------------|---|---------------------------|
| | et steel | Start Start Start Start | and an are and a | and the construction of the | ర్ రో% రో రో రి | <u>ర్ ర్</u> యోజు |
| and States States States States | 196 | 391 | 406 | 798 | 61.1 | 75.5 |
| | 20 | 210 | 219 | 602 | 61.1 | 77.0 |
| | 100 | 188 | 196 | 551 | 55.0 | 70.9 |
| State State State State St | 200 | 164 | 168 | 528 🗸 🗸 | of the second | 71.4 |
| Station Station Station Station Station | 300 | 133 | 136 | 505 | 55.6 | 68.0 |
| and satisfies allowed allowed allowed a | 400 | 133 | 136 | 511 | 62.2 | 64.3 |
| | 500 | 119 | 124 | 493 | 64.4 | 67.8 |
| and and and and a | 600 | 113 | 116 | 440 | 55.5 | 44.6 |
| or states states states states st | 700 | 117 | 124 | 334 | 31.1 | 37.3 |
| and a station of the station of the station of the | 800 | 137 | 145 | 232 | 35.6 | 32.0 |
| en and an and a constant and the | 900 | 66 | 74 | 122 | 86.7 | 61.9 |
| of of 1 | 000 | 37 | 42 | 73 | 97.8 | 66.3 |

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

| india <mark>Stationa</mark> Stati | | 0 .1% proof s tress (MPa) | 0.2% proof stress (MPa) | Tensile s trength (MPa) | Elongation on 5.65 √ So | Reduction of a rea |
|-----------------------------------|-------------------------------------|--|--|--|----------------------------|---------------------------|
| | water shaftaan shaftaan shaftaan sh | Train Shelfman Shelfman Shelfman Shelfman Shelfman | and alternated alternated alternated alternated alternated | a shelford shelford shelford shelford shelford she | % | % |
| trainer trainer to | -196 | 558 | 579 | 951 | 31.1 | 41.6 |
| | 20 | 360 | 380 | 672 | 38.9 | 71.1 |
| | 100 | 290 | 314 5 | 468 5 | 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 |

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

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 | I, heat treated |
|--|-----------------|
| 10 min/1020°C/AC) | |

| N N N | | N IN IN IN IN | |
|----------------|--|---------------------------|-----------------|
| | °C | | J |
| Ster Ster Ster | -196 ් ් ් | J J J 1 | 41 |
| | -100, 500, 500, 500, 500, 500, 500, 500, | ar out of the second by | 56 |
| | 20 | and start strand in 1 | 80 |
| | 100 | | 99 |
| | 200 | 1 | 97 |
| | 300 | 2 | 201 |
| | 400 | and when a when a start 1 | 78 |
| | 500 | 1 | 71 |
| | 600 | 1 | 74 |
| | 700 | and and set 1 | 56 🖉 🧹 🏑 |
| | 800 | 1 - 5 - 5 - 5 - 1 | 48 |
| | 900 | / / / / / / 1 | 56 |
| Ster Ster Ster | 1000 | 2 | 203 |
| Star Star Star | Se se se se | Star Star Star | The the the the |

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

| | t af af a | | S.C. |
|-------------------------|-----------------------------|----------|------|
| 0° | | / | à |
| and a set and and a | -196 | 217 | |
| and and and and and and | -100 | 247 | |
| 20 | estimate estimate estimates | 270 | |
| | 100 | 288 | |
| | 200 | 285 | |
| | 300 | 290 | |
| | 400 | 260 | |
| | 500 | 266 | |
| | 600 | 260 0 0 | |
| | 700 🧹 💡 | 236 | |
| | 800 | 157 | |
| | 900 | 184 | |
| an an an an an an an | 1000 | 184 | È. |

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.

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.

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

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

| Soaking time, h | Soaking | Soaking temperature, °C | | | | | | |
|-----------------------|---------|-------------------------|-----|-------------|------|--|--|--|
| | 800 | 8 50 | 900 | 9 50 | 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.

| Soaking time, h | Soaking and test temperature, °C | | | | | | |
|-----------------------|----------------------------------|-------------|-----|-------------|------|--|--|
| | 800 | 8 50 | 900 | 9 50 | 1000 | | |
| 30 | 190 | 176 | 180 | 209 | 216 | | |
| 100 | 152 | 189 | 231 | 170 | 201 | | |
| 300 | 203 | 136 | 155 | 178 | 202 | | |
| 1000 | / 144 | Just - Just | 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.

| State State State State State | Heat treated 15 min/1020°C/AC | | | Heat treated 1 h/1150°C/AC | | |
|--------------------------------|-------------------------------|-------------------------|----------------|----------------------------|----------------|------------------|
| °C - of the other of the other | 100 h | 1 000 h | 10 000 h | 100 h | 1 000 h | 1 0 000 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 | States States States States | State State State State | and a star and | 11.4 | 6.7 | 3.9 |

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

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 | Stafford Stafford Stafford Stafford | 2.08 |
| 910 | >1000 | all and a street and a street | 3.19 |
| 990 | 400 | 0.112 | -50.4 |
| 1010 | 375 | 0.174 | -87.8 |
| 1090 | 50 | 0.5 | -541 |
| 1110 | 50 | 0.5 | -487 |

INCOLOY® alloy DS

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.

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 |
| | |

Pickling

A fused caustic soda mixture is a suitable pre-treatment to be followed by a cold water rinse before acid pickling (HNO₃/FeCl₃) 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