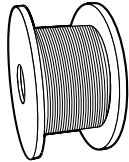


ZAPP PRECISION WIRE

ALLOY 316 (UNS S31600)

QUALITY SYSTEM CERTIFIED TO ISO 9001:2015

ZAPP



ALLOY 316 (UNS S31600) WIRE FOR:

- _ Armoring applications on electromechanical cables
- _ Wirelines for down hole service applications

CHARACTERISTICS

Alloy 316 (UNS S31600) is an austenitic stainless steel that provides good corrosion resistance in CO₂ well environments. The 316 stainless steel alloy is our entry level CRA (corrosion resistant alloy) product for oil patch applications. It contains about 17% chromium, 12% nickel, and 2.5% molybdenum, which readily enables it to replace conventional carbon/plow steel in corrosive environments.

The alloy offers good resistance to pitting and crevice corrosion, but is not recommended for use in H₂S environments. Performance in these areas is often measured using Critical Pitting Temperatures (CPT), Critical Crevice Temperatures (CCT), and Pitting Resistance Equivalent Numbers (PREN). ASTM Standard Test Methods G 48 is also referenced. It covers the procedures for the determination of the resistance of various alloys to pitting and crevice corrosion.

CHEMISTRY STANDARDS

UNS S31600

Alloy-No. 1.4401

ASTM A580

LIMITING CHEMICAL COMPOSITION OF ALLOY 316

| Ni | Cr | Mo | N | C | Mn | Fe |
|---------------|---------------|-------------|-----------|-----------|-----------|-----------|
| 10.00 – 14.00 | 16.00 – 18.00 | 2.00 – 3.00 | 0.10 max. | 0.08 max. | 2.00 max. | remainder |

Tensile strengths in the order of 205/260,000 psi are achieved through cold drawing. At these strength levels, the wire is ductile and able to successfully pass the wrap test in the as drawn condition as well as the as drawn plus exposed to temperatures as high as 300°F conditions. This wrap or bend test shows no surface cracking or failure in either condition.

For comparison purposes, PREN and CPT numbers are presented for these alloys:

PREN AND CPT NUMBERS*

| Alloy | PREN | CPT (°F) | CPT (°C) |
|------------|------|----------|----------|
| 316 | 26 | 72 | 22 |
| alloy 2205 | 36 | 108 | 42 |
| XM19 | 38 | 106 | 41 |
| alloy 2507 | 41 | 143 | 61 |
| alloy 28 | 40 | 129 | 54 |
| 25-6MO | 47 | 149 | 65 |
| 27-7MO | 56 | 176 | 80 |
| MP35N® | 53 | 183 | 84 |
| C276 | 68 | >302 | >150 |

*PREN = Cr + 3.3 Mo + 30N

*CPT (°C) = 2.5 Cr + 7.6 Mo + 31.9 N – 41

WEIGHT PER FOOT (LBS.) FOR WIRELINES

| Alloy | .082" | .092" | .108" | .125" | .140" | .150" | .160" |
|--------|-------|-------|-------|-------|-------|-------|-------|
| 316 | 0.018 | 0.023 | 0.031 | 0.042 | 0.053 | 0.060 | 0.069 |
| 2205 | 0.018 | 0.022 | 0.031 | 0.041 | 0.052 | 0.059 | 0.068 |
| XM19 | 0.018 | 0.023 | 0.031 | 0.042 | 0.053 | 0.060 | 0.069 |
| 2507 | 0.018 | 0.022 | 0.031 | 0.041 | 0.052 | 0.059 | 0.068 |
| 25-6MO | 0.018 | 0.023 | 0.032 | 0.043 | 0.054 | 0.062 | 0.070 |
| 27-7MO | 0.018 | 0.023 | 0.032 | 0.043 | 0.054 | 0.062 | 0.070 |
| MP35N® | 0.020 | 0.025 | 0.034 | 0.046 | 0.057 | 0.066 | 0.075 |
| C276 | 0.018 | 0.022 | 0.031 | 0.041 | 0.052 | 0.059 | 0.068 |

PHYSICAL PROPERTIES OF ALLOY 316 AT ROOM TEMPERATURE ARE AS FOLLOWS

| | |
|--|--|
| Density | 0.287 [lb/in ³] / 7.94 [g/cm ³] |
| Melting range | 2,500 – 2,550 [°F] / 1,370 – 1,400 [°C] |
| Specific heat | 0.12 [Btu/lb·°F] / 500 [J/kg · °C] |
| Electrical resistivity | 445 [ohm-circ mil/ft] / 0.74 [μΩ · m] |
| Permeability at 200 oersted (15.9 kA/m) | 1.02 max. [annealed] |
| Young's modulus at 70 °F (21 °C) | 28.0 [10 ³ ksi] / 193.0 [GPa] |
| Thermal Expansion at 200 °F (100 °C) | 8.90 [in/in/°F · 10 ⁻⁶] / 16.0 [cm/cm/°C · 10 ⁻⁶] |

Alloy 316 is also identified as UNS S31600. Wire products are covered by ASTM A580.

Material produced to the UNS S31600 chemistry ranges and manufactured into armor wire or wirelines by Zapp Precision Wire will provide an excellent quality product. Zapp Precision Wire technology, quality, and superior wire drawing capabilities will make the difference for these critical applications.

The Zapp Precision Wire quality system is registered to ISO-9001:2008. For additional information on this or any other Zapp Precision Wire product, please contact the Customer Service Department at 843-851-0700 or fax your inquiry to 843-851-0010, or e-mail the inquiry to sales@zapp.com.

ZAPP TECHNICAL DATA

ALLOY CHEMISTRY

| Alloy | UNS | C | Mn | Cr | Ni | Mo | Cu | N | Co | Ti | Fe |
|---------|--------|-----|-----------|-------------|-------------|-------------|-----------|-----------|------|-----|-----------|
| 316 | S31600 | .08 | 2.0 | 16.0 – 18.0 | 10.0 – 14.0 | 2.0 – 3.0 | - | - | - | - | bal. |
| 2205 | S32205 | .03 | 2.0 | 21.0 – 23.0 | 4.5 – 6.5 | 2.5 – 3.5 | - | .18 | - | - | bal. |
| XM19 | S20910 | .06 | 4.0 – 6.0 | 20.5 – 23.5 | 11.5 – 13.5 | 1.5 – 3.0 | - | .20 – .40 | - | - | bal. |
| 2507 | S32750 | .03 | 1.2 | 25.0 | 7.0 | 4.0 | - | .30 | - | - | bal. |
| 25-6MO | NO8926 | .02 | 2.0 | 19.0 – 21.0 | 24.0 – 26.0 | 6.0 – 7.0 | 0.5 – 1.5 | .15 – .25 | - | - | bal. |
| 27-7 MO | S31277 | .02 | 3.0 | 20.5 – 23.0 | 26.0 – 28.0 | 6.6 – 8.0 | 0.5 – 1.5 | .30 – .40 | - | - | bal. |
| MP35N® | R30035 | .02 | 0.1 | 19.0 – 21.0 | 33.0 – 37.0 | 9.0 – 10.5 | - | - | bal. | 1.0 | 1.0 |
| C276 | N10276 | .01 | 1.0 | 14.5 – 16.5 | - | 15.0 – 17.0 | - | - | 2.5 | - | 4.0 – 7.0 |

(Maximum values unless range specified)

ARMOR WIRE TYPICAL TENSILE STRENGTH RANGES (KSI)

| Size | 316 | XM19 | 25-6MO | 27-7MO | MP35N® |
|---------------|---------|---------|---------|---------|---------|
| .020" – .029" | 230/265 | 250/280 | 245/275 | 255/280 | 275/300 |
| .030" – .066" | 225/260 | 245/280 | 240/275 | 255/280 | 275/300 |

WIRELINE MINIMUM BREAK STRENGTH**

| Size | 316 | 2205 | XM19 | 2507 | 25-6MO | 27-7MO | MP35N® | C276 |
|-------|-------|-------|-------|-------|--------|--------|--------|-------|
| .082" | 1150# | 1345# | 1215# | 1345# | 1175# | 1300# | 1300# | 1280# |
| .092" | 1500# | 1690# | 1540# | 1690# | 1500# | 1650# | 1690# | 1615# |
| .108" | 2000# | 2240# | 2215# | 2240# | 2130# | 2250# | 2300# | 2210# |
| .125" | 2700# | 2945# | 3000# | 2975# | 2750# | 3000# | 3100# | 2935# |
| .140" | 3300# | 3540# | 3540# | 3694# | 3250# | 3670# | 3725# | 3680# |
| .150" | 3750# | 3975# | 4065# | 4150# | 3750# | 4155# | 4240# | 4205# |
| .160" | 4225# | 4425# | 4625# | 4665# | 4250# | 4650# | 4825# | 4785# |

(** The recommended **safe working load** is 60% of minimum break strength)

DENSITY/CORROSION

| Alloy | Density (lb/in ³) | Corrosion (PREN)* | CPT (°F) | CPT (°C)** |
|--------|-------------------------------|-------------------|----------|------------|
| 316 | .287 | 26 | 72 | 22 |
| 2205 | .278 | 36 | 108 | 42 |
| XM19 | .285 | 38 | 106 | 41 |
| 2507 | .281 | 41 | 144 | 62 |
| 25-6MO | .290 | 47 | 149 | 65 |
| 27-7MO | .289 | 56 | 176 | 80 |
| MP35N® | .309 | 53 | 183 | 84 |
| C276 | .321 | 68 | >302 | >150 |

* PREN = Cr + 3.3 Mo + 30N

** CPT (°C) = 2.5 Cr + 7.6 Mo + 31.9 N - 41

EXAMPLES OF THEORETICAL ACCEPTABLE WELL ENVIRONMENTS FOR 316 WIRE*

| Chlorides | Temp °F | H ₂ S | CO ₂ | Pressure (PSI) | Req. Minimum Pitting Index (PI) | 316 (PI) | 316 (PREN) |
|------------|---------|------------------|-----------------|----------------|---------------------------------|----------|------------|
| 20,000 ppm | 325 | 0 % | 6 % | 12,000 | 16.50 | 25.25 | 26 |
| 10,000 ppm | 106 | 0 % | 5 % | 1,100 | 13.00 | 25.25 | 26 |
| 25,000 ppm | 275 | 0 % | 8 % | 3,000 | 16.50 | 25.25 | 26 |
| 50,000 ppm | 240 | 0 % | 10 % | 3,500 | 13.00 | 25.25 | 26 |
| 5,000 ppm | 276 | 0 % | 0.5 % | 13,000 | 16.50 | 25.25 | 26 |

* The theoretical acceptable well environments are based on the SOCRATES software. SOCRATES is a comprehensive material selection tool for oil and gas applications that selects corrosion resistant alloys (CRA) through material evaluation based on mechanical strength parameters, heat treatment/cold work and hardness limitations. The program also evaluates the characterization of the environment in terms of operating pressure, temperature, pH, H₂S, chlorides, elemental sulfur, aeration, gas to oil ratio and water to gas ratio water cut. Stress corrosion cracking, hydrogen embrittlement cracking, sulfide stress cracking and resistance to pitting corrosion are also evaluated.

The examples above are based on the environment listed and do not take into consideration the actual values of elemental sulfur, aeration, gas to oil ratio and water to gas ratio water cut.

PI= Cr + 3.3Mo + 11N + 1.5(W+Nb)

PREN = Cr + 3.3Mo + 30N

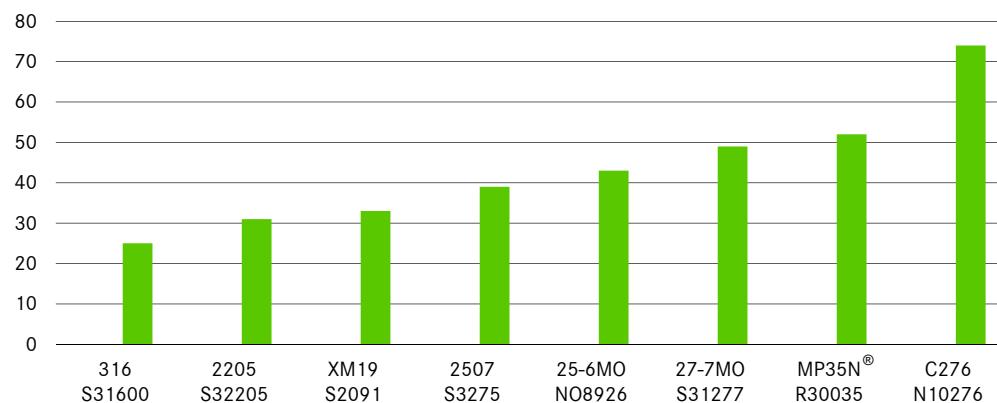
NOTE: The information in the Socrates summary report does not represent a commitment by Honeywell InterCorr International or Zapp Precision Wire, Inc. The information contained in this document and the Socrates software is purely advisory in nature. In no event shall Honeywell InterCorr, Zapp Precision Wire, Inc., or their employees or agents have liability for damages, including but not limited to, consequential damages arising out of or in connection with any person's use or inability to use the information in this document.

NOMINAL CHEMICAL COMPOSITION COMPARISON

| Chemical Element | 316 | 2205 | XM19 | 2507 | 25-6MO | 27-7MO | MP35N® | C276 |
|------------------|-------|-------|-------|-------|--------|--------|--------|-----------|
| Fe | 65.40 | 67.71 | 56.40 | 62.43 | 46.30 | 39.65 | 1.00 | 5.5 |
| Mn | 2.00 | 2.0 | 5.00 | 0.6 | 2.00 | 3.00 | 0.15 | 0.5 |
| Ni | 12.00 | 5.5 | 12.50 | 7.0 | 25.00 | 27.00 | 35.00 | 55.0 bal. |
| Co | * | * | * | * | * | * | 32.90 | 2.0 |
| Cr | 17.00 | 22.0 | 22.00 | 25.0 | 20.00 | 21.75 | 20.00 | 15.5 |
| Mo | 2.50 | 2.5 | 2.25 | 4.0 | 6.50 | 7.25 | 9.75 | 16.0 |
| W | * | * | * | * | * | * | * | * |
| Nb | * | * | 0.20 | * | * | * | * | * |
| N | * | .12 | 0.30 | * | 0.20 | 0.35 | * | * |
| * Trace | | | | | | | | |
| PI | 25.25 | 31.57 | 33.03 | 39.85 | 43.65 | 49.53 | 52.18 | 74.43 |

MATERIAL SELECTION OVERVIEW

Pitting Index



ZAPP PRECISION WIRE STANDARDS

1. All wirelines must pass an eddy current test as part of our NDT quality assurance program.
2. All wirelines and armor wires must pass an aged wrap test as part of our NDT quality assurance program.
3. All wirelines and armor wires have full traceability.
4. All 316 wirelines are 100% weld free and supplied in continuous lengths.

ZAPP PRECISION WIRE QUALITY

The Zapp Precision Wire technology, quality, and superior wire drawing capabilities will make the difference for critical armor wire and wireline applications.

The Zapp Precision Wire quality system is registered to ISO 9001:2015.

ZAPP PRECISION WIRE

WIRE | BAR | PROFILE | FLAT WIRE
 Zapp Precision Wire, Inc.
 475 International Circle
 Summerville, South Carolina 29483
 U.S.A.
 Phone 1 843 851-0700
 Fax 1 843 851-0010
 Toll-free 1 888-777-3962
 Precisionwire-usa@zapp.com
 www.zapp.com

Further information regarding our products and locations are available in our image brochure and under www.zapp.com

The illustrations, drawings, dimensional and weight data and other information included in this data sheet are intended only for the purposes of describing our products and represent non-binding average values. They do not constitute quality data, nor can they be used as the basis for any guarantee of quality or durability. The applications presented serve only as illustrations and can be construed neither as quality data nor as a guarantee in relation to the suitability of the material. This cannot substitute for comprehensive consultation on the selection of our products and on their use in a specific application. The brochure is not subject to change control.
 Last revision: July 2018