WIRELINES | SLICKLINES
ZAPP C276 (UNS N10276)

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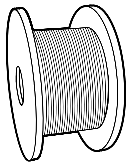

Alloy ZAPP C276 (UNS N10276) Wire for

- Armoring applications on electromechanical cables
- Wirelines for down hole service applications
- Shaping/shaped wire for down hole well screens

Characteristics

ZAPP C276 (UNS N10276) is known for its corrosion resistance in a wide range of aggressive media. It is used in chemical processing as well as oil field applications. It offers excellent corrosion resistance in a wide variety of aggressive, downhole environ-ments. It has exceptional resistance to sulfuric, phosphoric, and hydrochloric acid.

ZAPP C276 is one of the premier materials for recovery and handling of "sour" natural gas, which contains hydrogen sulfide and usually carbon dioxide and chlorides. The gas can be extremely corrosive to carbon and alloy steels, and may cause brittle failure of many alloys by sulfide stress cracking (hydrogen embrittlement) or stress-corrosion cracking. The high levels of nickel, chromium, and molybdenum in alloy ZAPP C276 make the alloy resistant to sour environments even at high temperatures in deep wells. The alloy is also used for tubing and a variety of other downhole and surface components.

The alloy ZAPP C276 material contains about 57% nickel, 16% chromium, 16% molybdenum, and 1.0% manganese. See Table 1 for chemical composition limits. Nickel and molybdenum provide resistance to reducing media while the high chromium content offers resistance to oxidizing media. The alloy performs well in mixed acid environments, especially those containing oxidizing and reducing acids. The nickel content provides strong resistance to stress corrosion cracking and also attack by caustic media. The alloy offers excellent resistance to corrosion in seawater, brine, and high chloride environments. The chemical composition and balance of elements of the ZAPP C276 alloy produces a wire material which can provide excellent service in many of the most aggressive downhole environments. It is expected to be an ideal material for acidizing wells using HCL and for high temperature geothermal applications.

Table 1 - Limiting Chemical Composition of Alloy ZAPP C276, Weight %

Ni	Cr	Mo	W	C	Co	Mn	Fe
bal.	14.50 - 16.50	15.00 – 17.00	3.75 – 4.50	0.01 max	2.50	1.00 max	4.00 – 7.00

Chemistry Standards

- UNS N10276
- W.Nr.2.4819
- ASTM B574
- ASME SB574

TABLE 2 - Minimum Break Loads for a 0.108" Diameter Wireline Product

Alloy	Min. Break Load	Recommended Safe Working Load
ZAPP 316	2,000#	1,200#
ZAPP 2205	2,240#	1,344#
ZAPP XM19	2,200#	1,320#
ZAPP 2507	2,240#	1,344#
ZAPP 25-6MO	2,150#	1,290#
ZAPP C276	2,200#	1,320#
ZAPP 27-7MO	2,250#	1,350#
ZAPP MP35N	2,300#	1,380#
ZAPP C276	2,210#	1,326#

The ZAPP C276 alloy offers excellent resistance to pitting and crevice corrosion. Relative performance in these areas is often measured using Critical Pitting Temperatures (CPT), Critical Crevice Temperatures (CCT), and Pitting Resistance Equivalent Numbers (PREN). Alloys exhibiting higher PREN values are generally found to be more corrosion resistant than those with lower PREN values. The PREN can be calculated by using several different equations based upon the chemical composition of the alloys. For the comparisons in this technical summary, the following equation was used:

PREN = Cr + 3.3 Mo + 30 N

When comparing alloys by their PREN value, it is imperative that the same equation be used for all materials to be compared, otherwise, erroneous results can occur.

PREN values are listed in Table 3, comparing ZAPP C276 to a variety of alloys such as ZAPP 316, ZAPP 2205, ZAPP XM19, ZAPP 28, ZAPP 25-6MO, ZAPP 27-7MO and ZAPP MP35N. Based upon these values, ZAPP C276 compares quite favorably to these alloys which are currently being used extensively for armor wire and wireline applications. It should be noted that the PREN value for ZAPP MP35N doesn't reflect the true comparative corrosion resistance compared to ZAPP C276. ZAPP MP35N contains about 35% cobalt. Cobalt is a critical factor in terms of corrosion resistance and break strength. However, cobalt percentages are not included in the PREN formula and thus tend to skew the relative corrosion resistance results in this instance. As a point of reference, ASTM Standard Test Methods G-48 is noted. It covers the procedures for the determination of the resistance of various alloys to pitting and crevice corrosion.

Table 3 –
Pitting Resistance Equivalency Numbers (PREN)

Alloy	PREN*
ZAPP 316	26
ZAPP 2205	36
ZAPP XM19	38
ZAPP 2507	41
ZAPP 28	40
ZAPP 25-6MO	47
ZAPP 27-7MO	56
ZAPP MP35N	53
ZAPP C276	68

*PREN = Cr + 3.3 Mo + 30N

Alloys may also be ranked by the threshold temperature at which they begin to be attacked in a given medium. Samples may be directly exposed to the medium which may induce pitting, or a crevice device may be attached which may induce crevice corrosion. The samples are exposed at increasing temperatures until corrosive attack occurs. The lowest temperature at which measurable corrosion takes place is defined as the Critical Pitting Temperature (CPT) or Critical Crevice Temperature (CCT), depending on whether or not a crevice device is attached to the sample. One test method is covered by ASTM G48. Method C is a pitting test while Method D is a crevice corrosion test. The maximum test temperature is 85°C (185°F) as the test solution becomes unstable at higher temperatures.

CPT and CCT values for some alloys are presented in Table 4 and Table 5. It is seen that alloy ZAPP C276 exhibits
higher values than alloy ZAPP 25-6MO, ZAPP 27-7MO and alloy 625.

Table 4 - CPT and CCT per ASTM G48 Test Methods C and D

Alloy	Critical Pitting Temperature		Critical Crevice Temperature	
	°C	°F	°C	°F
ZAPP 25-6MO	70	158	35	95
ZAPP 27-7MO	>85	>185	45	113
Alloy 625	>85	>185	35	95
ZAPP C-276	>85	>185	50	122

Reference: Special Metals Technical Bulletin SMC-092

The ZAPP C276 alloy wire produces a tensile strength of 240/260,000 psi through cold drawing. At this strength level, 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 600°F conditions. This wrap or bend test shows no surface cracking or failure. Strong resistance to stress corrosion cracking (SCC) is one of the benefits of the ZAPP C276 alloy wire.

Several corrosion testing results for ZAPP C276 in HCL environments may be found in Special Metals Technical Bulletin SMC – 019 (see Tables 5, 6, 7).

Material produced to the UNS N10276 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, Inc. product, please contact the Customer Service Department at 843-851-0700 or fax your inquiry to 843-851-0100, or e-mail the inquiry to sales@zapp.com.

Table 5 - Physical Properties of Alloy ZAPP C276 in Annealed Condition at Room Temperature are as follows

Density	0.321 [lb/in^3]/ 8.885 [g/cm^3]
Melting Range	2,415 – 2,500 [°F]
Specific Heat	0.102 [Btu/lb·°F]
Electrical Resistivity	>739 ohms-cmil/ft.
Permeability at 200 Oersted (15.9kA/m)	>1.0002
Young´s Modulus 10^3ksi	>29.8
Mean Coefficient of Thermal Expansion	75 - 200 6.2 microinches/in.-°F 24-93 11.2 x 10^{-6} m/m·k 75 - 400 6.7 microinches/in.-°F 24 - 204 12.0 x 10^{-6} m/m·k

Zapp Technical Data

Alloy Chemistry

Alloy	UNS	C	Mn	Cr	Ni	Mo	Cu	N	Co	Ti	Fe
ZAPP 316	S31600	.08	2.0	16.0 – 18.0	10.0 – 14.0	2.0 – 3.0.	-	-	-	-	bal.
ZAPP 2205	S32205	.03	2.0	21.0 – 23.0	4.5 – 6.5	2.5 – 3.5	-	.18	-	-	bal.
ZAPP XM19	S20910	.06	4.0 - 6.0	20.5 – 23.5	11.5 – 13.5	1.5 – 3.0	-	.20 - .40	-	-	bal.
ZAPP 2507	S32750	.03	1.2	25.0	7.0	4.0	-	.30	-	-	bal.
ZAPP 25-6MO	NO8926	.02	2.0	19.0 – 21.0	24.0 - 26.0	6.0 – 7.0	.5 – 1.5	.15 - .25	-	-	bal.
ZAPP 27-7 MO	S31277	.02	3.0	20.5 – 23.0	26.0 – 28.0	6.6 – 8.0	.5 – 1.5	.30 - .40	-	-	bal.
ZAPP MP35N	R30035	.02	0.1	19.0 – 21.0	33.0 – 37.0	9.0 – 10.5	-	-	bal.	1.0	1.0
ZAPP C276	N10276	.01	1.0	14.5 – 16.5	bal.	15.0 - 17.0	-	-	2.5	-	4.0 – 7.0

(Maximum values unless range specified)

Armor Wire Typical Tensile Strength Ranges (ksi)

Size	ZAPP 316	ZAPP XM19	ZAPP 25-6MO	ZAPP 27-7MO	ZAPP MP35N	ZAPP C276
.020" - .029"	230/260	250/280	245/275	255/280	275/300	240/260
.030" - .066"	225/260	245/280	240/275	255/280	275/300	240/260

Wireline Minimum Break Strength**

Size	ZAPP 316	ZAPP 2205	ZAPP XM19	ZAPP 2507	ZAPP 25-6MO	ZAPP 27-7MO	ZAPP MP35N	ZAPP C276
.082"	1,150#	1,345#	1,215#	1,345#	1,175#	1,300#	1,300#	1,,,,,,280#
.092"	1,500#	1,690#	1,540#	1,690#	1,500#	1,650#	1,690#	1,615#
.108"	2,000#	2,240#	2,200#	2,240#	2,150#	2,250#	2,300#	2,210#
.125"	2,700#	2,945#	3,000#	2,975#	2,800#	3,000#	3,100#	2,935#
.140"	3,300#	3,540#	3,540#	3,694#	3,480#	3,670#	3,725#	3,680#
.150"	3,750#	3,975#	4,065#	4,150#	3,950#	4,155#	4,240#	4,205#
.160"	4,225#	4,425#	4,625#	4,665#	4,350#	4,650#	4,825#	4,785#

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

Density/Corrosion

Alloy	Density (lb/in³)	Corrosion (PREN)*	CPT (°F)	CPT (°C)**
ZAPP 316	.287	26	72	22
ZAPP 2205	.278	36	108	42
ZAPP XM19	.285	38	106	41
ZAPP 2507	.281	41	144	62
ZAPP 25-6MO	.290	47	149	65
ZAPP 27-7MO	.289	56	176	80
ZAPP MP35N	.309	53	183	84
ZAPP C276	.321	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"
ZAPP 316	0.018	0.023	0.031	0.042	0.053	0.060	0.069
ZAPP 2205	0.018	0.022	0.031	0.041	0.052	0.059	0.068
ZAPP XM19	0.018	0.023	0.031	0.042	0.053	0.060	0.069
ZAPP 2507	0.018	0.022	0.031	0.041	0.052	0.059	0.068
ZAPP 25-6MO	0.018	0.023	0.032	0.043	0.054	0.062	0.070
ZAPP 27-7MO	0.018	0.023	0.032	0.043	0.054	0.062	0.070
ZAPP MP35N	0.020	0.025	0.034	0.046	0.057	0.066	0.075
ZAPP C276	0.018	0.022	0.031	0.041	0.052	0.059	0.068

Examples of Theoretical Acceptable Well Environments for ZAPP C276 Wire in HCL Acidizing Environments*

Examples	Type of Acid	Inhibitor Used?	Chlorides	Temp °F	H_2S	CO_2	Pressure (PSI)	Req. Minimum Pitting Index (PI)	ZAPP C276 (PI)	ZAPP C276 (PREN)
A	15 % HCL	Yes	20,000 ppm	400	1%	10%	5,000	56	74.43	68
B	28 % HCL	Yes	150,000 ppm	450	3%	11%	5,000	70	74.43	68
C	28 % HCL	No	100,000 ppm	275	10%	10%	10,000	56	74.43	68
D	28 % HCL	No	120,000 ppm	380	20%	30%	15,000	70	74.43	68
E	15 % HCL	No	20,000 ppm	180	40%	60%	3,000	56	74.43	68
F	15 % HCL	Yes	25,000 ppm	425	3%	3%	3,000	56	74.43	68

*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, H_2S, 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.

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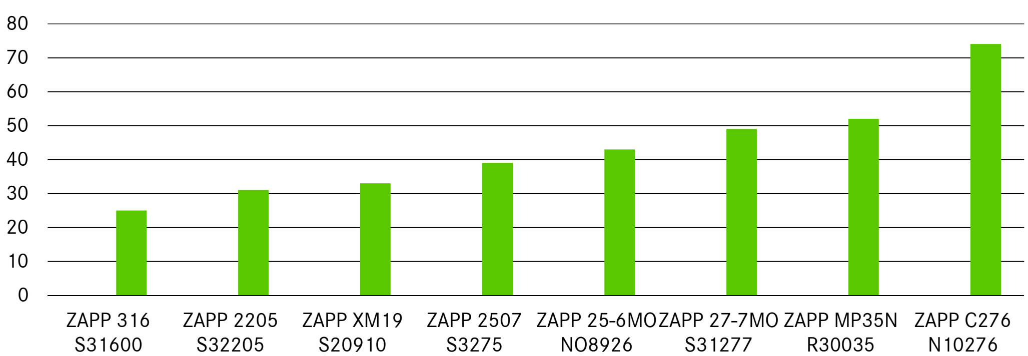
$PI = Cr + 3.3Mo + 11N + 1.5(W+Nb)$ $PREN = Cr + 3.3Mo + 30N$

Nominal Chemical Composition Comparison

Chemical Element	ZAPP 316	ZAPP 2205	ZAPP XM19	ZAPP 2507	ZAPP 25-6MO	ZAPP 27-7MO	ZAPP MP35N	ZAPP C276
Fe	65.4	67.71	56.40	62.43	46.3	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	*	0.12	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 ductility quality assurance program.
3. All wirelines and armor wires have full traceability.
4. All ZAPP C276 wirelines and armor wires are produced using shaved, defect free rod material.

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 9001:2008.

ZAPP PRECISION WIRE
WIRE I BAR I PROFILE I 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

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