ZAPP 27-7MO (UNS S31277)

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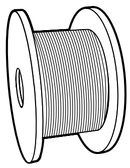


ZAPP 27-7MO (UNS S31277) Wire for

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

Characteristics

ZAPP 27-7MO (UNS S31277) is a new generation “super austenitic” stainless steel offering excellent corrosion resistance in a wide variety of aggressive, down hole environments. It provides superior corrosion resistance and performance compared to the currently approved ZAPP 25-6MO alloy. It contains about 7% molybdenum along with higher levels of chromium, nickel, nitrogen, and manganese, which enables it to approach the performance of much higher alloyed materials. It also represents a cost-effective alternative to the higher nickel alloys in some marine, petroleum, and chemical processing environments.

ZAPP 27-7MO material contains about 27% nickel, 22% chromium, 7.2% molybdenum, 1.5% manganese, and 0.34% nitrogen. See Table 1 for chemical composition limits. The nickel and nitrogen produce a stable austenitic structure. The molybdenum, chromium, nitrogen, and manganese content offers excellent resistance to pitting and crevice corrosion. Nickel, nitrogen, 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 and nitrogen 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 27-7MO alloy produces a wire material which can provide excellent service in many of the most aggressive down hole environments. It is expected to be an ideal material for the "oil patch".

Table 1 - Limiting Chemical Composition of Alloy ZAPP 27-7MO, Weight %

Ni	Cr	Mo	Cu	N	C	Mn	Fe
26.00 - 28.00	20.50 – 23.00	6.5 – 8.0	0.5 – 1.5	0.30 – 0.40	0.020 max	3.00 max	remainder

The alloy offers a unique combination of corrosion resistance, high strength, ease of fabrication, and commercial availability, all at an economical price. It provides strong improvements over ZAPP 25-6MO in terms of strength and corrosion resistance with no negatives on forming or wire availability. It is expected that ZAPP 27-7MO will achieve tensile strength levels greater than that of ZAPP 25-6MO.

Table 2 compares minimum room temperature break loads for a typical 0.108" diameter wireline of ZAPP 27-7MO, ZAPP 25-6MO, ZAPP 28, ZAPP XM19, ZAPP 316, and ZAPP MP35N.

Chemistry Standards:

- UNS S31277
- ASTM A580

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

Alloy	Min. Break Load	Recommended Safe Working Load (60%)
ZAPP 316	2000#	1200#
ZAPP XM19	2110#	1266#
ZAPP 28	1910#	1145#
ZAPP 25-6MO	2150#	1290#
ZAPP 27-7MO	2250#	1350#
ZAPP MP35N	2300#	1380#

The ZAPP 27-7MO 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 27-7MO to a variety of alloys such as ZAPP 316, ZAPP 2205, ZAPP XM19, ZAPP 28, ZAPP 25-6MO, and ZAPP MP35N. Based upon these values, ZAPP 27-7MO 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 27-7MO. 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. Corrosion tests would confirm that ZAPP MP35N is superior to ZAPP 27-7MO. 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 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 27-7MO exhibits higher values than alloy ZAPP 25-6MO and alloy 625 and approaches those of alloy ZAPP C276.

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
INCONEL® Alloy 625	>85	>185	35	95
ZAPP C-276	>85	>185	50	122

Table 5 provides CPT and CCT test results for cold drawn armor wire. As expected, the ZAPP 27-7MO alloy wire test results fall between ZAPP 25-6MO and ZAPP MP35N.

Table 5 - Test Results of Stressed Armor Wire in Pitting and Crevice Environments

Alloy	G 48 D at 25°C (Crevice Corrosion)	CPT in G 48 C (Pitting Corrosion)
ZAPP 25-6MO	Superficial attack	<60°C
36MO	All sites attacked	75°C
ZAPP 27-7MO	None	80°C
ZAPP MP35N	None	>80°C

The ZAPP 27-7MO alloy wire produces higher mechanical properties than the ZAPP 25-6MO alloy. Tensile strengths on the order of 220/280,000 psi can be 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 400°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 27-7MO alloy wire. Table 6 lists five sets of test conditions to determine resistance of cold drawn and stressed wire to stress corrosion cracking. Table 7 presents the test results and confirms that ZAPP 27-7MO has a high degree of resistance to SCC.

Table 6 – Test Conditions for Examination of SCC Resistance in Cold Drawn, Stressed Wire

Test 1	Saturated NaCl + 2.5% NH_4HSO_3 boiling for 1008 hours
Test 2	23.5% MgCl2 + 6%KCl + 0.3% CaO boiling for 1008 hours
Test 3	5% NaCl + 0.5% Acetic acid purged w/ H_2S room temp for 1008 hrs (not coupled to steel)
Test 3b	5% NaCl + 0.5% Acetic acid purged w/ H_2S room temp for 1008 hrs (coupled to steel)
Test 4	Saturated NaCl + 5%$MgCl_2$ + 5% H_2S at 350°F (177°C) and 5000 psi for 336 hours

Table 8 - Physical Properties of Alloy ZAPP 27-7MO in Annealed Condition at Room Temperature are as Follows

Density	0.289 [lb/in³]/ 8.02 [g/cm³]
Melting Range	2,410 – 2,550 [°F]
Specific Heat	0.11 [Btu/lb·°F]
Electrical Resistivity	604 [ohm·circ mil/ft]/ 1.00 [μΩ·m]
Permeability at 200 Oersted	1.004
Specific Heat	0.11 [Btu/lb·°F]/ 454 [J/kg·°C)
Young´s Modulus	27.7 [10^3 Ksi]/ 191.0 [GPa]
Thermal Expansion at 200 °F	8.3 [in/in·°F x 10^{-6}]/ 15.03 [cm/cm·°C x 10^{-6}]

ZAPP 27-7MO is also identified as UNS S31277. For comparison purposes, the ZAPP 25-6MO alloy is identified as UNS N08926. A number of other commercially available alloy designations are related to alloy ZAPP 25-6MO through the UNS N08926 designation or through published chemistry ranges. These alternate designations or trademarks include:

- ZAPP 25-6MO (trademark of Special Metals Corporation)
- D31MO (trademark of Central Wire Industries)
- SUPA 75 (trademark of Central Wire Industries)
- Cronifer® 1925hMo (trademark of Krupp VDM)
- AL6XN (trademark of Allegheny Ludlum Corporation)
- Phy 4529 (trademark of Metalimphy Alloys Corporation)

Material produced to the UNS S31277 or UNS N08926 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 7 - Test Results for SCC Resistance Studies on Cold Drawn, Stressed Wire

	Test 1	Test 2	Test 3	Test 3b	Test 4
ZAPP 25-6MO	No cracking	No cracking	No cracking	No cracking	No cracking
36MO	No cracking	No cracking	No cracking	No cracking	No cracking
ZAPP 27-7MO	No cracking	No cracking	No cracking	No cracking	No cracking
ZAPP MP35N	No cracking	No cracking	No cracking	No cracking	No cracking

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
.020" - .029"	230/260	250/280	245/275	250/280	270/300
.030" - .066"	225/260	245/280	240/275	245/280	265/300

Wireline Minimum Break Strength**

Size	ZAPP 316	ZAPP 2205	ZAPP XM19	ZAPP 2507	ZAPP 25-6MO	ZAPP 27-7MO	ZAPP MP35N	ZAPP C276
.082"	1150#	1345#	1215#	1345#	1175#	1300#	1300#	1280#
.092"	1500#	1690#	1540#	1690#	1500#	1650#	1690#	1615#
.108"	2000#	2240#	2000#	2240#	2150#	2250#	2300#	2210#
.125"	2700#	2945#	3000#	2975#	2800#	3000#	3100#	2935#
.140"	3300#	3540#	3540#	3694#	3480#	3670#	3725#	3680#
.150"	3750#	3975#	4065#	4150#	3950#	4155#	4240#	4205#
.160"	4225#	4425#	4325#	4665#	4350#	4650#	4825#	4785#

(** 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

Examples of Theoretical Acceptable Well Environments for ZAPP 27-MO Wire*

Chlorides	Temp °F	H_2S	CO_2	Pressure (PSI)	Req. Minimum Pitting Index (PI)	ZAPP 27-7MO (PI)	ZAPP 27-7MO (PREN)
20,000 ppm	400	1 %	10 %	5,000	37.00	49.53	56
150,000 ppm	450	3 %	11 %	5,000	40.00	49.53	56
100,000 ppm	275	10 %	10 %	10,000	43.00	49.53	56
120,000 ppm	380	20 %	30 %	15,000	43.00	49.53	56
20,000 ppm	180	40 %	60 %	3,000	40.00	49.53	56
25,000 ppm	425	3 %	3 %	3,000	37.00	49.53	56

*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.

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

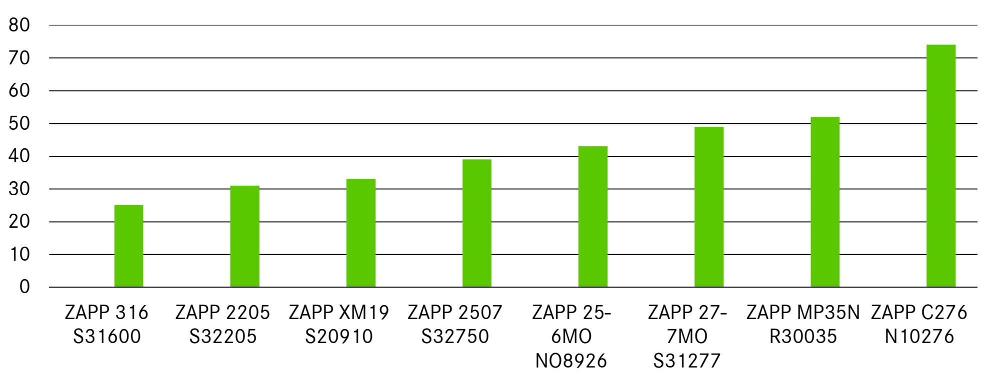
PREN = Cr + 3.3Mo + 30N

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	ZAPP 316	ZAPP 2205	ZAPP XM19	ZAPP 2507	ZAPP 25-6MO	ZAPP 27-7MO	ZAPP MP35N	ZAPP 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	*	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

Pitting Index



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

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 27-7MO 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 9001:2015.

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