

UNS N08935 – A New Versatile Grade for O&G

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ABSTRACT

UNS N08935 is a new versatile austenitic alloy with the composition 35Ni–30Fe–27Cr–6.5Mo–0.28N and a PREN of 52. It has an extreme pitting resistance which makes the grade a good candidate for O&G applications. The alloy is available in several strength levels with good ductility: seamless tubes with 62 ksi, 140 ksi and 180 ksi. It is an austenitic grade that is worked to strength which results in an alloy with very high resistance to hydrogen effects. According to NACE MR0175 / ISO 15156 the grade will be a Type 4c material.

For the 62 ksi material the resistance against Hydrogen Induced Stress Cracking (HISC) has been demonstrated by constant load testing of specimens polarized to $-1050 \text{ mV}_{\text{SCE}}$. For the cold worked material Slow Strain Rate Testing (SSRT) at Test Level VI in NACE MR0175 / ISO 15156, a condition within Type 4d is discussed.

With its high mechanical strength and pitting resistance as well as being not prone for HISC, UNS N8935 is an interesting candidate for subsea applications. Further, UNS N08935 is interesting as tubing for HPHT-wells due to its very high strength.

Key words: UNS N08935, SCC, hydrogen sulfide, hydrogen embrittlement

INTRODUCTION

UNS N08935 is a newly developed 6% Mo grade that has a high Pitting Resistance Equivalent Number (PREN) of 52. Earlier data has been presented for heat exchanger tubing where extreme pitting resistance was shown. In addition general corrosion results in Hydrochloric Acid and Sulfuric Acid have been reported.¹ For solution annealed tubes from the same heats as used in this work, a Critical Pitting Temperature, CPT, at 100.8°C and 102.5°C in modified ASTM⁽¹⁾ G150¹ with 3M MgCl₂, Magnesium Chloride, was reported.² Those investigations were made on annealed material. A mean CPT in ASTM G48E³ of 70°C for butt welded tubes with Alloy 59 as filler metal was reported.⁴

UNS N08935 is a structurally stable austenitic alloy where high pitting resistance and mechanical strength have been combined. This has been achieved by alloying with nitrogen while keeping the nickel content high. With such high nickel content as 35% the material is very structure stable and not prone to form intermetallic phases. Another aspect is that the material is fully austenitic which indicates that the alloy is not prone to hydrogen embrittlement. Some failures have occurred on precipitation hardened Ni-base alloys due to hydrogen embrittlement.⁵ It should be noted that UNS N08935 is cold worked to strength and not precipitation hardened. The nitrogen content around 0.28% can be dissolved in the austenite and hence no chromium nitrides are formed. The high nickel content together with 6.5 % molybdenum and 26-27% chromium indicates that UNS N08935 should have good resistance against Stress Corrosion Cracking (SCC) in H₂S environments.

The high yield strength as well as the high PREN and nickel content makes the grade interesting for other applications within oil and gas such as subsea applications and downhole tubing. For these applications resistance against hydrogen related cracking is very important. For subsea applications resistance against hydrogen embrittlement when subject to cathodic protection is required and for downhole applications such as OCTG, resistance against cracking in Hydrogen Sulfide environments is crucial.

In this work the resistance against hydrogen embrittlement was tested by constant load technique on solution annealed materials and slow strain rate, SSRT, was performed in sour environment at NACE MR0175 / ISO⁽²⁾ 15156⁶ Test level VI in cold worked condition in 140 and 180 ksi strength levels. In addition, to verify the earlier reported pitting resistance, CPT was measured on the 180 ksi material.

EXPERIMENTAL PROCEDURE

Material

Samples were taken from seamless tubing from full scale production of UNS N08935 and the composition is given in Table 1. The heat was produced by an Electric Arc furnace (EAF), and Argon Oxygen Decarburization (AOD), refining. Extrusion and cold pilgering were used for tube production. The sample for hydrogen embrittlement exposures was obtained from extruded material and the ones for the H₂S-testing from cold pilgered material. The PREN calculated according to NACE MR0175/ISO 15156-3 was 52.3.

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⁽²⁾ISO (ISO), Ch. de Blandonnet 8, CH-1214 Vernier, Geneva, Switzerland.

Table 1: Chemical composition of UNS N08935 [wt-%]

Material	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	N	PREN
UNS N08935	≤0.020	0.18	0.77	≤0.030	≤0.010	26.9	34.8	6.3	0.20	0.29	52.3

In Table 2 the mechanical properties and dimensions of the tested material are shown. In cold worked condition two strength levels were tested: 5" tubing at 140 ksi and 4.5" tubing at 180 ksi. The cold worked material passed flattening testing according to ISO 13680.⁷

Table 2: Mechanical properties of tested seamless tubes of UNS N08935

Strength level [ksi]	Dimension [mm]	Yield strength [MPa]	Tensile strength [MPa]	Elongation, A [%]	Hardness
62	63 x 7,0	425	812	62	96 HRB
140	127.7 x 7.52	1004	1138	26	35 HRC
180	114.3 x 6.88	1299	1444	15	40 HRC

H₂S-testing

SSRT was performed according to NACE TM 0198.⁸ The environment was Test Level VI according to NACE MR0175 / ISO 15156 which has partial pressures of 500 psi a H₂S and 500 psi CO₂. 20 wt-% sodium chloride was used as test solution and the temperature was 175°C ± 3. The extension rate was 4 x 10⁻⁶ in/s and sub size specimens were used. Two specimens were tested in the corrosive environment and one in nitrogen at the same temperature as baseline for the 180 ksi material and two for the 140 ksi material.

Pitting

CPT was measured in modified ASTM G150 at a potential at +700 mV_{SCE}. The modifications were that 3 M MgCl₂ was used instead of 1 M NaCl and the starting temperature was 20°C. The surface of the specimens was ground to P600 paper. This modified setup enables testing at higher temperatures and makes the test more aggressive. The method and its development have been described elsewhere.⁹

Hydrogen embrittlement testing

Samples from extruded and solution annealed seamless tubes with the dimension of 63 x 7 mm were used. Sub size specimens were used, and the surface was ground to P600 paper. Pre-charged specimens were subject to constant load testing with dead weight. The temperature was regulated to 4°C ± 1. The mean temperature was 4.2°C. As load 100% and 120% of the yield strength at room temperature were used. As electrolyte 3 wt-% sodium chloride purged with nitrogen was used and a potentiostat to impose a potential of -1050 mV_{SCE}. A three-electrode cell was used with platinum as counter electrode and Ag/AgCl₂ [3 M KCl] as reference electrode. Galvanostatic per-charging with a 20 mA/cm² current density in 10% sulfuric acid with 30 mg/l arsenic oxide (As₂O₃) was used.

RESULTS

H₂S-testing

Figure 1 shows the results from the SSRT experiments at Test level VI. For both 140 ksi and 180 ksi material ductile fractures were observed with ratios at 92% and above for time to failure, elongation to failure, plastic strain to failure and reduction in area compared to inert environment. The initial pH was