6Mo Alloys
Advantages of Alloy 6HN over Alloy 254

Introduction

Named for their 6% molybdenum content, 6Mo super austenitic stainless steel alloys are highly resistant to pitting corrosion and chloride-induced stress corrosion cracking. Commonly used 6Mo alloys include UNS S31254 (alloy 254) and UNS N08367 (AL-6XN® and alloy 6HN). Swagelok is using the name “alloy 6HN” for UNS N08367 material. The NORSOK M-630 Piping Data Standard includes information on additional 6Mo alloys in addition to the two covered in this document.

Table 1 Chemical Composition

Alloy	UNS	% Ni	% Cr	% Mo	% Cu	% N	Pitting Resistance Equivalent Number① (PREN)
254	S31254	17.5 — 18.5	19.5 — 20.5	6.0 — 6.5	0.50 — 1.00	0.18 — 0.22	42.2 — 45.5
6HN	N08367	23.5 — 25.5	20.0 — 22.0	6.0 — 7.0	0.75 max	0.18 — 0.25	42.7 — 49.1

① PREN = %Cr + 3.3 × %Mo + 16 × %N

Alloy 254 has commonly been the industry choice for applications needing NORSOK-approved 6Mo material. Yet, newer alloys, such as 6HN, have a 6 weight % higher nickel content which provides significantly better corrosion resistance than alloy 254 at a similar cost.

Improved Corrosion Resistance

The additional 6 weight % of nickel content in 6HN results in improved resistance to chloride-induced stress corrosion cracking, pitting corrosion, and crevice corrosion.

Critical Pitting Temperature

Critical Pitting Temperature (CPT) is the minimum temperature at which pitting corrosion is observed. Figure 1 compares the CPT for alloys 6HN and 254.

Test Conditions

The temperature of the 3% NaCl solutions was slowly increased from room temperature and the immersed samples were observed for signs of pitting. The appearance of pitting was used to determine the critical pitting temperature. The band shows the range of results, while the star shows the average of four tests.

Alloy 6HN resists pitting corrosion to a higher temperature than Alloy 254.

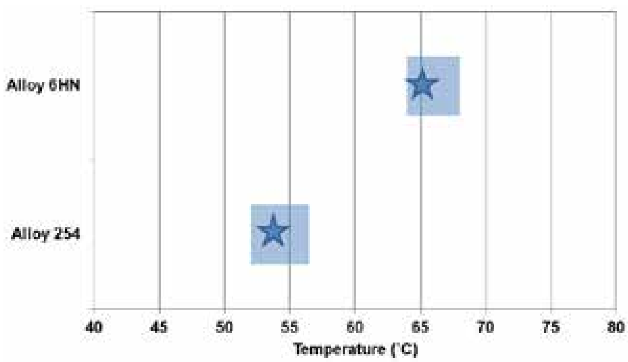

Fig. 1 Critical Pitting Temperature Range for 6Mo Alloys

Source Fig. 1: Drugli J.M. et al, “High alloyed stainless steels for chlorinated seawater applications — testing for critical pitting temperature”, Corrosion ‘93, Paper No. 645, NACE, 8-12 March 1993

Critical Crevice Corrosion Temperature

Critical crevice corrosion temperature (CCCT) is the minimum temperature at which crevice corrosion is observed. Figure 2 compares the CCCT for alloys 6HN and 254.

Test Conditions

The values were determined by three tests run in 3% NaCl to compare each grade's suitability for use in seawater applications in the North Sea. The band shows the range of results, while the star shows the average of three tests.

Alloy 6HN resists crevice corrosion to a higher temperature than Alloy 254.

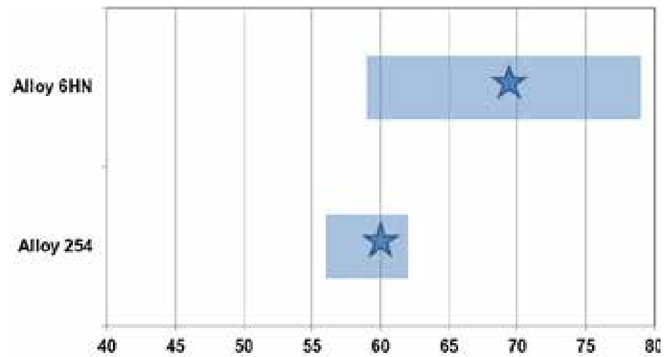

Fig. 2 Critical Crevice Corrosion Temperature Range for 6Mo Alloys

Source, Fig. 2: Drugli J.M. et al, "High alloyed stainless steels for chlorinated seawater applications — testing for critical pitting temperature", Corrosion '93, Paper No. 645, NACE, 8-12 March 1993

Resistance to Crevice Corrosion

Additional testing performed at the Swagelok® Chemistry and Corrosion Laboratory was done to measure the percentage of area showing crevice corrosion for alloys 254 and 6HN. Three to five test samples of each material were assembled with either ceramic or PTFE crevice washers and tested according to ASTM G48 Method F, which involves immersion in an aqueous solution of 6% $FeCl_3$ and 1% HCl, for 24 hours at 50°C. Figure 3 shows the range of results for the samples tested.

Alloy 6HN shows a lower percentage of area with crevice corrosion than Alloy 254.

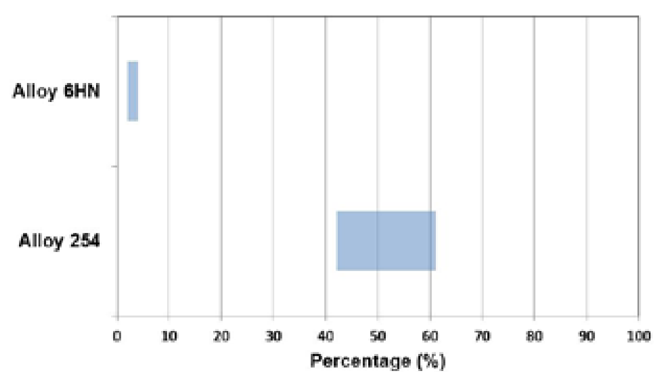

Fig. 3 Percentage of Surface Area Affected By Crevice Corrosion

Better Mechanical Properties

Alloy 6HN contains approximately 6 weight % more nickel than alloy 254. This additional nickel content helps stabilize austenite, making it less likely to form detrimental intermetallic phases. The superior stability of alloy 6HN allows for a lower minimum solution annealing temperature of 2025˚F (1105˚C) versus 2100˚F (1150˚C) for forgings of alloy 254, as required by ASTM A182. A higher solution annealing temperature can lead to a microstructure with larger grains and, as a result, a material with lower yield strength. Figure 4 shows a typical microstructure of a solution-annealed 254 forging.

Swagelok has taken the greater stability of alloy 6HN into account and developed a unique hot-forming process for alloy 6HN forgings. This process was qualified to the requirements of the NORSOK M-650 supply chain qualification standard. This innovative forging method makes it possible to achieve a much finer microstructure (Fig. 5). Table 2 compares the mechanical properties of 254 forgings produced by the traditional method with those of 6HN forgings made with Swagelok's forging process. The enhanced properties of the 6HN forgings are a result of their fine-grained microstructure.

Fig. 4 Typical Microstructure of Solution-annealed Alloy 254 Forging

Fig. 5 Typical Microstructure of Alloy 6HN Forging Produced with Swagelok Forging Process Qualified to the Requirements of NORSOK M-650

The mechanical property requirements of ASTM A479 for annealed bar and A182 for forgings are similar for alloy 6HN and alloy 254. A greater difference can be seen in the ASME B31.3 maximum allowable design stresses which are somewhat higher for 6HN than 254.

Table 2 Mechanical Properties of Alloy 254 and Alloy 6HN Forgings

	Yield Strength, ksi (MPa)		Tensile Strength, ksi (MPa)		Elongation, %		Reduction of Area, %	
Alloy	Swagelok (typical)	ASTM A182 (minimum)	Swagelok (typical)	ASTM A182 (minimum)	Swagelok (typical)	ASTM A182 (minimum)	Swagelok (typical)	ASTM A182 (minimum)
254	48 (331)	44 (303)	100 (690)	94 (650)	59	35	83	50
6HN	61 (420)	45 (310)	111 (762)	95 (655)	50	30	85	50

Conclusion

Valves and fittings produced from alloy 6HN have significant advantages over those made from alloy 254, including:

- Increased resistance to pitting and crevice corrosion and chloride-induced stress cracking
- Better stability with respect to formation of detrimental intermetallic phases such as sigma phase during thermomechanical processing
- Improved mechanical properties of forgings produced with Swagelok's NORSOK-approved forging process

For oil and gas customers using products in corrosive and high-pressure environments, Swagelok provides NORSOK-approved alloy 6HN material with documented improvement in corrosion resistance and mechanical properties over alloy 254. Contact your authorized sales and service center to learn more.

Safe Product Selection
When selecting a product, the total system design must be considered to ensure safe, trouble-free performance. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

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