

# Carpenter's Non-Magnetic Alloys: Meeting the Challenges of Directional Drilling



## THE EVOLUTION OF NON-MAGNETIC ALLOYS

The demands of directional drilling have evolved over the years, but the primary requirements remain for non-magnetic drill collars - they must have very low magnetic permeability (<1.005) to not interfere with the magnetometer readings and they must have sufficient strength to transfer the load to the bit. In the early days of directional drilling, non-magnetic drill collars were made of Nickel-Copper alloys, called Monels. But, these alloys were expensive and higher strength was needed. To meet the challenges of directional drilling, Carpenter developed a family of lower cost alloys with improved strength, fatigue and corrosion resistance.

## CARPENTER 15-15LC® MODIFIED STAINLESS

Carpenter's proprietary 15-15 LC MOD is a non-magnetic stainless steel developed to meet the requirements for standard non-magnetic drill collars as specified in API 7-1. The low carbon composition of 15-15 LC MOD provides improved resistance to pitting and Stress Corrosion Cracking (SCC).

## CARPENTER 15-15HS® MAX STAINLESS

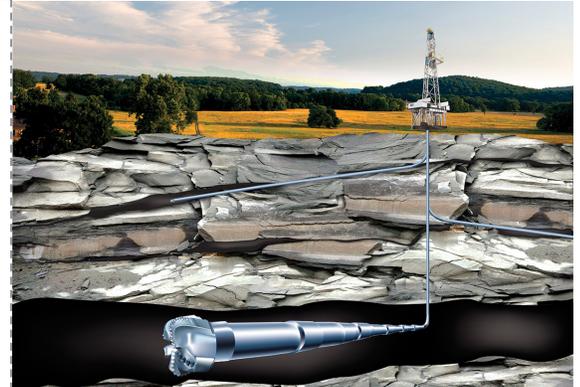
With the growth in directional drilling the mechanical demands on the collars and MWDs increased, particularly with horizontal drilling - fatigue and wear became predominant causes for scrapping collars. To address this, a higher strength alloy, Carpenter 15-15 HS MAX, was developed.

### Typical Mechanical Property Requirements:

Strength Class	Alloy	Size (in.)	YS (ksi)	TS (ksi)	EI (%)	RA (%)
Standard	15-15LC MOD	4 to 6.875	110	120	18	50
		7 to 12	100	110	20	50
High Strength	15-15 HS MAX SCF 260 SCF19 MAX	3.5 to 10	140	150	18	50

## CARPENTER SCF 260 ALLOY

Pitting corrosion has always been a problem with high chloride drilling muds. However, the growth in directional drilling has also increased the usage of MWDs and LWDs which have complex housings with features where mud can become trapped, making them even more prone to pitting and crevice corrosion. Carpenter SCF 260 was developed to provide superior resistance to pitting and crevice corrosion.



## Carpenter Technology Corporation

Carpenter Technology Corporation (NYSE:CRS) is a leading manufacturer and distributor of specialty alloys, including stainless steel and titanium. The company serves the aerospace, automotive, medical, consumer products, energy, and industrial markets with materials that meet customer requirements for strength, toughness, corrosion-resistance and high-temperature performance.

Carpenter's customers range from global corporations to machine shops, forgers and parts makers. The company's materials can be found in everything from jet engine blades to electronic equipment, medical devices and implants, industrial fittings, fuel injection systems and sporting goods.

## Amega West Services

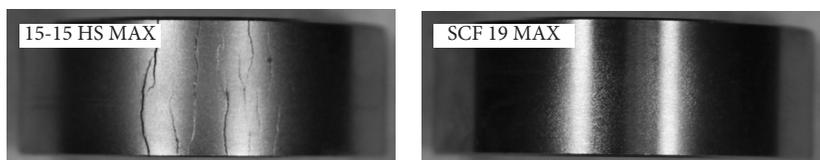
Amega West Services, a Carpenter Company, is a leader in the manufacture of oilfield equipment and the rental of downhole tool solutions for land and offshore directional drilling and related applications.

Based in Houston, TX, Amega West is committed to providing superior-quality tools, exceptional service, and competitive pricing. You'll find the drill-site tools, service and cost efficiencies to give you the advantage in the field. We develop equipment with durability to API Spec 7-1 standards.

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## CARPENTER SCF 19® MAX ALLOY

For severe drilling conditions such as high H<sub>2</sub>S, low pH, temperatures exceeding 350°F, or extreme dog-legs, nickel alloys may be required to provide the necessary corrosion resistance and strength. Carpenter SCF 19 MAX alloy was developed to meet these challenges and has demonstrated far superior stress corrosion resistance than other non-magnetic stainless steels.



C-ring specimens stressed to 140 ksi then exposed for 100 hrs at 350°F, to an environment containing 100,000 ppm chlorides and 32 psi H<sub>2</sub>S. At pH levels from 5.0 and 9.0, SCC occurred with 15-15 HS MAX while SCF 19 MAX was unaffected.

## MEASURING THE DIFFERENCES

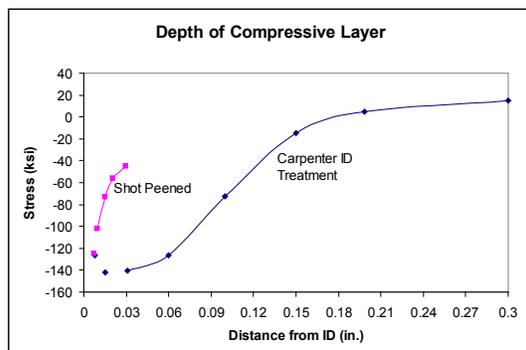
A common means for comparing the pitting resistance of stainless steels is the Pitting Resistance Equivalent Number calculated from the chemical composition. However the melting and thermomechanical processing of the Cr-Mn-N steels also play a critical role in optimizing the pitting resistance. These alloys are best compared by measuring their critical pitting temperature or pitting potential. The results demonstrate the superior pitting resistance developed by our proprietary processes as compared to a competitor's alloy with equivalent PREN.

## Pitting Potential vs. PREN

Alloy	Melting Process	PREN	Pitting Potential
			(mVolts @ 100µA/cm <sup>2</sup> )
15-15 LC MOD	EF + AOD	29	132
Competitor	EF + AOD	31	101
15-15 HS MAX	EF + AOD + ESR	31	294
SCF 260	EF + AEO + ESR	35	565
SCF 19 MAX	EF + AOD + ESR	41	1125

## CARPENTER'S PROPRIETARY ID TREATMENT

Non-magnetic stainless steels are susceptible to SCC when the surface exposed to the drilling mud is in tension. Compressive surface treatments are typically used to reduce this risk. Carpenter's proprietary ID treatment provides a compressive layer in excess of 3/16 inch, much deeper than other processes, to provide improved resistance to SCC.



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