Non-Magnetic Drill Collars

a. 15-15LC® Modified Stainless

i. Identification

US Patent Number 5,094,812

ii. Type Analysis

Carbon (Nominal)	0.04%	Manganese	15.00 to 19.00%
Phosphorus (Maximum)	0.050%	Sulfur (Maximum)	0.050%
Silicon (Maximum)	1.00%	Chromium	16..00 to 21.00%
Nickel (Maximum)		Molybdenum	0.50 to 3.00%
Nitrogen	0.20 to 0.08%	Iron	Balance

iii. General Information

Description

15-15LC® Modified stainless is an austenitic, nitrogen-strengthened stainless steel. It should be considered for oil and gas industry applications such as nonmagnetic drill collars, stabilizers, and MWD housings.

The lower carbon content of 15-15LC Modified stainless results in fewer tendencies for carbides to precipitate in grain boundaries compared with normal chrome-manganese stainless grades. This provides 15-15LC Modified stainless with improved resistance to intergranular stress- corrosion cracking. In addition, nickel, chromium, nitrogen, manganese and molybdenum are controlled to further enhance the resistance to intergranular stress-corrosion cracking.

A post-machining ID compressive stress treatment for drill collars has been developed to further improve the resistance to stress-corrosion cracking.

The strength of 15-15LC Modified stainless is achieved by warm working on a rotary forge at a temperature below the recrystallization temperature.

iv. Corrosion Resistance

Important Note: The following 5-level rating scale is intended for comparative purposes only. Corrosion testing is recommended; factors which affect corrosion resistance include temperature, concentration, pH, impurities, aeration, velocity, crevices, deposits, metallurgical condition, stress, surface finish and dissimilar metal contact

Nitric Acid	Good	Sulfuric Acid	Restricted
Phosphoric Acid	Restricted	Acetic Acid	Good
Sodium Hydroxide	Moderate	Salt Spray (NaCl)	Good
Sea Water	Moderate	Sour Oil/Gas	Moderate
Humidity	Excellent		

v. Properties

Physical Properties

Specific Gravity: 7.76

Density: 0.28 Lb/Cu. In

Mean Specific Heat: 0.118 Btu/b/ºF

Mean Coefficient of Thermal Expansion:

77.00 °F, 212.0 °F	8.85 x 10-6 in/in/°F
77.00 °F, 350.0 °F	9.11 x 10-6 in/in/°F
77.00 °F, 392.0 °F	9.34 x 10-6 in/in/°F
77.00 °F, 482.0 °F	9.57 x 10-6 in/in/°F
77.00 °F, 572.0 °F	9.75 x 10-6 in/in/°F
77.00 °F, 662.0 °F	9.96 x 10-6 in/in/°F
77.00 °F, 752.0 °F	10.2 x 10-6 in/in/°F
77.00 °F, 842.0 °F	10.4 x 10-6 in/in/°F
77.00 °F, 932.0 °F	10.5 x 10-6 in/in/°F
77.00 °F, 1022 °F	10.7 x 10-6 in/in/°F

Mean Coefficient of Thermal Expansion

TEMPRATURERANGE		10^{-5}/ ° F	10^{-5}/ ° k
77° F TO	25° C TO		
212	100	8.85	15.95
350	150	9.11	16.41
392	200	9.34	16.84
482	250	9.57	17.26
572	300	9.75	17.59
662	350	9.96	17.98
752	400	10.16	18.33
842	450	10.35	18.68
932	500	10.52	18.98
1022	550	10.67	19.25

Thermal Conductivity

Test TEMPRATURE		Btu-In F^3. h .° F	W/m-k
° F	° C		
73	23	95.57	13.8
122	50	98.84	14.3
212	100	104.62	15.1
392	200	114.90	16.6
572	300	124.51	18.0
752	400	133.01	19.2

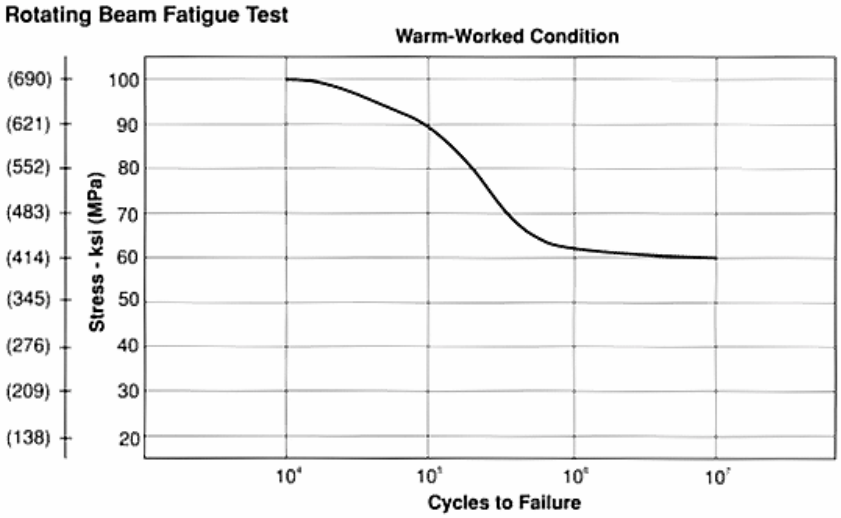
Modulus of Elasticity (E): 27.7 x 103 ksi

Electrical Resistivity: 70.0 °F 441.0 ohm-cir-mil/ft

Magnetic Properties

- 15-15LC Modified stainless is essentially nonmagnetic in both the annealed and warm worked conditions.
- Magnetic permeability of warm-worked material is less than 1.01 based on Severn gauge.
- ASTM A342 (field Strength-200 oversteps): 1.002

Typical Mechanical Properties



Typical Room Temperature Mechanical Properties - 15-15LC Modified Stainless

Condition	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area	Charpy V-Notch Impact Strength		Brinell Hardness
	ksi	MPa	ksi	MPa			ft-lb	J	
Annealed (1950°F, WQ)	63	434	110	758	50	60	210	285	210
Warm-Worked									
4¾" Diameter	130	896	150	1034	33	70	210	285	302
6½" Diameter	125	862	147	1013	35	72	202	274	293
9" Diameter	112	772	135	931	38	73	190	258	285

vi. Heat Treatment

Annealing

15-15LC Modified stainless is generally used in the as-forged, warm-worked condition. However, if annealing is desired, heat to 1900/2100°F (1040/1150°C), hold for one hour per inch of thickness, and water quench.

vii. Machinability

15-15LC Modified stainless can be machined but with somewhat greater effort than for Type 316. Slow to moderate speeds, moderate feeds and rigid tools are suggested. Following are typical feeds and speeds for 15-15LC Modified stainless.

Typical Machining Speeds and Feeds – 15-15LC® Modified Stainless

The speeds and feeds in the following charts are conservative recommendations for initial setup. Higher speeds and feeds may be attainable depending on machining environment.

Turning—Single-Point and Box Tools

Depth of Cut (Inches)	High Speed Tools			Carbide Tools (Inserts)			
	Tool Material	Speed (fpm)	Feed (ipr)	Tool Material	Speed (fpm) Uncoated	Speed (fpm) Coated	Feed (ipr)
.150	M2	55	.015	C6	250	300	.015
.025	T15	70	.007	C7	300	350	.007

Turning—Cut-Off and Form Tools

Tool Material		Speed (fpm)	Feed (ipr)						
			Cut-Off Tool Width (Inches)			Form Tool Width (Inches)			
High Speed Tools	Carbide Tools		1/16	1/8	1/4	1/2	1	1 ½	2
T15		40	.001	.001	.0015	.0015	.001	.0007	.0007
	C6	140	.004	.0055	.0045	.004	.003	.002	.002

Rough Reaming

High Speed		Carbide Tools		Feed (ipr) Reamer Diameter (Inches)					
Tool Material	Speed (fpm)	Tool Material	Speed (fpm)	1/8	1/4	1/2	1	1 ½	2
M7	60	C2	80	.003	.005	.008	.012	.015	.018

Drilling

Tool Material	Speed (fpm)	High Speed Tools: Feed (inches per revolution) Nominal Hole Diameter (inches)							
		1/16	1/8	1/4	1/2	3/4	1	1 ½	2
T15, M42	45-50	.001	.002	.004	.007	.010	.012	.015	.018

Die Threading

FPM for High Speed Tools				
Tool Material	7 or less, tpi	8 to 15, tpi	16 to 24, tpi	25 and up, tpi
T15, M42	4-8	6-10	8-12	10-15

Milling, End-Peripheral

Depth of Cut (inches)	High Speed Tools						Carbide Tools					
	Tool Material	Speed (fpm)	Feed (ipt) Cutter Diameter (in) 1/4	1/2	3/4	1-2	Tool Material	Speed (fpm)	Feed (ipt) Cutter Diameter (in) 1/4	1/2	3/4	1-2
.050	M2, M7	65	.001	.002	.003	.004	C2	245	.001	.002	.003	.005

Tapping

High Speed Tools	
Tool Material	Speed (fpm)
M1, M7, M10	12-25

Broaching

High Speed Tools		
Tool Material	Speed (fpm)	Chip Load (ipt)
M2, M7	10	.003

When using carbide tools, surface speed feet/minute (SFPM) can be increased between 2 and 3 times over the high-speed suggestions. Feeds can be increased between 50 and 100%.

Figures used for all metal removal operations covered are average. On certain work, the nature of the part may require adjustment of speeds and feeds. Each job has to be developed for best production results with optimum tool life. Speeds or feeds should be increased or decreased in small steps.

viii. Additional Machinability Tools

When using carbide tools, surface speed feet/minute (SFPM) can be increased between 2 and 3 times over the high-speed suggestions. Feeds can be increased between 50 and 100%.

ix. Weldability

15-15LC Modified stainless can be readily joined by the standard electric-arc welding methods. Welding consumables of matching composition are not currently available; however, other stainless steel consumables should be considered depending on the application. Contact Carpenter for specific details on filler metal selection.

b. Non Magnetic Drill Collar Oilfield Alloys Products

i. Product Detail

- Country of manufacture: USA
- Manufacture spec: API SPEC 7
    - 15-15LC® Modified Alloy data
    - 15-15HS® Stainless Alloy data
    - 15-15HS® Max Stainless Alloy data

Note

- ODs and IDs other than those listed above are available by special request.
- Bored bars offered are for long product application. Concentricity is according to API Spec 7
- All dimensional and mechanical specifications are according to API Spec

DIRECTIONAL DRILLING SERVICES
Non Magnetic Drill Collars And Subs Brochures

NON-MAGNETIC DRILL COLLARS/SUBS Specifications

Long Non-Magnetic drill Collar

SPECIFICATIONS	Unit	TOOL SIZES			
		9 5/8"	8"	6 ¾"	4 ¾"
Make		Amega West AP LTD	Amega West AP LTD	Amega West AP LTD	Amega West AP LTD
Type		Long MNL 15-15LC	Long MNL 15-15LC	Long MNL 15-15LC	Long MNL 15-15LC
Overall length	Ft.	31.50	31.50	31.11	31.17
Outside diameter	Inch	9 1/2	8 1/8	6 7/8	4 3/44
Inside diameter	Inch	4	31/2	3 ¼	2 11/16
Bevel diameter	Inch	8 13/18	7 17/32	6 33/64	4 19/32
Threaded connections size (upper)		7 5/8 R	6 5/8 R	4 ½ IF	3 ½ IF
" " " (lower)		7 5/8 R	6 5/8 R	4 ½ IF	3 ½ IF
Recommended max make-up torque	Ft.-Lb.	79722	48001	20703	8950
Tool serial number (identification code)		As Per delivery Ticket and Inspection Report			
Order number (purchase)		AWF-19-026	AWF-19-026	AWF-19-026	AWF-19-026
Fabrication year		2019	2019	2019	2019
Last inspection date		2020	2020	2020	2020
Total weight	LB.	6288	4228	2963	1940
Other					

DIRECTIONAL DRILLING SERVICES
Non Magnetic Drill Collars And Subs Brochures

NON-MAGNETIC DRILL COLLARS/SUBS Specifications

Short Non-Magnetic drill Collar

SPECIFICATIONS	Unit	TOOL SIZES			
		9 5/8"	8"	6 ¾"	4 ¾"
Make		Amega West AP LTD	Amega West AP LTD	Amega West AP LTD	Amega West AP LTD
Type		Long MNL 15-15LC	Long MNL 15-15LC	Long MNL 15-15LC	Long MNL 15-15LC
Overall length	Ft	16.233	16.233	16.233	16.233
Outside diameter	Inch	9 1/2	8 1/8	6 7/8	4 3/44
Inside diameter	Inch	4	31/2	3 ¼	2 11/16
Bevel diameter	Inch	8 13/18	7 17/32	6 33/64	4 19/32
Threaded connections size (upper)		7 5/8 R	6 5/8 R	4 ½ IF	3 ½ IF
" " " (lower)		7 5/8 R	6 5/8 R	4 ½ IF	3 ½ IF
Recommended max make-up torque	Ft.-Lb.	79722	48011	20703	8950
Tool serial number (identification code)		As Per delivery Ticket and Inspection Report			
Order number (purchase)		AWF-19-026	AWF-19-026	AWF-19-026	AWF-19-026
Fabrication year		2019	2019	2019	2019
Last inspection date		2020	2020	2020	2020
Total weight	LB.	3240	2179	1526	1000
Other					

NON-MAGNETIC DRILL COLLARS/SUBS Specifications

Non-Magnetic Pulser Sub

SPECIFICATIONS	Unit	TOOL SIZES			
		9 5/8"	8"	6 ¾"	4 ¾"
Make		Amega West AP LTD	Amega West AP LTD	Amega West AP LTD	Amega West AP LTD
Type		Long MNL 15-15LC	Long MNL 15-15LC	Long MNL 15-15LC	Long MNL 15-15LC
Overall length	Ft.	3.17	3.17	3.17	3.17
Outside diameter	Inch	9 1/2	8 1/8	6 7/8	4 3/44
Inside diameter	Inch	4	31/2	3 ¼	2 11/16
Bevel diameter	Inch	8 13/18	7 17/32	6 33/64	4 19/32
Threaded connections size (upper)		7 5/8 R	6 5/8 R	4 ½ IF	3 ½ IF
" " " (lower)		7 5/8 R	6 5/8 R	4 ½ IF	3 ½ IF
Recommended max make-up torque	Ft.-Lb.	79722	48011	20703	8950
Tool serial number (identification code)		As Per delivery Ticket and Inspection Report			
Order number (purchase)		AWF-19-026	AWF-19-026	AWF-19-026	AWF-19-026
Fabrication year		2019	2019	2019	2019
Last inspection date		2020	2020	2020	2020
Total weight	LB.	633	425	298	195
Other					

NON-MAGNETIC DRILL COLLARS/SUBS Specifications

Non-Magnetic WP R Saver Sub

SPECIFICATIONS	Unit	TOOL SIZES			
		9 5/8"	8"	6 ¾"	4 ¾"
Make		Amega West AP LTD	Amega West AP LTD	Amega West AP LTD	Amega West AP LTD
Type		Long MNL 15-15LC	Long MNL 15-15LC	Long MNL 15-15LC	Long MNL 15-15LC
Overall length		2.47	2.47	2.47	2.47
Outside diameter	Inch	9 1/2	8 1/8	6 7/8	4 3/44
Inside diameter	Inch	4	31/2	3 ¼	2 11/16
Bevel diameter	Inch	8 13/18	7 17/32	6 33/64	4 19/32
Threaded connections size (upper)		7 5/8 R	6 5/8 R	4 ½ IF	3 ½ IF
" " " (lower)		7 5/8 R	6 5/8 R	4 ½ IF	3 ½ IF
Recommended max make-up torque	Ft.-Lb.	79722	48011	20703	8950
Tool serial number (identification code)		As Per delivery Ticket and Inspection Report			
Order number (purchase)		AWF-19-026	AWF-19-026	AWF-19-026	AWF-19-026
Fabrication year		2019	2019	2019	2019
Last inspection date		2020	2020	2020	2020
Total weight	LB.	493	332	232	152
Other					

DIRECTIONAL DRILLING SERVICES
Non Magnetic Drill Collars And Subs Brochures

NON-MAGNETIC DRILL COLLARS/SUBS DATA Specifications

Non-Magnetic WPR Double Pin Sub

SPECIFICATIONS	Unit	TOOL SIZES			
		9 5/8"	8"	6 ¾"	4 ¾"
Make		Amega West AP LTD	Amega West AP LTD	Amega West AP LTD	Amega West AP LTD
Type		Long MNL 15-15LC	Long MNL 15-15LC	Long MNL 15-15LC	Long MNL 15-15LC
Overall length	Ft.	0.67	0.67	0.67	0.67
Outside diameter	Inch	9 1/2	8 1/8	6 7/8	4 3/44
Inside diameter	Inch	4	31/2	3 ¼	2 11/16
Bevel diameter	Inch	8 13/18	7 17/32	6 33/64	4 19/32
Threaded connections size (upper)		7 5/8 R	6 5/8 R	4 ½ IF	3 ½ IF
" " " **(lower)**		7 5/8 R	6 5/8 R	4 ½ IF	3 ½ IF
Recommended max make-up torque	Ft.-Lb.	79722	48011	20703	8950
Tool serial number (identification code)		As Per delivery Ticket and Inspection Report			
Order number (purchase)		AWF-19-026	AWF-19-026	AWF-19-026	AWF-19-026
Fabrication year		2019	2019	2019	2019
Last inspection date		2020	2020	2020	2020
Total weight	LB.	134	90	63	41
Other					