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Steels for Oil- and Gas-Exploration

Providing special steel solutions

Deutsche Edelstahlwerke

Member of Swiss Steel Group

Providing special steel solutions

In search of new oil and gas sources high performance steels with defined mechanical, physical and chemical properties are required.

New oil and gas fields have been identified in large depths under the sea. The tools for exploring these fields are exposed to various rock formations and aggressive media which react with the tools being used.

Depending on the ambient conditions special high strength steels with a high resistance to corrosion are required. Deutsche Edelstahlwerke possess more than 150 years of experience in the development and production of special steels and are thus ideally suited to be your partner in the supply of special steels.

This brochure provides information about the production routes for special oil tool steels and the products which we are able to deliver. Furthermore, mechanical and physical properties for alloyed and stainless grades are provided.

Our technology and experience – your guarantee for premium quality

The purity and homogeneity of our special steels stem from producing them in our modern steelworks.

We fulfill our clients, predefined demands by means of precision alloying and optimized process specifications for melting, shaping and heat treating.

Our state of the art melting and combination of ingot and vertical continuous casting allow bars of various dimensions to be hot rolled or forged. Usually an optimized vertical continuous casting method is used, but for large forging sizes, ingot casting is employed. Our combination of processing facilities are unique world wide and allow us to produce all forms of long products required by the market.

With our electroslag and vacuum remelting facilities we are also an important player in other special steel markets, for example the aerospace industry.

Hot forming

Our rolling mills are capable of producing hot rolled bars up to 250 mm (10 inches), as well as flat plates.

Our forges are equipped with a 33 MN and 45 MN press, a GFM RF 70 (currently one of the largest in the world) and a GFM LSX 25 long forging machine which allows us to produce bars and step forgings having a maximum diameter of 460 mm (18 inches).

Heat treatment

Modern heat treatment facilities are available to carry out annealing, hardening, quenching and tempering of the special steel grades. Our furnaces have been approved to the requirements of API 6 A to ensure homogenous material properties for all sections.

Finishing

Peeling and grinding machines as well as modern non-destructive testing lines, to ensure ultimate quality, are available for rolled and forged products and steel bars. Our machining division, which is equipped with deep hole drilling, milling, turning and grinding facilities, is also capable of producing finished or semifinished components (e.g. drive subs and drill collars).

For deep drilling of drill collars and bars up to 12 m (35 feet) length, 4 special drilling machines are available. This equipment has been specially developed in cooperation with the machine manufacturer.

In order to guarantee an improved fatigue life and better resistance to stress corrosion cracking (SCC) in operation, a new work hardening process has been developed in which two ceramic balls rotate in contact with the inner surface of the collar (roller burnishing) to produce defined residual compressive stresses.

Steel grades and applications

Based on its extensive production facilities Deutsche Edelstahlwerke is able to supply the entire portfolio of steel grades required for oil and gas exploration.

This includes the low and high alloyed engineering steels, ferritic and martensitic as well as high alloyed austenitic and duplex stainless steels.

Specialties as strain hardened nonmagnetic steels play a major role in the detection of new oil and gas sources. Low alloyed steels of the types SAE/AISI 41xx and 86xx series are based on the alloying elements Cr-Mo and Cr-Ni-Mo with carbon contents between 0,25 and 0,50 %. After quenching and tempering hardness according to NACE specifications and impact toughness values (Charpy-V) at low temperatures are required. Specific metallurgical procedures and heat treatments are necessary to obtain these properties in combination with a homogeneous fine grain microstructure. Typical applications for these grades include flanges, valves, blow out preventers and manifolds. High strength engineering steels like SAE 4340 or 4330 V with yield strength levels > 1100 MPa (160 ksi) are more highly alloyed with Nickel-, Molybdenum- and Vanadiumcontents. These grades must exhibit enhanced toughness properties even at low temperatures and sometimes also in the transverse direction.

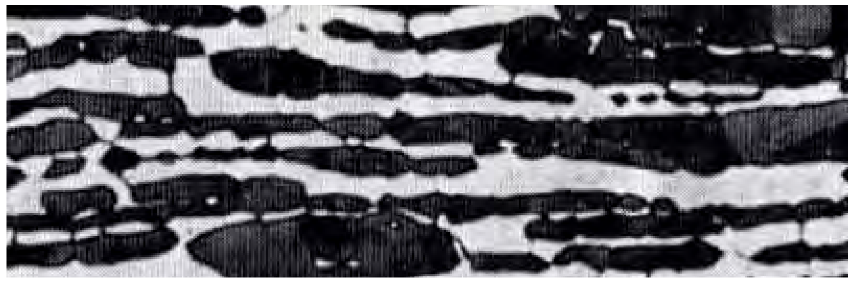
Martensitic stainless grades

Martensitic stainless grades with 13 % Cr (AISI 410 and 420) are used if the corrosion resistance of the low alloyed engineering steels is not sufficient and the required strength level is similar. Details of the Specification NACE MR 0175 with a narrow tolerance of hardness and strength have to be respected. A reliable process control in all steps of production is necessary to secure these properties. For applications like drive components (drive trains) for the drill bit within the drill string (down hole motors) precipitation hardening martensitic stainless steels with low carbon contents are used. The most common grade is the steel 17-4 PH (AISI 630) with 15-17 % Cr, 5 % Ni and 3 % Cu. Since components of this grade also have to comply with the NACE specification, only the condition DH 1150 is allowed (approved). In addition to an excellent combination of strength and toughness, the pitting resistance of these steels is also good.

Austenitic stainless grades

Environmental media are often contaminated with aggressive chloride ions and since austenitic steels are susceptible to stress corrosion cracking (SCC) these grades are rarely used.

Duplex- and super duplex stainless steels



Duplex and super duplex stainless steels, like F 51 and F 55 (1.4462/1.4501), are specified for applications where best corrosion resistance is required.
These grades combine the advantages of ferritic and austenitic steels thus providing high strength, improved fatigue and corrosionresistance and better resistance to SCC.

More than

3.000 meters under the sea

Nonmagnetic steels (non mags)

In oil and gas field applications, particular emphasis is placed on nonmagnetic steels (non mags).

These steels rely upon the combination of high Chromium, Manganese and Nitrogen contents in addition to small amounts of Nickel to ensure a stable austenitic microstructure. These non mags can be work hardened to increase yield and tensile strength corresponding to the requirements of the API 7. A homogeneous austenitic microstructure is the precondition to guarantee the specified magnetic permeability of $\mu r < 1{,}01$. Since no magnetic inclusion or local ferritic microstructure is allowed within the material, a particular clean steel production and stringent temperature control in the subsequent hot forming process is necessary. Non mag steels are used to house the extremely sensitive measuring instruments contained near the drill bit. Typical tools are MWDs (Measuring while drilling) and LWDs (Logging while drilling). MWDs (Messuring While Drilling) use the magnetic field of the earth to determine the precise position of the drilling tools and then control the direction of drilling, while LWDs (Logging While Drilling) gather information about the geological formation being drilled.

Depending on their application, low and high strength steels are specified.
For simple drill collars, heavy weights, flex collars and stabilizers with a low strength level according to API 7 the non mag grade Magnadur 501 can be used.
For more demanding applications like MWDs with increased strength and corrosion resistance we recommend the use of the superior grade Magnadur 601. Beside the higher strength (> 150 ksi) which is obtained by a higher nitrogen content and work hardening, the resistance to corrosion is also superior. Since the corrosion resistance of these non mag grades decreases slightly with increasing strength (work hardening), it is possible to improve the corrosion properties even further by specifying a lower strength Magnadur 601 variant. This lower strength grade is also available upon request.

Corrosion Properties

In oil and gas field applications, the materials used are always subjected to corrosive conditions of varying severity.

In fact the dwindling reserves are forcing exploration in ever increasingly harsh environments which are sour and/or contain high levels of chlorides. In addition to this, the combination of materials used and the high strengths which are required lead to a host of different forms of corrosion which have to be avoided. Some of the most common forms of corrosion which are encountered include:

Pitting corrosion resistance

This form of corrosion occurs when the protective passive film on stainless steels is locally damaged, allowing the corrosive environment to come into contact with the unprotected surface of the metal.
The passive film is capable of regenerating itself, provided that oxygen is present in the environment, but in the presence a high concentrations of chloride ions, it is possible that the rate of destruction of the passive film is faster than the regeneration and this then results in localised corrosion or pitting.

Once pits have formed, they continue to grow at an ever increasing rate until in extreme cases the metal is perforated.
The resistance of an alloy to this unfortunately common form of corrosion can be estimated empirically by using the so-called *pitting resistance equivalent number* or *PREN,* which is based on the chemical composition of the steel. Generally speaking, the higher this number, the better the resistance to pitting. *PREN = %Cr + 3,3 x %Mo + 16 x %N.* Further differentiation is given by the *pitting potential* or the *Critical Pitting Temperature* (CPT) which is determined by following the ASTM G61 and G150.

Galvanic corrosion

It is almost impossible to avoid this type of corrosion which arises due to potential differences which arise when two dissimilar metals are placed in contact with one another in an electrolyte (corrosive environment). This essentially results in the formation of a battery in which one of the metals, the less noble, corrodes preferentially to protect the more noble metal. This form of corrosion can be reduced by ensuring that the potential difference between two contacted metals is as small as possible and by insulating the metals so that they are not in electrical contact with one another. Tests to determine the susceptibility of metals to this form of corrosion include visual examination after immersion in an electrolyte (140,000 ppm chloride, 71° C, 14 days).

Stress corrosion

Cracking (SCC). This form of corrosion arises when a susceptible material is placed in a chloride or other halide containing environment and then subjected to tensile stresses. These stresses can either be residual or applied. The removal of any one of these conditions result in the avoidance of SCC. From this we can see that the residual and applied stresses must be kept as low as possible or that steps are taken to ensure that only compressive stresses are present. The latter requirement is the reason for the purpuseful deformation of the inner surface of the hollow bars to produce high compressive residual stresses. High nickel contents are also known to promote stress corrosion cracking and it is for this reason that high grade non mags are not alloyed with significant amounts of nickel. Susceptability to SCC can be measured according to ASTM G36, G123.

Intergranular corrosion

Although this form of corrosion is readily avoidable by accurate control of the chemical analysis and by performing adequate heat treatment, many customers require proof that the steels supplied are free from intergranular corrosion (IGC).
The most common tests to determine freedom from IGC are performed according to ASTM A 262, Practice A and E.

AISI 4130 – API 6A / NACE MR 01.75, Firmodur 7216

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Mo	Ni	Cu
Min	0,28	015	0,40	≤	≤	0,90	0,20	≤	≤
Max	0,33	0,30	0,60	0,025	0,025	1,10	0,25	0,25	0,30

b) Mechanical properties in the quenched and tempered (QT) condition

0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	≥ 517 *(75)*
Tensile Strenght R_m in MPa *(ksi)*	≥ 655 *(95)*
Elongation L_0 = 4 d (A_4) in %	≥ 18 %
Reduction of Area (Z) in %	≥ 35 %
Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*	≥ 54 J *(40)*
Impact Toughness (Charpy-V at -60°C) in J *(ft-lbs)*	≥ 27 *(20)*
Hardness in BHN *(HRC)*	197 – 234 *(18 – 22)*

AISI 4140 H – L 80 (API 6A / 5 CT / NACE MR 01.75), Firmodur 7223

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Mo	Ni	Cu
Min	0,38	015	0,75	≤	≤	0,90	0,20	≤	≤
Max	0,43	0,30	1,00	0,025	0,025	1,20	0,25	0,25	0,25

b) Mechanical properties in the quenched and tempered (QT) condition

0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	≥ 517 *(75)*
Tensile Strenght R_m in MPa *(ksi)*	≥ 655 *(95)*
Elongation L_0 = 4 d (A_4) in %	≥ 18 %
Reduction of Area (Z) in %	≥ 35 %
Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*	≥ 54 J *(40)*
Impact Toughness (Charpy-V at -60°C) in J *(ft-lbs)*	≥ 27 *(20)*
Hardness in BHN *(HRC)*	197 – 234 *(18 – 22)*

AISI 4145 H mod (API 7), Firmodur 7225

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Mo	Ni	Cu
Min	0,42	≤	0,70	≤	≤	0,90	0,20	0,25	≤
Max	0,49	0,40	1,20	0,025	0,025	1,20	0,35	0,40	0,35

b) Mechanical properties in the quenched and tempered (QT) condition

Diameter OD range	79,4 – 174. 6 mm / 3 1/8 – 6 7/8 inches	> 174,6 mm / 6 7/8 inches
0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	≥ 757 *(110)*	≥ 689 *(100)*
Tensile Strenght R_m in MPa *(ksi)*	≥ 965 *(140)*	≥ 931 MPa *(135)*
Elongation L_0 = 4 d (A_4) in %	≥ 15 %	
Reduction of Area (Z) in %	≥ 45 %	
Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*	≥ 54 J *(40)*	
Impact Toughness (Charpy-V at -20°C) in J *(ft-lbs)*	≥ 30 J *(22)*	
Hardness	285 – 340 BHN	

AISI 4330 V mod, Firmodur 6562

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Mo	V	Ni
Min	0,29	≤	0,70	≤	≤	0,80	0,30	0,05	1,60
Max	0,35	0,40	1,00	0,015	0,010	1,10	0,50	0,10	3,00

b) Mechanical properties in the quenched and tempered (QT) condition

Diameter OD range	75 – 203 mm / 3 – 8 inches	> 203 mm / 8 inches
0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	≥ 1035 *(150)*	≥ 930 *(135)*
Tensile Strenght R_m in MPa *(ksi)*	≥ 1105 *(160)*	≥ 1050 MPa *(152)*
Elongation L_0 = 4 d (A_4) in %	≥ 15 %	
Reduction of Area (Z) in %	≥ 45 %	
Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*	≥ 60 J *(45)*	
Impact Toughness (Charpy-V at -40°C) in J *(ft-lbs)*	≥ 27 J *(20)*	
Hardness	304 – 405 BHN	320 – 380 BHN

AISI 4340, Firmodur 6595

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Mo	Ni
Min	0,38	≤	0,60	≤	≤	0,70	0,20	1,60
Max	0,43	0,40	0,90	0,020	0,015	1,00	0,30	2,00

b) Mechanical properties in the quenched and tempered (QT) condition

Diameter OD range	75 – 203 mm / 3 – 8 inches	> 203 mm / 8 inches
0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	≥ 1000 *(145)*	≥ 900 *(130)*
Tensile Strenght R_m in MPa *(ksi)*	≥ 1100 *(160)*	≥ 1000 MPa *(145)*
Elongation L_0 = 4 d (A_4) in %	≥ 15 %	
Reduction of Area (Z) in %	≥ 45 %	
Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*	≥ 60 J *(45)*	
Impact Toughness (Charpy-V at -40°C) in J *(ft-lbs)*	≥ 27 J *(20)*	
Hardness	330 – 395 BHN	300 – 370 BHN

AISI 8630 / 8630 mod (API 6A / NACE MR 01.75), Firmodur 6591

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu
Min	0,28	015	0,75	≤	≤	0,85	0,35	≤	≤	≤
Max	0,33	0,45	1,00	0,025	0,025	1,50	0,65	1,00	0,06	0,25

b) Mechanical properties in the quenched and tempered (QT) condition

0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	≥ 517 *(85)*
Tensile Strenght R_m in MPa *(ksi)*	≥ 655 *(95)*
Elongation L_0 = 4 d (A_4) in %	≥ 18 %
Reduction of Area (Z) in %	≥ 35 %
Impact Toughness (Charpy-V at 23°C) in J	≥ 54 *(40)*
Impact Toughness (Charpy-V at -60°C) in J	≥ 27 *(20)*
Hardness in BHN *(HRC)*	207 – 234 *(19 – 22)*

ASTM A182 F22 / 1.7380 (API 6A / NACE MR 01,75)

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu
Min	0,10	0,15	0,30	≤	≤	2,00	0,90	≤	≤	≤
Max	0,15	0,45	0,60	0,025	0,025	2,50	1,10	0,50	0,03[*)]	0,35

b) Mechanical properties in the quenched and tempered (QT) condition

0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	≥ 517 *(75)*
Tensile Strenght R_m in MPa *(ksi)*	≥ 655 *(95)*
Elongation L_0 = 4 d (A_4) in %	≥ 18 %
Reduction of Area (Z) in %	≥ 35 %
Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*	≥ 80 J *(59)*
Impact Toughness (Charpy-V at -60°C) in J *(ft-lbs)*	≥ 27 *(20)*
Hardness in BHN *(HRC)*	207 – 234 *(19 – 22)*

AISI 4130 (API 6A/NACE MR 01.75)
AISI 4140 H – L 80 (API 6A/ 5 CT/NACE MR 01.75)
AISI 4145/ AISI 4145 H mod (API 7)
AISI 4330V mod
AISI 4340
AISI 8630/ 8630 mod (API 6A/NACE MR 01.75)
ASTM A182 F22/ 1.7380 (API 64/NACE MR 01.75)

Surface condition	black, shot-blast (descaled) or peeled		
Strainghtness	max. 2,0 mm per meter ($^{1}/_{8}$″ per 5 ft), 1,0 mm per meter ($^{1}/_{16}$″ per 5 ft) upon request		
Availability	hot-rolled:	round:	22 – 250 mm ($^{14}/_{16}$ – 9 $^{13}/_{16}$″)
		+ peeled:	Ø 20 – 230 mm ($^{13}/_{16}$ – 9 $^{1}/_{16}$″)
		square:	50 – 160 mm (1 $^{15}/_{16}$ – 6 $^{5}/_{16}$″)
	forged:	round:	60 – 1.100 mm (2 $^{6}/_{16}$ – 43 $^{5}/_{16}$″)
		+ peeled/turned:	Ø 55 – 1.050 mm (2 $^{3}/_{16}$ – 41 $^{11}/_{32}$″)
		square:	65 – 650 mm (2 $^{9}/_{16}$ – 25 $^{9}/_{16}$″)

Other diameters upon request

AISI 410 (API 6A), Corrodur 4006

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Ni
Min	0,08	≤	≤	≤	≤	11,5	≤
Max	0,15	1,00	1,50	0,040	0,030	13,5	0,75

b) Mechanical properties in QT condition acc. to DIN EN 10088-3 respectively QDT acc. to NACE MR0175

Condition	A	QT 650	QT 650	QDT (NACE)
Dimension in mm *(inch)*		up to 160 (6 ¼)	> 160 - 220 (6 ¼ - 8 ⅝)	up to 380 mm *(15)*
min. 0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*		450 *(65)*	450 *(65)*	517 *(65)*
Tensile Strenght R_m in MPa *(ksi)*	max. 730	650 – 850 (94 – 123)	650 – 850 (94 –123)	655 *(95)*
min. Elongation L_0 = 5 d (A_5) in %		15		18
min. Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*		25 *(18)*		at – 30°C *(-20 °F)*: 27 J *(20)*
Hardness in BHN	max. 220	192 – 252	192 – 252	197 –235

Forms of delivery: Hot rolled or forged bars, annealed, quenched + tempered or quenched + double tempered
Diameter: 20 – 500 mm

AISI 420 (API 6A), Corrodur 4021

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Ni
Min	0,16	≤	≤	≤	≤	12,0	≤
Max	0,25	1,00	1,50	0,040	0,030	14,0	0,75

b) Mechanical properties in QT condition acc. to DIN EN 10088-3 respectively QDT acc. to NACE MR0175

Condition	A	QT 700	QT 800	QDT (NACE)
Dimension in mm *(inch)*		up to 160 (6 ¼)	up to 160 (6 ¼)	up to 380 mm *(15)*
min. 0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*		500 *(73)*	600 *(87)*	517 *(75)*
Tensile Strenght R_m in MPa *(ksi)*	max. 760	650 – 850 (94 – 123)	800 – 950 (116 –138)	655 – 790 (95 –115)
min. Elongation L_0 = 5 d (A_5) in %		13	12	15
min. Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*		20 *(15)*	20 *(15)*	at – 10°C *(14 °F)*: 20 J *(15)*
Hardness in BHN	max. 230	192 – 252	238 – 280	207 – 235 (max. 22 HRC)

Forms of delivery: Hot rolled or forged bars, annealed, quenched and tempered or quenched + double tempered
Diameter: 20 – 500 mm

Super13Cr, Acidur 4418 mod.

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Ni	Mo	V	N	Nb / Ti
Min	≤	≤	≤	≤	≤	11,8	4,5	1,5	≤	≤	
Max	0,03	0,50	1,00	0,020	0,005	15,0	7,0	3,0	0,50	0,12	+

b) Mechanical properties in the quenched and tempered (QT) condition

Condition	A	QT 725	QT 825
Dimension in mm *(inch)*		up to 220 (6 ¼)	up to 220 (6 ¼)
min. 0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*		655 *(95)*	755 *(110)*
min. Tensile Strenght R_m in MPa *(ksi)*	max. 800	725 *(105)*	825 *(120)*
min. Elongation L_0 = 5 d (A_5) in %		19	17
min. Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*		70 *(15)*	70 *(50)*
Hardness in BHN	max. 250	225 – 300	250 – 320

Forms of delivery: Hot rolled or forged bars, annealed or quenched and tempered
Diameter: 20 – 220 mm

AISI 630, Acidur 4542

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Mo	Ni	Nb	Cu
Min	≤	≤	≤	≤	≤	15,0	≤	3,0	5 x C	3,0
Max	0,07	0,50	1,50	0,030	0,030	17,0	0,60	5,0	0,45	5,0

b) Mechanical properties after age hardening heat treatment according to ASTM A564 / A564M

Condition	H900		H925		H1025	H1075	H1100	H1150	H1150M	H1150D
Dimension in mm *(inch)*	up to 75 (3)	> 75 – 200 *(3 – 8)*	up to 75 (3)	> 75 – 200 *(3 – 8)*	up to 200 *(8)*	up to 200 *(8)*	up to 200 *(8)*	up to 200 *(8)*	up to 200 *(8)*	up to 200 *(8)*
min. 0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	1170 *(170)*		1070 *(155)*		1000 (145)	860 (125)	795 (115)	725 (105)	520 (75)	725 (105)
min. Tensile Strenght R_m in MPa *(ksi)*	1310 *(190)*		1170 *(170)*		1070 (155)	1000 (145)	965 (140)	930 (135)	795 (115)	860 (125)
min. Elongation L_0 = 5 d (A_5) in %	10		10		12	13	14	16	18	16
min. Reduction of Area (Z) in %	40	35	44		45	45	45	50	55	50
min. Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*	...		6,8 *(5)*	38	20 *(15)*	27 *(20)*	34 *(25)*	41 *(30)*	75 *(55)*	41 *(30)*
min. Hardness in BHN *(HRC)*	*388 (40)*		*375 (38)*		331 (35)	311 (32)	302 (32)	277 (28)	255 (24)	255 (24)

Forms of delivery: Hot rolled bars, solution annealed or solution annealed + precipitation hardened, machined
Diameter: 20 – 350 mm

F51 – S31803 (Norsok M-650 Rev. 3), Acidur 4462

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Ni	Mo	N
Min	≤	≤	≤	≤	≤	21,0	4,5	2,5	0,08
Max	0,030	1,00	2,00	0,030	0,020	23,0	6,5	3,5	0,20

b) Mechanical properties in the solution annealed condition

Condition	A
Dimension in mm *(inch)*	20 – 240 *(0,75 – 9,5)*
min. 0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	450 *(65)*
min. Tensile Strenght R_m in MPa *(ksi)*	620 *(90)*
min. Elongation L_0 = 5 d (A_5) in %	25
min. Reduction of Area (Z)	45
min. Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*	80 *(60)*
Hardness in BHN	max. 280

Forms of delivery: Hot rolled bars, solution annealed, machined
Diameter: 20 – 240 mm

F55 – S32760, Acidur 4501

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Ni	Mo	W	Cu	N
Min	≤	≤	≤	≤	≤	24,0	6,0	3,0	0,50	0,50	0,20
Max	0,030	1,00	1,00	0,030	0,010	26,0	8,0	4,0	1,00	1,00	0,30

b) Mechanical properties in the solution annealed condition

Condition	A
Dimension in mm *(inch)*	80 – 240 mm *(3,0 – 9,5)*
min. 0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	550 *(80)*
Tensile Strenght R_m in MPa *(ksi)*	750 – 895 *(109 – 130)*
min. Elongation L_0 = 5 d (A_5) in %	25
min. Reduction of Area in %	45
min. Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*	80 *(60)*
Hardness in BHN	max. 295

Forms of delivery: Hot rolled bars, solution annealed, machined
Diameter: 120 – 200 mm, further measurements on request

XM19, Magnadur 3964 mod

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Ni	Mo	V	Nb	N
Min	≤	≤	4,0	≤	≤	20,5	11,5	1,50	0,10	0,10	0,20
Max	0,06	1,00	6,0	0,045	0,030	23,5	13,5	3,00	0,30	0,30	0,40

b) Mechanical properties in the solution annealed and strain-hardened condition

Condition	A	High Strength
Dimension in mm *(inch)*	40 – 350 *(1,5 – 14)*	60 – 220 *(2,25 – 8,75)*
min. 0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	380	725 *(105)*
min. Tensile Strenght R_m in MPa *(ksi)*	690	850 – 1150 *(120 – 165)*
min. Elongation L_0 = 5 d (A_5) in %	35	20
min. Reduction of Area in %	55	50
min. Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*	115 *(110)*	80 *(60)*
Hardness in BHN	max. 250	260 – 340

Forms of delivery: Hot rolled bars, solution annealed, machined or forged bars, strain hardened, machined
Diameter: 40 – 350 mm, respectively 60 – 220 mm (HS)

API 7, Magnadur 501

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Mo	Ni	N	PREN
Min		0,30	18,5	≤	≤	13,0	0,35	0,25	0,32	**19**
Max	0,04	0,60	22,0	0,030	0,005	15,0	0,50	0,50	0,40	**23**

b) Mechanical properties in the forged and strain-hardened condition

Diameter in mm *(inch)*	80 – 175 *(3½ – 6)*	
0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	825 *(120)* ⅞	176 – 255 *(7 – 9¾)*
Tensile Strenght R_m in MPa *(ksi)*	930 *(135)*	770 *(112)*
Elongation L_0 = 4 d (A_4) in %	25	900 *(130)*
Reduction of Area (Z) in %	50	
Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*	130 *(100)*	
Hardness in BHN	min. 277	

Forms of delivery: Forged bars (strain hardened), machined
Diameter: 80 – 250 mm

Magnadur 601

a) Chemical composition in wt-%

	C	Si	Mn	P	S	Cr	Mo	Ni	N	PREN
Min		≤	18,0	≤	≤	15,5	2,0	4,2	0,40	**28,5**
Max	0,05	0,30	20,0	0,030	0,005	17,5	2,8	5,0	0,50	**35**

b) Mechanical properties in the forged and strain-hardened condition

Diameter in mm *(inch)*	80 – 241,3 *(3½ – 9¼)*	>241,3 – 254 *(> 9¼ – 10)*
0,2%-Offset-Yield Strenght $R_{p0,2}$ in MPa *(ksi)*	965 *(140)*	900 *(130)*
Tensile Strenght R_m in MPa *(ksi)*	1035 *(150)*	1035 *(150)*
Elongation L_0 = 4 d (A_4) in %	20	
Reduction of Area (Z) in %	50	
Impact Toughness (Charpy-V at 23°C) in J *(ft-lbs)*	100 *(74)*	
Hardness in BHN	min. 290	

Forms of delivery: Forged bars (strain hardened), machined
Diameter: 80 – 250 mm

b) If not otherwise stated, all sample positions are 1 inch below surface.

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