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Alloy steel tubes for high-temperature service

Material Data Sheet

Steel designation:	Name	Material No.
	P91	**UNS Designation: K91560**
	T91	**K90901**
	(X10CrMoVNb9-1)	**(1.4903)**

Scope

This data sheet applies for seamless tubes.

Application

The material P91/T91 is especially suited for steam boiler, boiler parts, boiler drum, pressure vessel for the apparatus engineering and similar purposes. It can be used in permanent operation with wall temperatures up to about 650 °C (1202 °F).

Chemical composition (Heat analysis in %)

Name	C	Si	Mn	P	S	Al	Cr	Mo	Ni	V	N	others
P91	0,08-0,12	0,20-0,50	0,30-0,60	≤0,020	≤0,010	≤0,040	8,0-9,50	0,85-1,05	≤0,40	0,18-0,25	0,030-0,070	Nb 0,06-0,10
T91	0,07-0,14	0,20-0,50	0,30-0,60	≤0,020	≤0,010	≤0,02	8,0-9,5	0,85-1,05	≤0,40	0,18-0,25	0,030-0,070	Nb 0,06-0,10
X10CrMoVNb9-1	0,08-0,12	0,20-0,50	0,30-0,60	≤0,020	≤0,010	≤0,040	8,0-9,5	0,85-1,05	≤0,40	0,18-0,25	0,030-0,070	Nb 0,06-0,10 Cu ≤0,30

Mechanical properties at room temperature

Material	Usual[1] Delivery condition	Yield/ proof strength $R_{p0,2}$ N/mm² min.	Tensile strength R_m N/mm²	Elongation A % min.		Impact energy KV Temperature °C	Impact energy KV J min.	
P91[5]	+NT	415	≤ 585	20[2][4]	(13)[4]	-	-	
T91[5]	+NT	415	≤ 585	20[2][4]	(13)[4]		-	
X10CrMoVNb9-1	+NT	450	620-850	19[2]	17[3]	+20	40[2]	27[3]

1) NT: normalizing and tempered
2) Longitudinal test piece
3) Transverse test piece
4) For wall thicknesses ≤ 8 mm the values of the transverse testpiece apply
5) Hardness max. 25 HRC

Minimum values of the proof strength $R_{p0,2}$ at elevated temperatures

Name	0,2 %-Proof strength at the temperature °F in Ksi									
	300	400	500	600	700	800	900	1000	1100	1200
P91 ASME B31.3[a]	28,3	28,2	28,1	27,7	26,7	24,9	22,3	18,0	10,3	4,3

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Name	0,2 %-Proof strength at the temperature °F in Ksi											
	-20 bis 100	200	300	400	500	600	700	800	900	1000	1100	1200
P91/T91 ASME B31.1[b]	24,3	24,3	24,3	24,2	24,1	23,7	22,9	21,3	19,1	16,3	9,6	4,3

[a] ASME 31.3 - Process Piping

[b] ASME 31.1 - Power Piping

Conversion Ksi in N/mm² (MPa): Value in Ksi x 6,895

Conversion Fahrenheit in Celsius: C = (Temp. in F - 32) x 5/9

Name	0,2 %- Proof strength at the temperature r °C in N/mm² (MPa)										
	100	150	200	250	300	350	400	450	500	550	600
X10CrMoVNb9-1	410	395	380	370	360	350	340	320	300	270	215

Reference data for some physical properties

Density at 20 °C	Modulus of elasticity kN/mm² at				Thermal conductivity at 20 °C	spec. thermal capacity at 20 °C	spec. electrical resistivity at 20 °C
kg/dm³	20 °C	300 °C	400 °C	500 °C	W/m K	J/kg K	Ω mm²/m
7,76	210	185	175	165	33	622	0,24

Linear coefficient 10^{-6} K^{-1} of thermal expansion between 20 °C and

300 °C	400 °C	500 °C	600 °C
12,9	13,5	13,9	14,1

Hot forming / Heat treatment

Hot forming		Heat treatment (quenched and tempered), microstructure		
Temperature °C	Type of cooling	Austenitization	Annealing [1)]	Microstructure
1100 - 950	Air	920 - 980 °C	680 - 760 °C	bainitic/ferritic

[1)] When annealing the mentioned temperatures have to be hold after achieving over the whole cross-section for minimum 30 minutes.
Stress relieving anneal: 600 - 650°C. Holding time 1-2 minutes per mm plate thickness, minimum 30 minutes

Processing / Welding

Standard welding processes for these steel grades are:

TIG-welding
MAG-welding massive wire
MAG- welding cored wire
Arc welding (E)
Submerged arc welding (SAW)

Depending on the welding position and the plate thickness, maybe other filler metals have to be applied, which can be inquired at the manufacturer in case of need.

For these steel grades as filler metal the following electrodes and welding wires are recommended:

Process	Filler metal
TIG	Union I CrMo 910
MAG massive wire	Union I CrMo 910
MAG cored wire	Union MV CrMo - M21
Arc welding (E)	Phoenix SH Chromium 2KS

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SAW	Union S1CrMo2 / UV 420 TTR

Remark
The material is magnetizable.

References
ThyssenKrupp
ASTM A213:2011-02
ASTM A335:2009-03
ASME 31.3:2010
ASME 31.1:2010
DIN EN 10216-2:2007-10

Important Hint
Information given in this data sheet about property or applicability of materials respective products are no assurance of characteristics but serve for description.

Information, with which we like to advise you, relate to the experience of the producers and our own. Warranty for the results of the treatment and application of the products cannot be granted.