

Low Alloy Steels

DATA SHEET

A-17

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P91 - MODIFIED 9CrMo

Alloy type

Modified 9CrMo for high temperature creep resistance.

Materials to be welded

ASTM

A 213 T91 (seamless tubes)
 A 335 P91 (seamless pipes)
 A 387 Gr 91 (plates)
 A 182 / A336 F91 (forgings)
 A 217 C12A (castings)
 A 234 WP91
 A 369 FP91

DIN / BS EN

1.4903 (X10CrMoVNb 9 1)

BS

1503 Gr91
 3059-2 Gr91

AFNOR

NF A-49213/A-49219 Gr TU Z 10 CDVNb 09-01

Applications

These consumables are designed to weld equivalent 'type 91' 9CrMo steels modified with small additions of niobium, vanadium and nitrogen to give improved long term creep properties.

These consumables are specifically intended for high integrity structural service at elevated temperature so the minor alloy additions responsible for its creep strength are kept above the minimum considered necessary to ensure satisfactory performance. In this case, weldments will be weakest in the softened (intercritical) HAZ region of parent material, as indicated by so-called 'type IV' failure in transverse weld creep tests.

Modified 9CrMo steels are now widely used for components such as **headers, main steam piping and turbine casings**, in fossil fuelled **power generating plants**. They may also find future use in **oil refineries and coal liquefaction and gasification plants**.

Microstructure

In the PWHT condition the microstructure consists of tempered martensite with alloy carbides.

PWHT

Minimum preheat temperature 150°C with maximum interpass temperature of 300°C; in practice a preheat-

interpass range of 200–300°C is normal. To ensure full martensite transformation, welds should be cooled to ~100°C prior to PWHT.

ASME base material codes and AWS consumable classifications allow PWHT down to 730°C, whilst BS EN consumable classifications specify 750°C. Optimum properties are obtained with a tempering parameter (P) of around 21 or above, where $P = °C + 273 (\log t + 20) \times 10^{-3}$. Maximum PWHT temperature varies, AWS consumable specifications are 760°C, BS EN 770°C; BS 1503 allows up to 790°C for base material forgings.

When compared with directly matching weld metal, the addition of some nickel and reduction of niobium provides a useful improvement in toughness after conveniently short PWHT at 750–760°C. PWHT above 765°C is not generally recommended for Ni-containing consumables, because some re-hardening could occur due to the proximity of A_{c1} . Some authorities specify weld metal Ni + Mn < 1.5% to keep A_{c1} high enough to allow higher PWHT temperature if required.


Additional information

More detailed information on the products and properties of P91 are available in the Technical Profile – "Welding Consumables for P91 Steels for the Power Generation Industry" – available from the Technical Department.

Products available

Process	Product	Specification
MMA	Chromet 9MV-N	AWS E9015-B9
	Chromet 9MVN+	AWS E9015-B9
	Chromet 9-B9	AWS E9015-B9
	Chromet 91VNB	AWS E9015-B9
TIG	9CrMoV-N	AWS ER90S-B9
MIG (MCW)	Cormet M91	AWS E90C-B9
SAW	9CrMoV-N (wire)	AWS EB9
	LA491 (flux)	BS EN SA FB 2
	LA492 (flux)	BS EN SA CS 1
	L2N (flux)	BS EN SF CS 2
FCW	Supercore F91	AWS E91T1-B9

General Data for all Modified 9CrMo (P91) Electrodes

Description	Recovery is approx 120% with respect to core wire, 65% with respect to whole electrode. Moisture resistant coatings giving very low weld metal hydrogen levels.																						
Operating parameters	DC +ve.	AC (OCV 70V min)																					
	ø mm	2.5	3.2	4.0	5.0																		
	min A	70	80	100	140																		
	max A	110	140	180	240																		
Storage	3 hermetically sealed ring-pull metal tins per carton, with unlimited shelf life. Direct use from tin will give hydrogen <5ml/100g weld metal during 8h working shift. For electrodes that have been exposed: Redry 250 – 300°C/1-2h to ensure H ₂ < 10ml/100g, 300 – 350°C/1-2h to ensure H ₂ < 5ml/100g. Maximum 420°C, 3 cycles, 10h total. Storage of redried electrodes at 100 – 200°C in holding oven, or 50 – 150°C in heated quivers: no limit, but maximum 6 weeks recommended.																						
Fume data	Fume composition (wt %) <table style="width: 100%; margin-top: 5px;"> <tr> <td style="text-align: center;">Fe</td> <td style="text-align: center;">Mn</td> <td style="text-align: center;">Ni</td> <td style="text-align: center;">Cr</td> <td style="text-align: center;">Cu</td> <td style="text-align: center;">Pb</td> <td style="text-align: center;">F</td> <td style="text-align: center;">OES mg/m³)</td> </tr> <tr> <td style="text-align: center;">15</td> <td style="text-align: center;">5</td> <td style="text-align: center;">< 0.1</td> <td style="text-align: center;">< 3</td> <td style="text-align: center;">< 0.1</td> <td style="text-align: center;">< 0.1</td> <td style="text-align: center;">18</td> <td style="text-align: center;">1.7</td> </tr> </table>							Fe	Mn	Ni	Cr	Cu	Pb	F	OES mg/m ³)	15	5	< 0.1	< 3	< 0.1	< 0.1	18	1.7
Fe	Mn	Ni	Cr	Cu	Pb	F	OES mg/m ³)																
15	5	< 0.1	< 3	< 0.1	< 0.1	18	1.7																

CHROMET 9MV-N

MMA electrode to AWS/BS EN with high Ni to maximise toughness

Product description	MMA electrode – Basic metal powder type made on high purity steel core wire with Ni addition and lower Nb for improved toughness, conforming to BS EN ISO 3580-A														
Specifications	AWS A5.5		E9015-B9												
	BS EN ISO 3580-A		E CrMo91 B 3 2												
ASME IX Qualification	QW422 P-No 5B group 2, QW432 F-No 4, QW442 A-No 5														
Composition (weld metal wt %)		C	Mn	Si	S	P	Cr	Ni*	Mo	Nb	V	N	Cu	Sn	Ni+Mn
	min	0.08	0.50	--	--	--	8.0	0.4	0.85	0.04	0.15	0.03	--	--	--
	max	0.12	1.20	0.30	0.01	0.01	10.0	0.8	1.2	0.07	0.25	0.07	0.25	<0.008	1.5
	typ	0.1	0.6	0.25	0.008	0.01	9	0.7	1	0.05	0.2	0.05	0.05	0.003	1.3
	* Low Ni variant is available, Chromet 9-B9 .														
All-weld mechanical properties	PWHT 760°C / 2h							min ⁽¹⁾	typical	550°C	600°C	650°C			
	Tensile strength						MPa	620	770	>450	>375	>285			
	0.2% Proof stress						MPa	530	640	>360	>255	>175			
	Elongation on 4d						%	17	22	--	--	--			
	Elongation on 5d						%	17	19	>15	>17	>21			
	Reduction of area						%	--	60	>68	>75	>80			
	Impact energy					+ 20°C	J	47	65	--	--	--			
	Lateral expansion					+ 20°C	mm	--	1.00	--	--	--			
	Hardness after PWHT						HV	--	250	--	--	--			
Hardness as-welded						HV	--	450	--	--	--				
	⁽¹⁾ Minimum strength for parent material is lower than AWS requirement shown.														
Packaging data	ø mm	2.5		3.2		4.0		5.0							
	length mm	350		380		450		450							
	kg/carton	12.9		15.0		17.4		16.5							
	pieces/carton	651		405		234		150							

CHROMET 9MVN+

MMA electrode to AWS/BS EN with high Ni to maximise toughness

Product description	MMA electrode – Basic type made on matching core wire with Ni addition and lower Nb for improved toughness, conforming to BS EN ISO 3580-A and AWS specifications.														
Specifications	AWS A5.5		E9015-B9												
	BS EN ISO 3580-A		E CrMo91 B 3 2												
ASME IX Qualification	QW422 P-No 5B group 2, QW432 F-No 4, QW442 A-No 5														
Composition (weld metal wt %)		C	Mn	Si	S	P	Cr	Ni*	Mo	Nb	V	N	Cu	Sn	Ni+Mn
	min	0.08	0.50	--	--	--	8.0	0.4	0.85	0.04	0.15	0.03	--	--	--
	max	0.12	1.20	0.30	0.01	0.01	10.0	0.8	1.2	0.07	0.25	0.07	0.25	<0.008	1.5
	typ	0.1	0.7	0.25	0.008	0.01	9	0.7	1	0.05	0.2	0.05	0.05	0.003	1.3
	* Low Ni variant is available, Chromet 9-B9 .														
All-weld mechanical properties	PWHT 760°C / 2h							min ⁽¹⁾		typical					
	Tensile strength						MPa	620	720						
	0.2% Proof stress						MPa	530	590						
	Elongation on 4d						%	17	22						
	Elongation on 5d						%	17	19						
	Reduction of area						%	--	62						
	Impact energy						+ 20°C	J	47	90					
	Hardness after PWHT							HV	--	250					
① Minimum strength for parent material is lower than AWS requirement shown.															
Packaging data	ø mm		2.5		3.2		4.0		5.0						
	length mm		250		350		350		450						
	kg/carton		10.2		13.5		14.1		16.5						
	pieces/carton		714		408		276		150						

CHROMET 9-B9

MMA electrode meeting AWS/ASME

Product description	MMA electrode – Basic metal powder type made on high purity steel core wire manufactured to the requirements of AWS A5.5 E9015-B9 and BS EN ISO 3580-B.																
Specifications	AWS A5.5		E9015-B9														
	BS EN ISO 3580-B		E 6216-9C1MV														
ASME IX Qualification	QW422 P-No 5B group 2, QW432 F-No 4, QW442 A-No 5																
Composition (weld metal wt %)		C	Mn*	Si	S	P	Cr	Ni*	Mo	Nb	V	N	Cu	Al			
	min	0.08	0.40	--	--	--	8.0	0.2	0.85	0.03	0.15	0.03	--	--			
	max	0.12	0.75	0.30	0.01	0.01	10.0	0.4	1.2	0.07	0.25	0.07	0.25	0.04			
	typ	0.1	0.55	0.25	0.008	0.008	9	0.3	1	0.04	0.2	0.05	0.05	<0.01			
	* Ni + Mn ≤ 1.0%. Nickel is below 0.4% (as parent material) although AWS allows up to 1.0%Ni. See Chromet 9MV-N or Chromet 9MVN+ for variant with 0.4–1.0%Ni conforming to BS EN ISO specification.																
All-weld mechanical properties	PWHT 760°C / 2h							min ⁽¹⁾		typical		550°C		600°C		650°C	
	Tensile strength						MPa	620	710		>450		>375		>285		
	0.2% Proof stress						MPa	530	590		>360		>255		>175		
	Elongation on 4d						%	17	22.5		--		--		--		
	Elongation on 5d						%	15	19		>15		>17		>21		
	Reduction of area						%	--	63		>68		>75		>80		
	Impact energy						+ 20°C	J	--	75		--		--		--	
	Lateral expansion						+ 20°C	mm	--	1.10		--		--		--	
	Hardness after PWHT							HV	--	240		--		--		--	
Hardness as-welded							HV	--	450		--		--		--		
① Minimum strength for parent material is lower than AWS requirement shown.																	
Packaging data	ø mm		2.5		3.2		4.0*		5.0								
	length mm		350		380		380/450		450								
	kg/carton		13.5		15		15/17.1		16.5								
	pieces/carton		657		378		264/249		150								
* 450mm is standard length for 4.0mm, 380mm produced to order.																	

CHROMET 91VNB

MMA electrode for root welding

Product description	MMA electrode - Basic coated for root welding applications made on high purity steel core wire.													
Specifications	AWS A5.5		E9015-B9											
	BS EN ISO 3580-A		E CrMo91 B 3 2											
ASME IX Qualification	QW422 P-No 5B group 2, QW432 F-No 4, QW442 A-No 5													
Composition (weld metal wt %)		C	Mn	Si	S	P	Cr	Ni	Mo	Nb	V	N	Cu	Al
	min	0.08	0.4	--	--	--	8.0	0.4	0.85	0.03	0.15	0.03	--	--
	max	0.12	1.2	0.3	0.01	0.01	9.5	0.8	1.2	0.07	0.25	0.07	0.25	0.04
	typ	0.1	0.8	0.25	0.008	0.008	8.5	0.5	1	0.04	0.2	0.05	0.05	0.01
All-weld mechanical properties	PWHT 760°C / 2h							min ⁽¹⁾		typical				
	Tensile strength						MPa	620	750					
	0.2% Proof stress						MPa	530	600					
	Elongation on 4d						%	17	20					
	Elongation on 5d						%	17	18					
	Impact energy						+ 20°C	J	--	55				
⁽¹⁾ Minimum strength for parent material is lower than AWS requirement shown.														
Operating parameters	DC +ve, DC -ve or AC (OCV 70V min)													
	ø mm		2.5											
	min A		60											
	max A		110											
Packaging data	ø mm		2.5											
	length mm		350											
	kg/carton		13.5											
	pieces/carton		678											

9CrMoV-N

Solid wire for TIG and SAW


Product description	Solid wire, non-copper coated, for TIG and SAW														
Specifications	AWS A5.23		TIG					SAW							
	AWS A5.28		--					EB9							
	BS EN ISO 21952-A		ER90S-B9					--							
	BS EN ISO 24598-A		W CrMo91					--							
	BS EN ISO 24598-A		--					(S CrMo91)							
ASME IX Qualification	QW422 P-No 5B group 2, QW432 F-No 6, QW442 A-No 5														
Composition (wire wt %)		C	Mn	Si	S	P	Cr	Ni	Mo	Nb	V	N	Cu	Al	
	min	0.08	0.40	0.15	--	--	8.5	0.40	0.85	0.03	0.15	0.03	--	--	
	max	0.13	0.80	0.50	0.010	0.010	9.5	0.80	1.10	0.08	0.25	0.07	0.10	0.04	
	typ	0.1	0.5	0.25	0.006	0.008	8.7	0.6	1	0.05	0.2	0.05	0.03	<0.01	
All-weld mechanical properties	PWHT 750 – 760°C / 2 – 3h						min	TIG typical	SAW typical LA491 flux	SAW typical L2N flux					
	Tensile strength						MPa	620	780	750					
	0.2% Proof stress						MPa	415	675	630					
	Elongation on 4d						%	16	22	25					
	Elongation on 5d						%	17	19	23					
	Reduction of area						%	--	70	70					
	Impact energy						+ 20°C	J	-- *	220	45				
	Hardness						HV (mid)	--	265	250					
* Minimum impact required by BS EN ISO is 47 J.															

9CrMoV-N (continued)

Parameters	TIG		SAW	MIG			
	Shielding	Argon		LA492, LA491 or L2N flux	9CrMoV-N not recommended for MIG, Cormet M91 or Supercore F91 should be used.		
Current	DC-		DC+				
Typical parameters 2.4mm ø	100A, 12V		450A, 30V, 450mm/min				
Packaging data	ø mm	TIG	SAW	MIG			
	0.8/0.9/1.0/1.2	0.7 / 5 / 15 kg spools to order.	--				
	1.6	5kg tube	--	Not recommended - see Supercore F91 or Cormet M91.			
	2.0	5kg tube					
	2.4	5kg tube	25kg coil				
	3.2	5kg tube	25kg coil				
Fume data	Fume composition (wt %); TIG and SAW fume are negligible:						
	Fe	Mn	Ni	Cr ³	Mo	Cu	OES (mg/m ³)
	50	4	< 0.4	6	0.5	< 0.5	5

CORMET M91

Metal cored wire for MIG welding

Product description	Metal cored wire for MIG welding. High purity steel sheath with 96% metal recovery with respect to wire.													
Specifications	AWS A5.28			E90C-B9										
	BS EN ISO 17634-B			T69T15-0M-9C1MV										
ASME IX Qualification	QW422 P-No 5B group 2, QW432 F-No 6, QW442 A-No 5													
Composition (weld metal wt %)		C	Mn*	Si	S	P	Cr	Ni*	Mo	Nb	V	N	Cu	Al
	min	0.08	0.60	--	--	--	8.0	--	0.85	0.03	0.18	0.03	--	--
	max	0.13	1.20	0.50	0.015	0.020	10.0	0.80	1.20	0.07	0.25	0.07	0.15	0.04
	typ	0.1	1	0.3	0.01	0.01	9	0.3	1	0.05	0.2	0.05	0.05	0.03
	* Ni + Mn ≤ 1.50													
All-weld mechanical properties	PWHT 760°C / 2h						min		typical					
									Ar-2½%CO ₂	80/20	Ar-He-CO ₂			
	Tensile strength						MPa	690	780	780	780			
	0.2% Proof stress						MPa	565	650	650	650			
	Elongation on 4d						%	16	17	17	17			
	Elongation on 5d						%	14	16	16	16			
	Impact energy						+ 20°C	J	--	30	25	35		
	Lateral expansion						+ 20°C	mm	--	0.30	0.28	0.45		
	Hardness						HV	--	260	260	260			
Parameters	Operability is influenced by the type of shielding gas; higher CO ₂ levels, up to 20%, give better arc characteristics but lower CO ₂ and O ₂ levels produce better impact properties. The best compromise is considered to be obtained from Ar-2½%CO ₂ although if impact properties are not a major concern, higher CO ₂ levels can be used to obtain optimum arc characteristics. 													
	ø mm	Gas flow				Optimum				Stickout				
	1.2	15 – 25 l/min				DC+ 260A 28V				10 – 20mm				
	1.6	15 – 25 l/min				DC+ 330A 29V				15 – 25mm				
Packaging data	Resistance to moisture absorption is high, but to maintain the high integrity of the wire surface and prevent any possibility of porosity, it is advised that part-used spools are returned to polythene wrappers. 15kg spools. Where possible, preferred storage conditions are 60% RH max, 18°C min.													
Fume data	Fume composition (wt %)													
	Fe	Mn	Ni	Cr ³	Mo	Cu	OES (mg/m ³)							
	60	5	< 0.5	5	< 0.1	< 0.1	5							

SUPERCORE F91

All-positional flux cored wire

Product description	All-positional flux cored wire designed to weld equivalent modified 9CrMo steels (P91). Rutile flux system with an alloyed strip producing weld metal recovery of about 90%.														
Specifications	AWS A5.29		E91T1-B9C/M												
	BS EN ISO 17634-B		T69T1-1C/M-9C1MV												
ASME IX Qualification	QW432 F-No -, QW442 A-No -														
Composition (weld metal wt %)		C	Mn	Si	S	P	Cr	Ni	Mo	Nb	V	N	Cu	Al	Ni+Mn
	min	0.08	0.60	--	--	--	8.0	--	0.85	0.02	0.15	0.02	--	--	--
	max	0.13	1.20	0.50	0.015	0.020	10.0	0.80	1.2	0.07	0.25	0.07	0.15	0.04	1.50
	typ	0.1	0.8	0.3	0.010	0.016	9	0.5	1	0.04	0.2	0.05	0.05	0.01	1.30
All-weld mechanical properties	PWHT 760°C / 2h (6h)					min	typical	typical	High Temperature						
							760°C/2h	760°C/6h	+566°C	+600°C	+650°C				
	Tensile strength				MPa	690	790	750	450	420	396				
	0.2% Proof stress				MPa	565	660	630	360	288	245				
	Elongation on 4d				%	16	20	23	21	27	29				
	Elongation on 5d				%	14	18	20	20	25	26				
	Reduction of area				%	--	55	58	73	81	85				
Impact energy			+ 20°C		J	--	28	36	--	--	--				
Hardness					HV	--	260	250	--	--	--				
Operating parameters	Shielding gas: 80%Ar-20%CO ₂ (or 15 – 25%CO ₂) or 100% CO ₂ at 20-25l/min.														
	Current: DC+ve ranges as below:														
	∅	welding position	amp-volt range *			typical			stickout						
1.2mm (0.045in)	Positional	140-170A, 24-26V			160A, 25V			15-25mm							
* Using 100%CO ₂ the voltage should be increased by 1-2V															
Packaging data	Spools vacuum-sealed in barrier foil with cardboard carton: 15kg (33 lbs) The as-packed shelf life is virtually indefinite. Resistance to moisture absorption is high, but to maintain the high integrity of the wire surface and prevent any possibility of porosity, it is advised that part-used spools are returned to polythene wrappers. Where possible, preferred storage conditions are 60% RH max, 18°C min.														
Fume data	Fume composition (wt %), shielding gas 80%Ar-20%CO ₂ :														
	Fe	Mn	Ni	Cr ³	Cr ⁶	Cu	F	OES (mg/m ³)							
	18	8	< 0.5	3	3	< 1	8	1.7							

LA492, LA491, L2N

Sub-arc fluxes for use with 9CrMoV-N solid wire

Product description	LA491 is an agglomerated fluoride-basic submerged arc welding flux. LA492 is an agglomerated calcium silicate flux for submerged arc welding. L2N is a fused calcium silicate flux for submerged arc welding.												
Specifications		LA491			LA492			L2N					
	BS EN 760 (flux) AWS A5.23 (flux wire combination)	SA FB 255 AC (F62PZ-EB9-B9)			SA CS 155 DC (F62PZ-EB9-B9)			SF CS 2 DC (F62PZ-EB9-B9)					
Composition (flux wt %)		LA491			LA492			L2N					
	SiO ₂ + Ti O ₂	15%			20%			30%					
	CaO + Mg O	40%			40%			35%					
	AlO ₃ + MnO	20%			20%			5%					
	CaF ₂	25%			20%			20%					
Basicity index (Boniszewski)	~2.7			~2.2			~1.3						
Analysis deposit (typical)		C	Mn	Si	S	P	Cr	Ni	Mo	Nb	V	N	
	9CrMoV-N Wire	0.10	0.6	0.30	0.005	0.005	8.8	0.6	1	0.06	0.20	0.05	
	Deposit with LA491	0.08	0.6	0.35	0.005	0.010	8.5	0.6	1	0.05	0.17	0.05	
	Deposit with LA492	0.08	0.5	0.30	0.005	0.012	8.3	0.6	1	0.05	0.16	0.05	
	Deposit with L2N	0.09	0.5	0.6	0.005	0.012	8.3	0.6	1	0.04	0.16	0.05	
All-weld mechanical properties	PWHT 750–760°C / 2–3h				min	SAW typical LA491 flux	SAW typical LA492 flux	SAW typical L2N flux					
	Tensile strength				MPa	620	750	720	750				
	0.2% Proof stress				MPa	415	630	610	630				
	Elongation on 4d				%	16	25	25	25				
	Elongation on 5d				%	17	23	23	23				
	Reduction of area				%	--	70	70	70				
	Impact energy + 20°C				J	--*	40	45	35				
	Hardness				HV (mid)	--	250	230	250				
	* Minimum impact required by BS EN 12070: SCrMo91 is 47 J.												
	Parameters	LA491, LA492						L2N					
AC or DC+ 800A maximum						AC or DC+ 900A maximum							
Packaging data	LA491			LA492			L2N						
	25kg sealed drums			22.5kg sealed drums			Packaging: 20kg sealed drums						
	Preferred storage <60%RH, > 18°C. If flux becomes damp, rebake at 300–350°C/ 1–2hours to restore to as-packed condition. For critical work, it is recommended to redry to ensure <5ml H ₂ /100g.						Preferred storage <60%RH, > 18°C. If flux becomes damp, rebake at 150-250°C/1–2hours to restore to as-packed condition.						