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 Ac_1. Some authorities specify weld metal Ni + Mn < 1.5% to keep Ac_1 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-G
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

Basic metal powder types made on high purity steel core wire.

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 %)

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 – 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 – made on matching core wire with Ni addition and lower Nb for improved toughness, conforming to BS EN ISO 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 – manufactured to the requirements of AWS A5.5 E9015-B9

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

Basic coated MMA electrode for root welding applications made on high purity steel core wire. 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.

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

	TIG	SAW
AWS A5.23	--	EB9
AWS A5.28	ER90S-B9	--
BS EN ISO 21952-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	750
0.2% Proof stress		MPa	415	675	630	630
Elongation on 4d		%	16	22	25	25
Elongation on 5d		%	17	19	23	23
Reduction of area		%	--	70	70	70
Impact energy	+ 20°C	J	-- *	220	45	35
Hardness		HV (mid)	--	265	250	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	Spool to order	--	
1.2	--	--	Not recommended - see Supercore F91 or Cormet M91.
1.6	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	typical 80/20	typical 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	1.5
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	1.3

All-weld mechanical properties

PWHT 760°C / 2h			min	typical	High Temperature		
					+566°C	+600°C	+650°C
Tensile strength		MPa	690	790	450	420	396
0.2% Proof stress		MPa	565	660	360	288	245
Elongation on 4d		%	16	20	21	27	29
Elongation on 5d		%	14	18	20	25	26
Reduction of area		%	--	55	73	81	85
Impact energy	+ 20°C	J	--	25	--	--	--
Hardness		HV	--	260	--	--	--

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:

ø	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)	SA FB 255 AC	SA CS 155 DC	SF CS 2 DC
AWS A5.23 (flux wire combination)	(F62PZ-EB9-B9)	(F62PZ-EB9-B9)	(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.