High Temperature Alloys

DATA SHEET **C-12**

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16.8.2 FOR HIGH TEMPERATURE 3XXH STAINLESS STEELS

Alloy type

16.8.2 for high temperature 3XXH stainless steels.

Materials to be welded

ASTM/UNS	DIN	BS
304H / S30409	1.4948	304S51
321H / S32109	1.4941	321S51
347H / S34709	1.4961	347S51
316H / S31609	-	316S51, 316S53

Applications

The 16.8.2 consumables have a controlled composition, optimised for performance in structural service at temperatures up to about 800°C. With molybdenum specifically at the lower limit for AWS 16.8.2, it is essentially a dilute hybrid between E308H and E316H. Rather than matching any single parent material, it has applications for welding all the '3XXH' series of stainless steels with 0.04-0.10% carbon, which combine creep, oxidation and general corrosion resistance.

A low total Cr+Mo with controlled carbon and ferrite content ensures high resistance to thermal embrittlement by intermetallic phases (and also excellent toughness at low temperatures). A strictly limited level of Mo provides valuable effects on creep ductility and thermal fatigue, balanced against control of oxidation under stagnant conditions above 650°C, and sigma or chi phase formation in service. No bismuth-bearing constituents are allowed in these consumables, to ensure <0.00 2%Bi as required by API 582.

For 304H, some authorities now choose 16.8.2 specifically to avoid hot ductility and creep-fatigue problems in thick sections which traditionally would have been welded with 308H. Historically, this weld metal was initially developed to avoid in-service HAZ failure in 347H of >12mm thickness. For the same reasons it is also a candidate for 321H, although HAZ failures here are not so well documented. For thermal stability, it is equally suitable for 316H in preference to matching weld metal.

In some applications, the chromium in 16.8.2 weld metal may be considered too low for satisfactory resistance to corrosion (possibly under dew-point conditions during plant shutdown). However, the weld root is normally on the process side, and is conventionally deposited by TIG using higher chromium weld metal. Similar electrodes for capping runs are available if required.

Applications include **catalytic crackers** (cat crackers)**, cyclones, transfer lines, furnace parts, thick wall steam piping, superheater headers**, some **gas** and **steam turbine** components used in **petrochemical, chemical process plants** and in **power generation industries**.

Owing to the lean composition and controlled ferrite content, the 16.8.2 consumables also show useful cryogenic toughness down to -196°C.

Microstructure

Austenite with delta ferrite of 1-6FN typically. Hot cracking is not reported at low FN.

Welding guidelines

Preheat is not required; maximum interpass temperature 250°C. Welds are left as-welded, no PWHT required.

Additional information

O R Carpenter and R D Wylie: "16-8-2 Cr-Ni-Mo for welding electrodes" Met. Prog. 1956, 70, (5), 65-73. This paper describes the original development (by Babcock and Wilcox) of E16-8-2 to weld 347 for power plant applications.

R D Thomas: "HAZ cracking in thick sections of austenitic stainless steels" Part 1, Weld J 1984, 63, 12, 24-32; Part 2 idem 355s-368s. This detailed review covers all standard stainless steels, in particular for high temperature structural applications.

There is also a Metrode Technical Profile available on the use of 16.8.2 consumables in cat crackers.

Related alloy groups

See also the consumables in the related alloy groups of 308H (C-10), 347H (C-11), 316H (C-13).

Products available

Process	Product	Specification
MMA	**Supermet 16.8.2**	AWS E16.8.2-17
	E16.8.2-15	AWS E16.8.2-15
TIG/SAW	**ER16.8.2**	AWS ER16.8.2
FCW	**Supercore 16.8.2/P**	None relevant

SUPERMET 16.8.2

Rutile electrode for 3XXH stainless steel

Product description

General purpose, all-positional MMA electrode with rutile-aluminosilicate flux on high purity 304L core wire.

Manufactured with 'controlled hydrogen' and moisture resistant flux covering technology to ensure high resistance to weld porosity.

Recovery is about 115% with respect to core wire, 65% with respect to whole electrode.

Specifications

AWS A5.4	E16-8-2-17
BS EN 1600	(E 16 8 2 R)
BS 2926	(17.8.2.AR)

ASME IX Qualification

QW432 F-No 5, **QW442** A-No 8

Composition (weld metal wt %)

	C	Mn	Si	S	P	Cr	Ni	Mo*	Cu	FN
min	0.04	0.5	--	--	--	14.5	7.5	1.0	--	1
max	0.08	2.5	0.60	0.03	0.03	16.5	9.5	2.0	0.75	6
typ	0.05	1	0.45	0.01	0.02	15.5	8.5	1.2	0.1	3

* Mo controlled around 1.0 – 1.3% unless requested otherwise.
BS EN E16 8 2 R has Mo 1.50 – 2.50%.

All-weld mechanical properties

As welded			min	typical	High Temperature		
					650°C	732°C	816°C
Tensile strength		MPa	550	> 620	310	232	161
0.2% Proof stress		MPa	--	> 410	225	179	126
Elongation on 4d		%	35	42	--	--	--
Elongation on 5d		%	25	42	28	47	43
Reduction of area		%	--	45	52	59	55
Impact energy (and LE*)	+ 20°C	J (mm)	--	> 70 (>1.3)	--	--	--
Impact energy (and LE*)	- 50°C	J (mm)	--	> 50 (>0.9)	--	--	--

* LE = Charpy lateral expansion, mm (0.38mm = 15 mils)

Operating parameters

DC +ve or AC (OCV: 55V min)

ø mm	2.5	3.2	4.0	5.0
min A	60	75	100	130
max A	90	120	155	210

Packaging data

ø mm	2.5	3.2	4.0	5.0
length mm	300	350	350	450
kg/carton	12.0	13.5	13.5	18.0
pieces/carton	648	381	249	165

Storage

3 hermetically sealed ring-pull metal tins per carton, with unlimited shelf life. Direct use from tin is satisfactory for much longer than a working shift of 8h. Excessive exposure of electrodes to humid conditions will cause some moisture pick-up and increase the risk of porosity.
For electrodes that have been exposed:
Redry 200 – 300°C/1-2h to restore to as-packed condition. Maximum 400° C, 3 cycles, 10h total.
Storage of redried electrodes at 50 – 200°C in holding oven or heated quiver: no limit, but maximum 6 weeks recommended. Recommended ambient storage conditions for opened tins (using plastic lid): < 60% RH, > 18°C.

Fume data

Fume composition, wt % typical:

Fe	Mn	Ni	Cr	Mo	Cu	F	OES (mg/m^3)
8	5	0.7	5	0.1	0.2	16	1

E16.8.2-15

Basic pipe welding electrode for 3XXH stainless steel

Product description

MMA electrode with fully basic lime-fluoride flux on high purity 304L core wire. **E16.8.2-15** is a basic coated all-positional electrode suited to the most demanding vertical and overhead welding applications, including fixed pipework in the ASME 5G/6G positions.

Recovery is about 115% with respect to core wire, 65% with respect to whole electrode.

Specifications

AWS A5.4	E16-8-2-15
BS EN 1600	(E16 8 2 B)
BS 2926	(17.8.2.B)

ASME IX Qualification

QW432 F-No 5, **QW442** A-No 8

Composition (weld metal wt %)

	C	Mn	Si	S	P	Cr	Ni	Mo*	Cu	FN
min	0.04	0.5	--	--	--	14.5	7.5	1.0	--	1
max	0.08	2.5	0.60	0.03	0.03	16.5	9.5	2.0	0.75	6
typ	0.05	1.8	0.3	0.01	0.02	15.5	8.5	1.2	0.06	3

* BS EN E16 8 2 B has Mo 1.50 – 2.50%
Mo controlled around 1.0 – 1.3% unless requested otherwise.

All-weld mechanical properties

As welded			min	typical	High Temperature		
					650°C	732°C	816°C
Tensile strength		MPa	550	> 620	294	230	165
0.2% Proof stress		MPa	--	> 410	216	187	132
Elongation on 4d		%	35	40	--	--	--
Elongation on 5d		%	--	37	27	36	57
Reduction of area		%	--	35	61	70	75
Impact energy	-100°C	J	--	> 50	--	--	--

Operating parameters

DC + ve. Unsuitable for AC.

ø mm	2.5	3.2	4.0
min A	60	75	100
max A	90	120	155

Packaging data

ø mm	2.5	3.2	4.0
length mm	300	350	350
kg/carton	12.0	13.5	13.5
pieces/carton	684	396	255

Storage

3 hermetically sealed ring-pull metal tins per carton, with unlimited shelf life. Direct use from tin is satisfactory for much longer than a working shift of 8h. Excessive exposure of electrodes to humid conditions will cause some moisture pick-up and increase the risk of porosity.
For electrodes that have been exposed:
Redry 200 – 300°C/1-2h to restore to as-packed condition. Maximum 400° C, 3 cycles, 10h total.
Storage of redried electrodes at 50 – 200°C in holding oven or heated quiver: no limit, but maximum 6 weeks recommended. Recommended ambient storage conditions for opened tins (using plastic lid): < 60% RH, > 18°C.

Fume data

Fume composition, wt % typical:

Fe	Mn	Ni	Cr	Mo	Cu	F	OES (mg/m^3)
8	5	0.7	5	0.1	0.2	16	1

ER16.8.2

Solid wire TIG and SAW for 3XXH stainless steel

Product description

Solid wire for TIG welding and sub-arc welding of 300H stainless steel.

Specifications

AWS A5.9	ER16-8-2
BS EN ISO 14343-A	16 8 2
BS EN ISO 14343-B	SS16-8-2

ASME IX Qualification

QW432 F-No 6, **QW442** A-No 8

Composition (wire wt %)

	C	Mn	Si	S	P	Cr	Ni	Mo*	Cu
min	0.04	1.0	0.3	--	--	14.5	7.5	1.0	--
max	0.10	2.0	0.6	0.02	0.03	16.5	9.5	2.0	0.3
typ	0.06	1.4	0.4	0.01	0.01	15.5	8.5	1.3	0.1

* Mo 1.0 – 1.3% on request.

Typical ferrite level 1-6FN.

All-weld mechanical properties

		typical		High Temperature (TIG)		
As welded		TIG	SAW	650°C	732°C	816°C
Tensile strength	MPa	620	630	315	241	173
0.2% Proof stress	MPa	450	360	221	178	147
Elongation on 4d	%	35	29	--	--	--
Elongation on 5d	%	--	29	31	36	42
Reduction of area	%	--	30	67	69	65
Impact energy –196°C	J	--	30	--	--	--

Typical operating parameters

	TIG	SAW
Shielding	Argon	SS300 or SSB flux
Diameter	2.4	2.4
Current	100A	350A, DC+
Voltage	12V	30V

Packaging data

ø mm	TIG	SAW
1.6	2.5kg tube	--
2.4	2.5kg tube	25kg spool

Fume data

Fume composition (wt %) (TIG & SAW fume negligible):

Fe	Mn	Cr^3	Ni	Mo	Cu	OES (mg/m^3)
40	10	12	7	0.5	< 0.5	4.2

SUPERCORE 16.8.2 / 16.8.2P

Rutile FCW for 3XXH stainless steel

Product description

These wires are made with an austenitic stainless steel sheath and rutile flux system with alloying controlled to maximise high temperature strength and resistance to service embrittlement. **Supercore 16.8.2** ismade in 1.6mm only and is designed for applications primarily in the downhand and HV positions on plate and material of about 6mm thickness and above. **Supercore 16.8.2P** is made in 1.2mm only and isdesigned for welding in all welding positions from ASME 1G/2G up to 5G/6G pipework, and also provides very good operability in the flat/HV position. Metal recovery is about 90% with respect to wire.

Specifications

AWS A5.22 None applicable
BS EN ISO 17633-B (nearest TS16-8-2-FM1)

ASME IX Qualification

QW432 F-No 6, **QW442** A-No 8

Composition (weld metal wt %)

	C	Mn	Si	S	P	Cr	Ni	Mo	Cu	FN
min	0.04	0.5	--	--	--	14.5	7.5	1.0	--	1
max	0.08	2.0	0.70	0.03	0.04	17.0	10.0	2.0	0.5	8
typ	0.05	1.2	0.5	0.01	0.02	16.2	9.2	1.1*	0.1	4

* Mo controlled around 1.0 – 1.3% unless requested otherwise.

All-weld mechanical properties

				High Temperature		
As welded		min	typical	650°C	732°C	816°C
Tensile strength	MPa	560	620	290	224	160
0.2% Proof stress	MPa	--	410	207	180	134
Elongation on 4d	%	35	42	--	--	--
Elongation on 5d	%	25	42	30	44	39
Reduction of area	%	--	50	66	68	79

All-weld mechanical properties (continued)

As welded			min	typical	
Impact energy (and LE*)	+ 20°C	J (mm)	--	100	(1.8)
	-130°C	J (mm)	--	50	(0.8)
	- 196°C	J (mm)	--	45	(0.7)

* LE = Charpy lateral expansion, mm (0.38mm = 15 mils)

Operating parameters

Shielding gas: 80%Ar-20%CO_2 or 100% CO_2 at 20-25l/min. Proprietary gases may be used but argon should not exceed 85%.

Current: DC+ve ranges as below for Ar-20%CO_2. Welding with 100%CO_2 requires approx 3V higher:

ø mm	amp-volt range	typical	stickout
1.2	120A-22V to 280A-34V	180A-29V	15 – 20mm
1.6	200A-28V to 350A-34V	300A-30V	15 – 25mm

Packaging data

Spools vacuum-sealed in barrier foil with cardboard carton: 15kg

The as-packed shelf life is virtually indefinite.

Resistance to moisture absorption is high, but to 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 maximum, 18°C minimum.

Fume data

Fume composition (wt %):

Fe	Mn	Ni	Cr^3	Cr^6	Cu	F	OES (mg/m^3)
17	11	1.5	4	4	<1	5	1.2