

C-12

High Temperature Alloys

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	347851
316H / S31609	-	316851, 316853

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

DATA SHEET

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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 1	T 16.8.2 Rutile electrode for 3XXH stair												
Product description	General purpose, a	ll-positiona	ıl MMA	electrode	with r	utile-al	uminosi	ilicate flu	ux on hig	h purity 304L	core wire.		
	Manufactured with to weld porosity.	'controlled	hydroge	en' and mo	isture	resista	nt flux co	overing t	echnolog	y to ensure hig	h resistance		
	Recovery is about	115% with	respect	to core wi	re, 65%	% with	respect	to whole	e electrod	le.			
Specifications	AWS A5.4 BS EN 1600 BS 2926	AWS A5.4 E16-8-2-17 3S EN 1600 (E 16 8 2 R) 3S 2926 (17.8.2.AR)											
ASME IX Qualification	QW432 F-No 5,	QW442	4-No 8										
Composition (weld metal wt %)	C Mi min 0.04 0.1 max 0.08 2.1 typ 0.05 1 * Mo controlled BS EN E16 8	n Si 5 5 0.60 0.45 around 1.0 2 R has Mo	S 0.03 0.01 0 - 1.3% 0 1.50 - 2	P 0.03 0.02 unless req 2.50%.	Cr 14.5 16.5 15.5 juested	Ni 7.5 9.5 8.5 I other	Mo* 1.0 2.0 1.2 wise.	Cu 0.75 0.1	FN 1 6 3				
All-weld mechanical	As welded				r	nin	typ	ical		High Tempera	ture		
properties	Tensile strength 0.2% Proof stress			MPa MPa	5	550	> 0	520 410	650°C 310 225	732°C 232 179	816°C 161 126		
	Elongation on 4d			%		35		2					
	Elongation on 5d		%		25	42		28 52	47 59	43 55			
	Impact energy (and	J (mm)			>70(>1.3)								
	Impact energy (and * LE = Charpy la	LE*) Iteral expan	- 50°C ision. mr	J (mm) n (0.38mn	 n = 15	 mils)	> 50	(>0.9)					
Operating parameters	DC +ve or AC (OC	CV: 55V m	in)					Ū					
	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 pieces/carton	12.0 648		13.5 381			13.5 249		18.0 165				
Storage	3 hermetically sea for much longer tha moisture pick-up a For electrodes that Redry 200 – 300° Storage of redried recommended. Red	led ring-pu an a workin nd increase have been C/1-2h to ra electrodes commended	all metal g shift of the risk exposed estore to at 50 – 1 d ambien	tins per ca f 8h. Exce of porosit : as-packed 200°C in h t storage c	arton, v ssive e ty. l condi nolding conditio	with ur exposu- ition. I g oven ons for	nlimited re of elec Maximu or heate	shelf life ctrodes to m 400° (ed quiver tins (usi	e. Direct o humid c C, 3 cycl r: no lim ng plastic	use from tin is conditions will es, 10h total. it, but maximu c lid): < 60% F	satisfactory cause some um 6 weeks RH, > 18°C.		
Fume data	Fume composition	, wt % typi	cal:										
	Fe	Mn	N	li C	Cr	Mo	0	Cu	F	OES (mg/m ³))		
	8	5	0	./	5	0.1	0	.2	16	1			



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 subject to the most demanding vertical and overhead velding applications, including fixed pipework in the ASME 5CA Go positions. Specifications AWS A6.4 BS EN 1600 E10-8-2-15 (17.8.2.B) ASME IX Qualification QW442 A-No 8 Composition (weld metal wt %) \overline{C} Mn Si P Cr Ni Mo* Cu FN Mode out 15% Si S P Cr Ni Mo* Cu FN Mode out 15% Si S P Cr Ni Mo* Cu FN Mode out 15% Si S P Cr Ni Mo* Cu FN Mode out 15% Si S P Cr Ni Mo* Cu FN Mode out 15% Si S P Cr Ni Mo* Cu FN Mode out 10% Si S P Cr Ni Mo* Cu FN Mind out 10 Si S P Cr Ni Mo* <th>E16.8.2-15</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th>Bas</th> <th>c pipe</th> <th>weldi</th> <th>ng eleo</th> <th>ctrode f</th> <th>for 32</th> <th>XXH stair</th> <th>less steel</th>	E16.8.2-15						Bas	c pipe	weldi	ng eleo	ctrode f	for 32	XXH stair	less steel
$ \begin{array}{ $	Product description	MMA all-pos pipewo	electrod sitional e ork in th	le with lectroo e ASN	fully ba de suited 1E 5G/60	sic lime to the i G posit	e-fluorid nost den ions.	e flux on anding v	high pu ertical a	urity 3041 and overh	L core win nead weld	re. E1 ling ap	6.8.2-15 is a plications, in	a basic coated acluding fixed
Specifications AWS A5.4 BS EN 1600 BS 2926 E16-8-2-15 (E1.6.8.2.B) BS 2926 ASME IX Qualification QW432 F-No 5, QW432 F-No 5, widd metal wt %) The field of the fiel		Recov	ery is ab	out 11	5% with	respec	t to core	wire, 659	% with	respect to	o whole e	electro	de.	
ASME IX Qualification QW432 F-No 5, QW442 A-No 8 Composition (weld metal wt %) $\begin{tabular}{ c c c c } \hline C & Mn & Si & S & P & Cr & Ni & Mo' & Cu & FN & min & 0.04 & 0.5 & & & & 1.4.5 & 7.5 & 1.0 & 0.7 & & 1 & min & 0.04 & 0.5 & & & & 1.4.5 & 7.5 & 1.0 & 0.7 & & 1 & min & 0.04 & 0.5 & & & & & 1.4.5 & 7.5 & 1.0 & 0.7 & & 1 & min & 0.05 & 0.05 & 0.05 & 0.05 & 0.05 & 0.05 & & & 1 & min & 0.06 & 3 & + & & 10.5 & 0.05 & 0.05 & 0.05 & & & & 0.05 & 0.$	Specifications	AWS BS EI BS 29	AWS A5.4 E16-8-2-15 BS EN 1600 (E16 8 2 B) BS 2926 (17.8.2.B)											
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	ASME IX Qualification	QW43	QW432 F-No 5, QW442 A-No 8											
(weld metal wt %) min 0.04 0.5 1.5 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 EI 6 8 2 B has Mo 1.50 – 2.50% Mo controlled around 1.0 – 1.3% unless requested otherwise. High Temperature 660°C 732°C 816°C properties As weldet min type 0.35 40 -	Composition		С	Mn	Si	S	Р	Cr	Ni	Mo*	Cu	FN		
$ \frac{\text{max}}{\text{hyp}} = 0.08 - 2.5 - 0.60 - 0.03 - 0.03 - 16.5 - 9.5 - 2.0 - 0.75 - 6 - 19.75 - 10.066 - 3 + 1$	(weld metal wt %)	min	0.04	0.5				14.5	7.5	1.0		1		
$\frac{1}{9} 0.05 1.8 0.5 0.01 0.02 15.5 8.5 1.2 0.06 5$ $\frac{1}{9} 0.05 1.8 0.5 0.01 0.02 15.5 8.5 1.2 0.06 5$ $\frac{1}{9} 0.05 1.8 0.5 0.01 0.02 15.5 8.5 1.2 0.06 5$ $\frac{1}{9} 0.05 1.8 0.5 0.01 0.02 15.5 8.5 1.2 0.06 5$ $\frac{1}{9} 0.05 1.8 0.5 0.01 0.02 15.5 8.5 1.2 0.06 5$ $\frac{1}{9} 0.05 1.8 0.5 0.50 0.01 0.02 15.5 8.5 1.2 0.06 5$ $\frac{1}{9} 0.05 1.8 0.5 0.50 0.01 0.02 15.5 8.5 1.2 0.06 5$ $\frac{1}{9} 0.5 1.5 0.5 0.50 0.5 0.50 0.5 0$		max	0.08	2.5	0.60	0.03	0.03	16.5	9.5	2.0	0.75	6		
* BS EN El 6 2 B has Mo 1.50 - 2.50% Mo controlled around 1.0 - 1.3% unless requested otherwise. All-weld mechanical properties As welded As welded Tensile strength Tensile strength T		тур	0.05	1.8	0.3	0.01	0.02	15.5	8.5	1.2	0.06	3		
All-weld mechanical propertiesAs weldedmintypicalHigh Temperature 60°CFigh Temperature 732°CBife/CTensile strength 0.2% Proof stressMPa> 410216187132Elongation on 4d%3540Elongation on 5d%37273657Reduction of area%35617075Impact energy-100°CJ> 50Operating parametersDC + ve. Unsuitable for AC.a mm2.53.24.0min A6075100max A90120155Packaging dataa mm2.53.24.0length mm300350350kg/carton12.013.513.5pieces/carton684396225StorageStorage of redride electrodes at 50 - 200°C in holding oven of heated quiver: no limit, but maximum 6 weeks recommended. Recommended ambient storage conditions. Maximum 400° C, 3 cycles, 10h total.Storage of redride electrodes at 50 - 200°C in holding oven of heated quiver: no limit, but maximum 6 weeks recommended. Recommended ambient storage conditions. For electrodes to humid conditions will cause some moisture pick-up and increase the risk of porosity. For electrodes to holding oven or heated quiver: no limit, but maximum 6 weeks recommended. Recommended ambient storage condi		* B	S EN E1	682] Jled a	B has Mo	5 1.50 -	- 2.50%	requested	dothers	viso				
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Initial starting Mira 3.00 > 0.20 224 230 103 0.2% Proof stress MPa > 0.10 216 187 132 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 <	properties	Topoil	atronat				MDa	550		> 620	650	4 1	732°C	816°C
Bit of 100 to		0.2% F	e strengt Proof stre	11 11			MPa MPa	550		> 620 > 410	292	+ 5	230 187	105
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Impact energy -100° CJ $ >50$ $ -$ Operating parametersDC + ve. Unsuitable for AC.Impact Packaging Action Acti		Reduc	tion of ar	rea		%			35		61		70	75
Operating parametersDC + ve. Unsuitable for AC.Image: Image: Imag		Impact	tenergy		-10	00°C	J			> 50				
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min A max A60 9075 120100 155Packaging dataø mm length mm kg/carton pieces/carton2.5 3.2 12.03.2 350 350 13.54.0 350 350 255Storage3 hermetically sealed ring-pull metal tins pieces/cartonger 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 dataFe Mn Ni 8 5 0.7 5Mo 0.1 0.2 0.2Cu F OES (mg/m ³) 16		ø mm			2.5		Э	.2		4.0				
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length mm 300 350 350 kg/carton 12.0 13.5 13.5 pieces/carton 684 396 255 Storage3 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 $50 - 200^{\circ}$ 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 dataFume composition, wt % typical: \underline{Fe} MnNiCrMoCuFOES (mg/m ³)	Packaging data	ø mm			2.5		3	.2		4.0				
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Storage3 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 dataFume composition, wt % typical: \underline{Fe} MnNiCrMoCuFOES (mg/m ³)850.750.10.2161		pieces	/carton		684	684 396								
Fume data Fume composition, wt % typical: Fe Mn Ni Cr Mo Cu F OES (mg/m³) 8 5 0.7 5 0.1 0.2 16 1	Storage	3 hern for mu moistu For ele Redry Storag recom	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 meaned.											
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				8	5		0.7	5	0.1	0.2	2 1	16	1	



ER16.8.2						S	olid w	ire TI	G and	SA	N for 3X	XH stainl	ess steel
Product description	Solid v	Solid wire for TIG welding and sub-arc welding of 300H stainless steel.											
Specifications	AWS A BS EN BS EN	A5.9 I ISO 14 I ISO 14											
ASME IX Qualification	QW43	QW432 F-No 6, QW442 A-No 8											
Composition (wire wt %)	min max typ * Mo Typica	C 0.04 0.10 0.06 0.06 1.0 - 1.3 1 ferrite le	Mn 1.0 2.0 1.4 5% on 1 evel 1-6	Si 0.3 0.6 0.4 request 6FN.	S 0.02 0.01	P 0.03 0.01	Cr 14.5 16.5 15.5	Ni 7.5 9.5 8.5	Mo* 1.0 2.0 1.3	Cu 0.3 0.1			
All-weld mechanical properties	As weld Tensile 0.2% P Elonga Elonga Reduct Impact	ded strength roof stres tion on 4d tion on 5d ion of are energy –	s I I a 196°C			MPa MPa % % % J	typic TIG 620 450 35 		al SAW 630 360 29 29 29 30 30		High 650°C 315 221 31 67 	Temperature 732°C 241 178 36 69 	(TIG) <u>816°C</u> <u>173</u> <u>147</u> <u></u> <u>42</u> <u>65</u> <u></u>
Typical operating parameters	Shieldi Diamet Curren Voltage	ng er t		T Arg 2 10 12	IG gon .4 0A 2V	SAW SS300 or SSB flux 2.4 350A, DC+ 30V			X				
Packaging data	ø mm 1.6 2.4			T 2.5kg 2.5kg	IG g tube g tube		SAW 25kg sp	ool					
Fume data	Fume of	compositi	on (wt Fe 40	%) (TI Mn 10	IG & SA C	W fume cr ³	negligib Ni 7	ole): Mo 0.5	C < (u).5	OES (m 4.2	g/m³)	



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 BS EI	AWS A5.22None applicableBS EN ISO 17633-B(nearest TS16-8-2-FM1)												
ASME IX Qualification	QW432 F-No 6, QW442 A-No 8													
Composition		С	Mn	Si	S	Ρ	Cr	Ni	Мо	Cu	FN			
(weld metal wt %)	min max	0.04	0.5 2.0	 0 70		 0 04	14.5 17.0	7.5 10.0	1.0		1			
	typ	0.08	1.2	0.70	0.03	0.04	16.2	9.2	1.1*	0.1	4			
	* Mo	o contr	olled arc	ound 1.0) – 1.3%	unless rec	uested	otherw	ise.					
All-weld mechanical											High Temperatu	re		
properties	As wel	ded	ath			MD	r	min	typical		650°C	732°C	816°C	
	0.2% F	Proof st	iress			MPa MPa	1 2 1		620 410		290 207	224 180	160	
	Elonga	ation or	n 4d			%	,	35 42						
	Elonga	ation or tion of	n 5d area			%		25	42		30 66	44	39 70	
			area				, I		50		00	00		
All-weld mechanical	As wel	ded	v (and LE	=*)	± 20°C	I (mm	r I	min ty		$\frac{picai}{(1.8)}$				
properties (continued)	impaci	cherg		-)	-130°C	J (mm)) (0.8)				
				-	· 196°C	J (mm)		45	(0.7)				
	* LE	= Cha	rpy latera	al expar	ision, mr	n (0.38mr	n = 15	mils)						
Operating parameters	Shield exceed	l ing ga 1 85%	s: 80% <i>A</i>	Ar-20%0	CO ₂ or 10	00% CO ₂ a	20-25	l/min. F	Proprieta	ry ga	ses may	be used but argo	1 should not	
	Curren	nt: DC	2+ve rang	ges as b	elow for	Ar-20%C	O ₂ . We	lding w	ith 100%	$5CO_2$	require	s approx 3V higl	ier:	
	ømm			am	o-volt ran	ge		typ	ical		5	stickout		
	1.2			120)A-22V t)A-28V t	o 280A-34 o 350A-34	4V 4V	180)A-29V		-	15 – 20mm 15 – 25mm		
	1.0			1 200		0 33011-3-		500				19 – 2511111		
Packaging data	Spools	s vacut	ım-seale	d in bar	rier foil v	with cardb	oard ca	arton: 1	5kg					
	The as	-packe	d shelf li	ife is vi	rtually in	definite.								
	Resista spools	ance to are ret	moistur turned to	e absor polyth	ption is l ene wrap	nigh, but t pers.	o preve	ent any	possibili	ty of	porosit	y it is advised the	it part-used	
	Where	e possił	ole, prefe	erred sto	orage con	ditions ar	e 60%	RH may	kimum, 1	8°C	minimu	m.		
Fume data	Fume	compo	sition (w	/t %):										
			Fe	Mr	n I	Ni	Cr ³	Cr ⁶	Cu		F	OES (mg/m ³)		
			17	11	1	.5	4	4	<1		5	1.2	-	