TECHNICAL GUIDE

WELDING

INTRODUCING OUR NEW PRODUCT NOMENCLATURE

BISALLOY® has recently introduced a new product nomenclature. The following table details the grade equivalents.

Note: Only the designation has changed – not the product

Previous Name	New Name
BISPLATE® 60	BISALLOY® Structural 60 steel
BISPLATE® 70	BISALLOY® Structural 70 steel
BISPLATE® 80	BISALLOY® Structural 80 steel
BISPLATE® 100	BISALLOY® Structural 100 steel
BISPLATE® 80PV	BISALLOY® Structural 80 Pressure Vessel steel
BISPLATE® 320	BISALLOY® Wear 320 steel
BISPLATE® 400	BISALLOY® Wear 400 steel
BISPLATE® 450	BISALLOY® Wear 450 steel
BISPLATE® 500	BISALLOY® Wear 500 steel
BISPLATE® 600	BISALLOY® Wear 600 steel
BISPLATE® HIA - Class 2	BISALLOY® Armour RHA300 steel
BISPLATE® HIA - Class 1	BISALLOY® Armour RHA360 steel
BISPLATE® HTA	BISALLOY® Armour HTA400 steel
BISPLATE® UHT	BISALLOY® Armour UHT440 steel
BISPLATE® HHA	BISALLOY® Armour HHA500 steel
BISPLATE® UHH	BISALLOY® Armour UHH600 steel

WELDING OF BISALLOY® QUENCHED AND TEMPERED STEELS

GENERAL INFORMATION

All grades of BISALLOY® steel can be readily welded using any of the conventional low hydrogen welding processes.

Their low carbon content combined with selective addition of alloying elements (Mn, Cr, Mo, B) ensures good weldability, in addition to the advantages of higher strength, hardness and impact toughness.

To ensure ideal welding of BISALLOY® steel, it is necessary to be more mindful of the levels of hydrogen, preheat temperatures and arc energy inputs in order to minimise the hardening and maintain the properties of the weld Heat Affected Zone (HAZ).

HYDROGEN CONTROL

Particular attention must be paid to the control of hydrogen content to minimise the risk of weld and HAZ cracking. Weld hydrogen content is minimised by careful attention to the cleanliness and dryness of the joint preparation and the use of hydrogen controlled welding consumables. Recommendations on the correct storage and handling of consumables may be obtained from welding consumable manufacturers, for instance the use of "Hot Boxes" for storage and reconditioning are required when using manual metal arc welding electrodes . Refer WTIA Tech Note 3 for further guidance.

HEAT AFFECTED ZONE PROPERTY CONTROL

The HAZ, a region directly adjacent to the weld, experiences a thermal gradient ranging from unaffected parent plate to near melting at the fusion boundary.

The properties of this HAZ are determined by the steel composition as well as the cooling rate.

Table 1:

BISALLOY® steel grade	PLATE THICKNESS (mm)	CARBON EQUIVALENT (IIW) TYPICAL	CET TYPICAL AVERAGE
60, 70, 80, 100, 320, 400	5 - <8	0.40	0.29
60, 70, 80, 100, 320, 400	8 - <30	0.44	0.26
60, 70, 80, 320, 400	≥30 - 80	0.54	0.32
60, 70, 80, 320, 400	81 - 100	0.58	0.34
450	6 - 20 25 - 50 60 - 100	0.46 0.58 0.62	0.30 0.36 0.42
500	8 - 100	0.62	0.42
600	12 - 50	0.75	0.52

STEEL COMPOSITION

BISALLOY® steel grades and chemical compositions may be divided into categories based on Carbon Equivalent and CET as seen in Table 1:

Notes:

1. $$C.E.\ (IIW) = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15}$$

2. $$CET = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40}$$

These categories give an indication of the degree of care required in the proper selection of welding preheat/heat inputs.

COOLING RATE

Limitations on both preheat and heat input are necessary to ensure that the HAZ cools at an appropriate rate and that the correct hardness and microstructure are achieved. Too slow a cooling rate can result in a soft HAZ and thus a loss of tensile and fracture toughness properties. Too rapid a cooling rate produces a hard HAZ which may cause loss of ductility.

Cooling is controlled by a balance between preheat and heat input for a particular plate thickness and joint configuration.

PREHEAT/HEAT INPUT

The preheat/heat input recommendations outlined in tables 2 and 3 will ensure that the cooling rate of the HAZ is satisfactory.

RECOMMENDED PREHEAT/INTERPASS TEMPERATURES (°C) FOR BISALLOY® STEEL

Table 2:

BISALLOY® steel grade	JOINT COMBINED THICKNESS ($t_1 + t_2 + t_3$) (mm)				
	<30	≥30 ≤40	>40 <50	≥50 <100	≥100
Minimum Preheat Temperature °C High Strength Structural Grades					
60 (AS 3597 Grade 500)	Nil*	Nil*	Nil*	75	140
70 (AS 3597 Grade 600)	Nil*	50	50	75	140
80 (AS 3597 Grade 700)	Nil*	50	50	75	140
100 (AS3597 Grade 900)	Nil*	50	50	75	140
Minimum Preheat Temp°C Abrasion Resistant Grades					
Wear 320	Nil*	50	75	125	150
Wear 400	Nil*	50	75	125	150
Wear 450	Nil*	50	100	125***	**
Wear 500	100	150	150	150	**
Wear 600	150	150	150	**	**
Maximum Interpass Temperature °C					
80 - 450 Grades	150	150	175	200	220
500 Grade	150	175	175	200	220
600 Grade	150	175	175	220	220

* Chill must be removed from plates prior to welding.
** Refer to Bisalloy Steels for availability, preheat/interpass requirements.
***A reduced 100°C min preheat can be used for product ≥50 – 60 JCT

Note that under rigid weld joint restraint or high ambient humidity conditions preheating temperature should be increased by 25°C

PERMISSIBLE HEAT INPUT (KJ/mm) FOR BISALLOY® STEEL

Table 3:

Welding Process	MAXIMUM PLATE THICKNESS IN JOINT (mm)			
	≤40	>40 ≤60	>60 ≤100	>100
MMAW	1.25-2.5	1.25-3.5	1.5-4.5	1.5-5.0
GMAW	1.0-2.5	1.0-3.5	1.5-4.5	1.5-5.0
FCAW	0.8-2.5	0.8-3.5	1.5-4.5	1.5-5.0
SAW	1.0-2.5	1.0-3.5	1.5-4.5	1.5-5.0

$$\textbf{Heat Input (kJ/mm)} = \frac{\textbf{Volts} \times \textbf{Amps} \times \textbf{0.06}}{\textbf{Travel Speed (mm/minute)}}$$

Note: For thicknesses up to 12 mm in structural grades, the maximum arc energy may need to be limited to 1.5 KJ/mm maximum in specific applications

WELDING CONSUMABLES

Welding Consumable Selection Guide for BISALLOY® steel (AS/NZS Classifications)

Table 4a:

BISALLOY® steel grade		BISALLOY® Structural 60 steel	BISALLOY® Structural 70 steel	BISALLOY® Structural 80 steel	BISALLOY® Structural 100 steel	BISALLOY® Wear 320, 400, 450, 500 & 600 steel
MMAW Consumables* Warning: Only use Hydrogen Controlled consumables						
Strength Level	Matching	B-E55XX/E62XX+	B-E69XX~	B-E76XX	A-E89°	N.R.
	Lower	B-E49XX	B-E55XX	B-E55XX/E62XX	B-E76XX/E69XX	B-E55XX
	Lower	B-E49XX	B-E49XX	B-E49XX	B-E62XX/E55XX	B-E49XX
Hardness	Matching	N.R.	N.R.	N.R.	N.R.	1430-AX, 1855-AX^
GMAW Consumables**						
Strength Level	Matching	B-G55A/G62A+	B-G69A~	B-G76A	A-G89°	N.R.
	Lower	B-G49A	B-G55A	B-G62A/G69A	B-G76A/G69A	B-G55A
	Lower	B-G49A	B-G49A	B-G55A	B-G62A/G55A	B-G49A
Hardness	Matching	N.R.	N.R.	N.R.	N.R.	1855-BX^
FCAW Consumables***						
Strength Level	Matching	B-T 55X/B-T62X+	B-T69X~	B-T76X	A-T89°	N.R.
	Lower	B-T49X	B-T 62X/55X	B-T62X/69X	B-T76X/69X	B-T55X
	Lower	B-T49X	B-T49X	B-T55X/49X	B-T62X/55X	B-T49X
Hardness	Matching	N.R.	N.R.	N.R.	N.R.	1430-BX, 1855-BX, 1860-BX^
SAW Consumables****						
Strength Level	Matching	B-SU55A/G62+	B-SU69A~	B-SU76A	A-SU89°	N.R.
	Lower	B-SU49A	B-SU49A	B-SU49A	B-SU49A	B-SU49
	Lower	B-SU43A	B-SU43A	B-SU43A	B-SU43A	B-SU43
Hardness	Matching	N.R.	N.R.	N.R.	N.R.	1855-BX^

Table 4a courtesy of WTIA (Tech. Note 15)

Notes:

*	MMAW - AS/NZS 4855 and AS/NZS 4857 consumable classification
**	GMAW - AS/NZS 14341 and AS/NZS 16834 consumable classification
***	FCAW - AS/NZS17632 and AS/NZS18276 consumable classification
****	SAW - AS/NZS 14171 and AS/NZS 26304 consumable classification
X	A Variable - any value allowed by the relevant standard may be acceptable provided that the consumable is hydrogen controlled (ie low hydrogen)
+	E62XX and G62A type consumables overmatch the strength requirements but may be used
~	These Consumables may be difficult to obtain. In some cases E62XX, G62A or B-T 62X consumables may be substituted, otherwise use E76XX, G76A or B-T 76X types
^	AS2576 and WTIA TN 4 Classifications
N.R.	Not Recommended
°	These consumables may be difficult to obtain. They are available in Europe. Otherwise use E76XX, B-G76A, B-T76X, B-SU76 followed by full testing of welds.

WELDING CONSUMABLES

Welding Consumable Selection Guide for BISALLOY® steel (AWS Classifications)

Table 4b:

BISALLOY® steel grade		BISALLOY® Structural 60 steel	BISALLOY® Structural 70 steel	BISALLOY® Structural 80 steel	BISALLOY® Structural 100 steel	BISALLOY® Wear 320, 400, 450, 500 & 600 steel
MMAW Consumables* Warning: Only use Hydrogen Controlled consumables						
Strength Level	Matching	E80XX/E90XX+	E100XX~	E110XX	E120XX°	N.R.
	Lower	E70XX	E80XX	E80XX/E90XX	E110XX/E100XX	E80XX
	Lower	E70XX	E70XX	E70XX	E90XX/E80XX	E70XX
Hardness	Matching	N.R.	N.R.	N.R.	N.R.	1430-AX, 1855-AX^
GMAW Consumables**						
Strength Level	Matching	ER80S-X/ER90S-X+	ER100S-X~	ER110S-X	ER120S-X°	N.R.
	Lower	ER70S-X	ER80S-X	ER90S-X/ER100S-X	ER110S-X/ER105-X	ER80S-X
	Lower	ER70S-X	ER70S-X	ER80S-X	ER100S-X/ER90S-X	ER70S-X
Hardness	Matching	N.R.	N.R.	N.R.	N.R.	1855-BX^
FCAW Consumables***						
Strength Level	Matching	E8XTX-X/E9XTX-X+	E10XTX-X~	E11XTX-X	E12XTX-X°	N.R.
	Lower	E7XTX-X	E9XTX-X	E9XTX-X	E11XTX-X/E10XTX-X	E8XTX-X
	Lower	E7XTX-X	E8XTX-X	E8XTX-X	E9XTX-X/E8XTX-X	E7XTX-X
Hardness	Matching	N.R.	N.R.	N.R.	N.R.	1430-BX, 1855-BX, 1860-BX^
SAW Consumables****						
Strength Level	Matching	F8XX/F9XX+	F10XX~	F11XX	F12XX°	N.R.
	Lower	F7XX	F7XX	F7XX	F7XX	F7XX
	Lower	F6XX	F6XX	F6XX	FGXX	F6XX
Hardness	Matching	N.R.	N.R.	N.R.	N.R.	1855-BX^

Table 4b courtesy of WTIA (Tech. Note 15)

Notes:

*	MMAW – AWS A5.1-2004 and AWS A5.5 consumable classification
**	GMAW – AWS A5.18-2005 and AWS A5.28 consumable classification
***	FCAW – AWS A5.20-2005 and AWS A5.29 consumable classification
****	SAW – AWS A5.17-1997 and AWS A5.23 consumable classification
X	A Variable - any value allowed by the relevant standard may be acceptable provided that the consumable is hydrogen controlled (ie low hydrogen)
+	E90XX, ER90S, E9XTX and F9XX type consumables overmatch the strength requirements but may be used
~	These Consumables may be difficult to obtain. In some cases E90XX, ER90S, E9XTX or F9XX type consumables may be substituted, otherwise use E110XX, ER110S, E11XTX or F11XX types
^	AS2576 WTIA TN 4 Classifications
N.R.	Not Recommended
°	These consumables have slightly lower strength, but can be used subject to full testing of welds. Investigation on fitness for purpose is recommended.

WELDING CONSUMABLES

Welding Consumables suitable for matching strength, lower strength and matching hardness are readily available from a range of consumable manufacturers as per following tables 5 to 8.

Welding Consumables for Manual Metal Arc Welding (MMAW)

Table 5:

Brands		BISALLOY® Structural 60 steel	BISALLOY® Structural 70 steel	BISALLOY® Structural 80 steel	BISALLOY® Structural 100 steel	BISALLOY® Wear 320, 400, 450, 500 & 600 steel
CIGWELD/ STOODY/ ESAB	M.S.	Atom Arc 9018	Atom Arc 9018 (under)Atom Arc T (over)	Atom Arc T	N.A.	N.R.
	L.S.	Ferrocraft 61 OK 48.04/OK 53.16 Spezial	Ferrocraft 61 OK 48.04/OK 53.16 Spezial	Ferrocraft 61 OK 48.04/OK 53.16 Spezial	Atom Arc T Atom Arc 9018 Ferrocraft 61 OK 48.04/OK 53.16 Spezial	Ferrocraft 61 OK 48.04/OK 53.16 Spezial
	M.H.	N.R.	N.R.	N.R.	N.R.	Cobalarc 350, 650
Lincoln	M.S.	Conarc 70-G	Conarc 80+	Conarc 80, Conarc 85+	Conarc 85°	N.R.
	L.S.	Conarc 49C, Easyarc 7018-1	Conarc 49C, Easyarc 7018-1	Conarc 49C, Easyarc 7018-1	Conarc 80 Conarc 49C, Easyarc 7018-1	Conarc 49C, Easyarc 7018-1
	M.H.	N.R.	N.R.	N.R.	N.R.	Wearshield BU30, Wearshield MM
W.I.A	M.S.	N.A.	Weldwell PH118	Weldwell PH118	N.A.	N.R.
	L.S.	Austarc 16TC, 18TC or Austarc 77	Austarc 16TC, 18TC or Austarc 77	Austarc 16TC, 18TC or Austarc 77	Weldwell PH118 Austarc 16TC, 18TC or Austarc 77	Austarc 16TC, 18TC or Austarc 77
	M.H.	N.R.	N.R.	N.R.	N.R.	Abraso Cord 350, 700
Specialised Welding Products (SWP) ^WAG = Welding Alloys Group	M.S.	Metrode E9018-D1	Metrode E10018-D2	Metrode E11018-M	N.A.	N.R.
	L.S.	WAG^ Speedarc 7018-1-E, WAG^ Speedarc 7016-E	WAG^ Speedarc 7018-1-E, WAG^ Speedarc 7016-E	WAG^ Speedarc 7018-1-E, WAG^ Speedarc 7016-E	Metrode E11018-M, Metrode E10018-D2 WAG^, Speedarc 7018-1-E, WAG^ Speedarc 7016-E	WAG^ Speedarc 7018
	M.H.	N.R.	N.R.	N.R.	N.R.	Metrode Methard 350 Metrode Methard 650 WAG^ Hardface 400-E WAG^ Hardface L-E
SMENCO Eutectic Castolin	M.S.	N.A.	N.A.	N.A.	N.A.	N.R.
	L.S.	Eutectrode 66*66	Eutectrode 66*66	Eutectrode 66*66	Eutectrode 66*66	Eutectrode 66*66
	M.H.	N.R.	N.R.	N.R.	N.R.	N.R.
BOC	M.S. L.S. M.H.	N.A. Smootharc 16 and 18 N.R.	N.A. Smootharc 16 and 18 N.R.	N.A. Smootharc 16 and 18 N.R.	N.A. Smootharc 16 and 18 N.R.	N.A. Smootharc 16 and 18 N.R.

M.S. Matching Strength
L.S. Lower Strength
M.H. Matching Hardness
N.R. Not Recommended
N.A. Not Available
\+ Overmatching strength

N.B. Consumables in brackets will match mechanical property requirements in the majority of instances as per manufacturer's recommendations and where the appropriate weld procedure is applied. Weld Qualification procedures should be carried out to establish actual Weld metal properties.

° These consumables have slightly lower strength, but can be used subject to full testing of welds. Investigation on fitness for purpose is recommended.

WELDING CONSUMABLES

Welding Consumables for Gas Metal Arc Welding (GMAW)

Table 6:

Brands		BISALLOY® Structural 60 steel	BISALLOY® Structural 70 steel	BISALLOY® Structural 80 steel	BISALLOY® Structural 100 steel	BISALLOY® Wear 320, 400, 450, 500 & 600 steel
CIGWELD	M.S.	Autocraft MnMo	Autocraft MnMo (Under) Autocraft NiCrMo (Over)	Autocraft NiCrMo	OK Anisto Rod 89	N.R.
	L.S.	Autocraft LW1 or Autocraft LW1-6	Autocraft LW1 or Autocraft LW1-6	Autocraft LW1 or Autocraft LW1-6	Autocraft NiCrMo Autocraft MnMo Autocraft LW1 or Autocraft LW1-6	Autocraft LW1 or Autocraft LW1-6
	M.H.	N.R.	N.R.	N.R.	N.R.	Autocraft HF650
Lincoln	M.S.	LNM Ni1	LNM Ni1 [1]	Superarc LA-100	N.A.	N.R.
	L.S.	UltraMag S4, UltraMag S6**	UltraMag S4, UltraMag S6**	LNM Ni1, UltraMag S4, UltraMag S6**	Superarc LA-100 LNM Ni1 UltraMag S4, UltraMag S6**	UltraMag S4, UltraMag S6**
	M.H.	N.R.	N.R.	N.R.	N.R.	N.R.
W.I.A	M.S.	Austmig ESD2/ CO^2 or Mixed Gas	Austmig $NiCrMo^+$	Austmig NiCrMo	N.A.	N.R.
	L.S.	Austmig ES6/CO^2 or Mixed Gas	Austmig ES6/CO^2 or Mixed Gas	Austmig ES6/CO^2 or Mixed Gas	Austmig NiCrMo Austmig ES6/CO^2 or Mixed Gas	Austmig ES6/CO^2 or Mixed Gas
	M.H.	N.R.	N.R.	N.R.	N.R.	TD600/CO2 or Mixed Gas
Specialised Welding Products (SWP)	M.S.	SWP D2	SWP 110^+	SWP 110	N.A.	N.R.
	L.S.	SWP S6	SWP S6	SWP S6	SWP 110 SWP D2 SWP S6	N.R.
	M.H.	N.R.	N.R.	N.R.	N.R.	SWP HF350 SWP HF600
SMENCO/ Eutectic Castolin	M.S.	AN45252$^+$/ CO^2 or Mixed Gas	AN45252$^+$/ CO^2 or Mixed Gas	AN45252/ CO^2 or Mixed Gas	N.A.	N.R.
	L.S.	DO*65/CO^2 or Mixed Gas	DO*65/CO^2 or Mixed Gas	DO*65/CO^2 or Mixed Gas	AN45252/ CO^2 or Mixed Gas DO*65/CO^2 or Mixed Gas	DO*65/CO^2 or Mixed Gas
Solid Technologies Pty Ltd	M.S.	Solid MIG-Ni1; Solid MIG-Ni25; Solid MIG-90-G	Solid MIG-100-G	Solid MIG-110-G	N.A.	N.A.
	L.S.	Solid MIG-S6	Solid MIG-Ni25, Solid MIG-Ni1, Solid MIG-S6	Solid MIG-100-G, Solid MIG-Ni25, Solid MIG-Ni1, Solid MIG-S6	Solid MIG-110-G Solid MIG-100-G, Solid MIG-Ni25, Solid MIG-Ni1, Solid MIG-S6	Solid MIG-Ni25, Solid MIG-100-G
	M.H.	N.R.	N.R.	N.R.	N.R.	B320: Solid MIG 350-G B400/450: Solid MIG 450-G B500: Solid MIG 500-G B600: Solid MIG 600-G
BOC	M.S. L.S. M.H.	N.A. BOC MS MIG N.R.	N.A. BOC MS MIG N.R.	N.A. BOC MS MIG N.R.	N.A. BOC MS MIG N.R.	N.R. BOC MS MIG N.A.

M.S. Matching Strength
L.S. Lower Strength
M.H. Matching Hardness
N.R. Not Recommended
N.A. Not Available
\+ Overmatching strength
1 Undermatch strength

N.B. Consumables in brackets will match mechanical property requirements in the majority of instances as per manufacturer's recommendations and where the appropriate weld procedure is applied. Weld Qualification procedures should be carried out to establish actual Weld metal properties.

** CO^2 or mixed gas

WELDING CONSUMABLES

Welding Consumables for Flux Cored Arc Welding (FCAW)

Table 7:

Brands		BISALLOY® Structural 60 steel	BISALLOY® Structural 70 steel	BISALLOY® Structural 80 steel	BISALLOY® Structural 100 steel	BISALLOY® Wear 320, 400, 450, 500 & 600 steel
CIGWELD/ STOODY	M.S. Seamless	Verticor 91K2 H4	Verticor 91K2 H4 (Under) Verticor 111K3 H4*** (Over) Tensicor 110TXP H4 (Over) Metalcor 110 H4 (Over)	Verticor 111K3 H4*** Tensicor 110TXP H4 Metalcor 110 H4	N.A.	N.R.
	L.S. Seamless (E6XT-X)	Verticor XP LT H4	Verticor XP LT H4	Verticor XP LT H4	Verticor XP LT H4	Verticor XP LT H4
	L.S. Seamless	Verticor 3XPH4, Verticor 5XP H4, Metalcor 5 H4, Verticor 81Ni1 H4	Verticor 3XPH4, Verticor 5XP H4, Metalcor 5 H4, Verticor 81Ni1 H4	Verticor 3XPH4, Verticor 5XP H4, Metalcor 5 H4, Verticor 81Ni1 H4	Verticor 111K3*** H4 Tensicor 110TXP H4 Metalcor 110 H4 Verticor 3XPH4 Verticor 5XP H4, Metalcor 5 H4, Verticor 81Ni1 H4	Verticor 3XPH4, Verticor 5XP H4, Metalcor 5 H4, Verticor 81Ni1 H4
	L.S. Seamed	Verticor 3XP, Suprecor 5, Metalcor XP, Verticor 81Ni1 81Ni2	Verticor 3XP, Suprecor 5, Metalcor XP, Verticor 81Ni1 81Ni2	Verticor 3XP, Suprecor 5, Metalcor XP, Verticor 81Ni1 81Ni2	Verticor 3XP, Suprecor 5, Metalcor XP, Verticor 81Ni1 81Ni2	Verticor 3XP, Suprecor 5, Metalcor XP, Verticor 81Ni1 81Ni2
	L.S. Self Shielded	Shieldcor 8XP Shieldcor 8Ni	Shieldcor 8XP Shieldcor 8Ni	Shieldcor 8XP Shieldcor 8Ni	Shieldcor 8XP Shieldcor 8Ni	Shieldcor 8XP Shieldcor 8Ni
	M.H.	N.R.	N.R.	N.R.	N.R.	Stoody Super Build-Up-G, Stoody 965-G, Stoody 965 AP-G
Lincoln	M.S.	Outershield 91Ni1-HSR / Steelcore 80MC-D2	Outershield 91Ni1-HSR / Steelcore 80MC-D2 [1]	Outershield 690-H	Ultracore 121K3M-H°	N.R.
	L.S.	Outershield 81Ni1-H, MC-715Ni1, 71E-H Innershield NR-555, NR-232, NR-233	Outershield 81Ni1-H, MC-715Ni1 Innershield NR-555, NR-232, NR-233	Outershield 81Ni1-H, MC-715Ni1 Innershield NR-555, NR-232, NR-233	Outershield 690-H Outershield 81Ni1-H, MC-715Ni1 Innershield NR-555, NR-232, NR-233	Outershield 81Ni1-H, 71-EH, 71-CX Innershield NR-555, NR-232, NR-233
	M.H.	N.R.	N.R.	N.R.	N.R.	Lincore 33, Lincore 50, Lincore 55-G
W.I.A/ Hobart Brothers	M.S.	Austfil 81N1M/ Mixed Gas, TM-71 HYD/CO2, TM-811N2/CO2 or Mixed Gas	FabCO 110K3M/ Mixed Gas	FabCO 110K3M/ Mixed Gas	N.A.	N.R.
	L.S.	Austfil 71T-1/CO2, Austfil 70C-6M, 71T-1M/Mixed Gas, Formula XL-525/Mixed Gas, Fabshield 4, XLR-8	TM-991K2/CO2 or Mixed Gas, Austfil 81N1M/Mixed Gas, TM-71 HYD/ CO2, TM-811N2/ CO2 or Mixed Gas, Metalloy 80N1/ Mixed Gas	TM-991K2/CO2 or Mixed Gas, Austfil 81N1M/Mixed Gas, TM-71 HYD/CO2, TM-811N2/CO2 or Mixed Gas, Metalloy 80N1/Mixed Gas	FabCO 110K3M/ Mixed Gas TM-991K2/CO2 or Mixed Gas, Austfil 81N1M/Mixed Gas, TM-71 HYD/ CO2, TM-811N2/ CO2 or Mixed Gas, Metalloy 80N1/ Mixed Gas	Austfil 70C-6M, 71T-1M, 81N1M/ Mixed Gas, Austfil 71T-1, TM-71, HYD/ CO2 TM-811N2/ CO2 or Mixed Gas, Metalloy 80N1/Mixed Gas, Formula XL-525/Mixed Gas, Fabshield 4, XLR-8
	M.H.	N.R.	N.R.	N.R.	N.R.	Vertiwear 600/ Mixed Gas

Table 7 Continued:

Brands		BISALLOY® Structural 60 steel	BISALLOY® Structural 70 steel	BISALLOY® Structural 80 steel	BISALLOY® Structural 100 steel	BISALLOY® Wear 320, 400, 450, 500 & 600 steel
SMENCO/ Eutectic Castolin	M.S.	N.A.	N.A.	N.A.	N.A.	N.R.
	L.S.	Teromatec OA2020	Teromatec OA2020	Teromatec OA2020	Teromatec OA2020	Teromatec OA2020
	M.H.	N.R.	N.R.	N.R.	N.R.	N.A.
Specialised Welding Products (SWP) ^WAG = Welding Alloys Group	M.S.	WAG^ Robofil R Ni1+, WAG^ Robofil M Ni1, WAG^ Robofil B Ni1	WAG^ Robofil R 690+, WAG^ Robofil M 700, WAG^ Robofil B 700	WAG^ Robofil R690+, WAG^ Robofil M 700, WAG^ Robofil B 700	N.A.	N.R.
	L.S.	WAG^ Robofil R 71+, WAG^ Robofil M 71, WAG^ Robofil B 71	WAG^ Robofil R 71+, WAG^ Robofil M 71, WAG^ Robofil B 71	WAG^ Robofil R 71+, WAG^ Robofil M 71, WAG^ Robofil B 71	WAG^ Robofil R690+, WAG^ Robofil M 700, WAG^ Robofil B 700 WAG^ Robofil R 71+, WAG^ Robofil M 71, WAG^ Robofil B 71	WAG^ Robofil R 71+
Solid Technologies Pty Ltd	M.S.	Solid FC 81Ni1-H2; Solid FC 81Ni2-H2; Solid FC-91K2-H2 (Seamless);	Solid FC-100-H2 (Seamless)	Solid FC-110-H2 (Seamless)	N.A.	N.R.
	L.S.	Solid FC-715-H2 (seamless); Solid FC-71 (seamed)	Solid FC-715-H2, Solid FC-81Ni2-H2, Solid FC-91K2-H2 (Seamless)	Solid FC-715-H2, Solid FC-81Ni1-H2, Solid FC-81Ni2-H2, Solid FC-100-H2 (Seamless)	Solid FC-100-H2 (Seamless) Solid FC-110-H2 (Seamless) Solid FC-715-H2, Solid FC-81Ni1-H2, Solid FC-81Ni2-H2, Solid FC-100-H2 (Seamless)	Solid FC-715-H2 (seamless); Solid FC-71 (seamed)
	M.H.	N.R.	N.R.	N.R.	N.R.	B320: Solid FC MM350-H2 (Seamless), B400/450: Solid FC MM450-H2-O/G (Seamless), B500: Solid FC MA50-H2-O/G (Seamless) B600: Solid FC MA60-H2-O/G (Seamless)
BOC	M.S.	SmoothCor 81Ni1H4	SmoothCor 115+	SmoothCor 115	N.A.	N.R.
	L.S.	SmoothCor 711	SmoothCor 81Ni1H4 SmoothCor 711	SmoothCor 81Ni1H4 SmoothCor 711	SmoothCor 115 SmoothCor 81Ni1H4 SmoothCor 711	SmoothCor 81Ni1H4 SmoothCor 811K2

M.S.	Matching Strength	N.B.	Consumables in brackets will match mechanical property requirements in the majority of instances as per manufacturer's recommendations and where the appropriate weld procedure is applied. Weld Qualification procedures should be carried out to establish actual Weld metal properties.
L.S.	Lower Strength		
M.H.	Matching Hardness		
N.R.	Not Recommended		
N.A.	Not Available	**	CO^2 or mixed gas
+	Overmatching strength	***	Verticor 111K3 H4 not recommended for plate thickness over 20 mm
1	Undermatch strength	°	These consumables have slightly lower strength, but can be used subject to full testing of welds. Investigation on fitness for purpose is recommended.

WELDING CONSUMABLES

Welding Consumables for Submerged Arc Welding (SAW)

Table 8:

Brands		BISALLOY® Structural 60 steel	BISALLOY® Structural 70 steel	BISALLOY® Structural 80 steel	BISALLOY® Structural 100 steel	BISALLOY® Wear 320, 400, 450, 500 & 600 steel
CIGWELD/ STOODY/ ESAB	M.S.	N.A.	Autocraft NiCrMo (Over)/ Satinarc 4	Autocraft NiCrMo/ Satinarc 4	N.A.	N.R.
	L.S.	Autocraft SA1 SA2/ Satinarc 4 or 15	Autocraft SA1 SA2/ Satinarc 4 or 15	Autocraft SA1 SA2/ Satinarc 4 or 15	Autocraft NiCrMo/ Satinarc 4 Autocraft SA1 SA2/ Satinarc 4 or 15	Autocraft SA1 SA2/ Satinarc 4 or 15
	M.H.	N.R.	N.R.	N.R.	N.R.	Stoody 105 or 107/ Stoody S Flux
Lincoln	M.S.	Lincolnweld LA-90 wire with 880, 888, 8500	Lincolnweld LAC-690 / 888+	Lincolnweld LAC-690 / 888	Lincolnweld MIL800-HPNi°	N.R.
	L.S.	Lincolnweld L-61 or L-S3 with 860, 880M, 888	Lincolnweld L-61 or L-S3 with 860, 880M, 888	Lincolnweld L-61 or L-S3 with 860, 880M, 888	Lincolnweld LAC-690 / 888 Lincolnweld L-61 or L-S3 with 860, 880M, 888	Lincolnweld L-61 or L-S3 with 860, 880M, 888
	M.H.	N.R.	N.R.	N.R.	N.R.	Lincore 30-S, Lincore 42-S, Lincore 50 / 880 or 802 flux
Specialised Welding Products (SWP) ^WAG = Welding Alloys Group	M.S.	S3Ni1Mo Wire/ BF10 Flux	S3Ni1Mo Wire/ BF10 Flux	S3Ni2.5CrMo Wire/ BF10 Flux	N.A.	N.R.
	L.S.	SWP EM12K Wire/ WAG^ WAF325 Flux	SWP EM12K Wire/ WAG^ WAF325 Flux	SWP EM12K Wire/ WAG^ WAF325 Flux	S3Ni1Mo Wire/ BF10 Flux S3Ni2.5CrMo Wire/ BF10 Flux SWP EM12K Wire/ WAG^ WAF325 Flux	SWP EM12K Wire/ WAG^ WAF325 Flux
	M.H.	N.R.	N.R.	N.R.	N.R.	WAG^ Hardface T-S Wire/ WAG^, WAF325 Flux, WAG^ Hardface P-S Wire/ WAG^, WAF325 Flux, WAG^ Hardface L-S/WAG^ WAF325 Flux
Solid Technologies Pty Ltd	M.S.	Solid SAW-90/ JSMF-8	Solid SAW-100/ JSMG-8	Solid SAW-110/ JSMF-8	N.A.	N.R.
	L.S.	Solid SAW-16/ JSMF-8	Solid SAW-16/ JSMF-8, Solid SAW-90/JSMF-8	Solid SAW-16/JSMF-8, Solid SAW-90/ JSMF-8, Solid SAW-100/JSMF-8	Solid SAW-110/ JSMF-8 Solid SAW-16/ JSMF-8, Solid SAW-90/JSMF-8, Solid SAW-100/ JSMF-8	Solid SAW-16/ JSMF-8, Solid SAW-90/JSMF-8
	M.H.	N.R.	N.R.	N.R.	N.R.	B320: Solid SAW 450-H2/HCF82 (Seamless), B400/450: Solid SAW 450-H2/ HCF82 (Seamless), B500: Solid SAW 50-H2/HCF82 (Seamless), B600: Solid SAW 60-H2/HCF82 (Seamless)

M.S. Matching Strength
L.S. Lower Strength
M.H. Matching Hardness
N.R. Not Recommended
N.A. Not Available
\+ Overmatching strength
1 Undermatch strength

N.B. Consumables in brackets will match mechanical property requirements in the majority of instances as per manufacturer's recommendations and where the appropriate weld procedure is applied. Weld Qualification procedures should be carried out to establish actual Weld metal properties.

° These consumables have slightly lower strength, but can be used subject to full testing of welds. Investigation on fitness for purpose is recommended.

AUSTENITIC STAINLESS STEEL CONSUMABLE

Due to the fact that the hydrogen diffusion rate is very low in austenitic steel than in ferritic steel, austenitic steel consumable has advantages over ferritic consumable when it is used for welding Q&T steel, especially for welding those high hardness, high carbon equivalent Q&T steels such as BISALLOY® Wear 500 & 600 steel.

For welding BISALLOY® Structural 80 steel and even BISALLOY® Wear 450 steel, no preheat is required if austenitic stainless steel consumable is used. For welding BISALLOY® Wear 600 steel grade, preheat temperature is much lower than the temperature required for ferritic consumables.

The following austenitic consumables are recommended for welding BISALLOY® grades.

Table 9:

Welding Method	AS classification	AWS classification
MMAW	ES308L, ES309L, ES316L	E308L, E309L, E316L
GMAW	SS308L, SS309L, SS316L	ER308L, ER309L, ER316L
FCAW	TS308LT, TS309LT, TS316LT	E308LT, E309LT, E316LT
SAW	ER308L, ER309L, ER316L	ER308L, ER309L, ER316L

The most common austenitic stainless steel consumable is ER308L which has a typical yield strength of 500MPa and a tensile strength of 630MPa with good ductility.

E307 has been also used successfully to fabricate quenched and tempered steel plate.

WELDING PROCEDURES

The specific effects of welding on weld joint properties in any practical situation will depend on many factors including the choice of consumables, total weld heat input, level of restraint, weld geometry and proximity of adjacent welds.

Guidance on weld procedures for specific applications may be sought from Bisalloy Steels technical staff or consumable suppliers.

ARC STRIKES

Arc strikes outside the welded zone can result in cracks, particularly on dynamically loaded structures. All strikes should be made within the joint preparation.

TACK WELDING

Tack welds require special care due to the abnormal stresses and high cooling rates experienced by the adjacent material.

The same preheat, heat input requirements should be employed and lower strength welding consumables considered.

FILLET WELDING

Good fillet welding techniques are important in welding Q&T steels because often very high stresses are applied in service. It is essential that welds have good root penetration, be smooth, correctly contoured and well flared into the legs of the joined pieces. Lower strength consumables are suggested when design permits.

WTIA Tech. Note 15 provides guidance on correct procedures for fillet welding.

REPAIR WORK

It is good practice to weld repair with lower strength consumables (low hydrogen type), since plate materials which have been highly stressed in service may tend to warp or distort slightly during welding and improved ductility may be required. In some situations, such as joints under restraint, joints subjected to impact/fatigue stresses, etc, special welding consumables may be necessary.

WELDING STRESSES

It should be emphasised that the recommended values of preheat and heat input are based on low to moderate levels of restraint. For conditions of high restraint it is important to minimise the degree to which free contraction is hampered and it may be necessary to use higher preheats. Proper welding sequence and small joint configurations would be considered important in high restraint situations and it is advisable to establish welding parameters with simulated full scale weld tests.

Care should also be exercised at the assembly stage to avoid offset and angular distortion at the plate edge, undercutting and bad appearance.

STRESS RELIEF

Stress relief may be conducted on BISALLOY® 60, 70, 80 and 80PV grades but is advisable only if absolutely necessary (eg. to comply with AS1210 in the case of road tankers). Stress relief is recommended within a 540 - 570°C temperature range for one hour per 25 mm of thickness. Thermal cycling is generally performed in accordance with AS1210 Code requirements for Q&T steels. The toes of weld beads should be dressed by grinding prior to any stress relief treatment in order to prevent stress relief cracking.

When stress relieving Bisalloy Steels ≤25 mm (typically 0.40 CE (IIW)) and matching strength across the weld is a requirement, it is recommended to weld with minimum permissible preheat/ interpass temperatures (Table 2) and heat input (Table 3) conditions to minimise the degree of softening or any loss of strength which may occur in the HAZ.

Consult Bisalloy Steels for further information if required.

POST-WELD HEATING

Post-weld heating at 200 - 250°C may be conducted as an effective hydrogen dissolution treatment particularly when consumables other than H5 or H10 are used.

HELPFUL HINTS

General rules for good quality welding of BISALLOY® steel:

- Use a low hydrogen process, eg. GMAW (MIG), FCAW (gas shielded)
- Adhere to the correct rules for storage and handling of low hydrogen consumables per the manufacturers' recommendations, or WTIA Tech. Note 3
- Clean joint area of all contaminants prior to welding
- Remove 1 - 2 mm from flame cut or gouged surfaces by grinding
- Select the recommended preheat, interpass and heat input parameters
- Position for downhand welding where possible
- Always use stringer beads, never wide weaves
- Use lower strength consumables on root runs and fillet welds (when the design permits)
- Use temper beads when necessary
- Arc strikes to be made in the joint preparation
- Particular attention should be given to tack welds re preheat, heat input and joint cleanliness requirements
- Grinding toes of fillet welds is particularly important in fatigue applications

REFERENCES / FURTHER READING

- AS1554 Part 4 Welding of Q&T Steels
- AS1554 Part 5 Welding of Steel Structures Subject to High Levels of Fatigue Loading
- WTIA Technical Note 15
- WTIA Technical Note 3
- WTIA Technical Note 1

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