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Prediction of Weld Metal Strength
(Report III)

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Abstract

The Sub-Commission IX-J made a database of weld metal properties and chemical compositions. The database includes 101 sets of SAW, 174 sets of GMAW, and 49 sets of SMAW. Based on this database and a weld metal database from a website of University of Cambridge, a formula predicting weld metal tensile strengths was proposed. This formula was verified to estimate the tensile strength of SAW, GMAW, and SMAW weld metals from a mild steel grade to 980MPa grade under welding conditions of arc energy from 1.0 to 14kJ/mm and inter-pass temperature from 20 to 450^{o}C with satisfactory accuracy.

1. Introduction

A weld metal database is being built in the IIW Sub-Commission IX-J (Metallurgical Behavior of Fused Metal). This database includes 49 sets of SMAW, 174 sets of GMAW and 101 sets of SAW[1]. There is another database that is available in a website provided by Prof. B. H. D. Bhadeshia, University of Cambridge[2]. There are 1,254 sets of SMAW, 281 sets of SAW and 85sets of FCAW weld metals in the U. Cambridge database, Both database provide us welding condition, chemical composition, hardness, yield strength, tensile strength, elongation, and FATT. The U. Cambridge database provides a volume fraction of phases of martensite, upper-bainite, primary ferrite, secondary ferrite, and accicular ferrite for a part of weld metals.

It is not easy task to predict weld metal properties. Recently, this predictive work is vigorously carried out by means of a neural network analysis[3,4]. A Baysian neural network analysis among analyses enables to provide an estimation error range[3,4]. However, the neural network analysis does not indicate a physical meaning of their prediction, such as effects of alloy elements on hardnenablity or precipitation hardening.

Four years work in the IIW SCIX-J has suggested that a predictive formula for the hardness and tensile strength of weld metals can be built but not for the yield strength and toughness. This report describes a predictive equation formulated based upon both the IIW SCIX-J database and the U. Cambridge database.

2. Database

Tables 1 to 5 show the databases used in this study. Although the mother databases include Charpy properties, the Tables show only tensile test results. Table 1 shows an IIW SCIX-J database of SAW weld metals[5]. Table 2 is a U. Cambridge database of SAW weld metals of as-welded and dehydrogen-heat-treated at around 200°C, while the data of weld metals subjected to PWHT being excluded.

Table 3 is a database of solid wire GMAW weld metals. The data denoted by NSW come from the catalogue data by Nippon Steel Welding Materials

Co[6], and the data from No.22 to No.29 are from Nippon Steel Labs[7]. The others are from a report of the investigation of the effects of the arc energy and inter-pass temperature on mechanical properties of weld metals for building construction[8]. Among these, the data from No.31 to 86 are for JIS (Japan Industrial Standard) Z YGW12 of a TS490MPa grade, those from No.87 to No.126 are for JIS Z YGW17 of a TS540MPa, and those from No127 to No.174 are for JIS Z YGW21 of a TS580MPa grade.

Table 4 is a database of SMAW weld metals, including those from a NSW catalogue[6] and those from Kobelco report[9]. Catalogues of welding materials do not, in general, show arc energy values but those shown in Table 4 are by private communication[10]. Table 5 is a U. Cambridge database of SMAW as welded and as dehydrogen heat-treated. The data from No.1085 to No.1100 in Table 5 is given as as-welded but the original paper[11] of the U. Cambridge database described the tensile tests results were from weld metals dehydrogen heat-treated at 250°C for 14hrs while Charpy test results being from those as-welded. Therefore, these data are considered for weld metals dehydrogen heat-treated in Table 5.

The welding cooling times from 800°C to 500°C, $t_{8/5}$(s) were calculated in a equation shown in Appendix, where the arc efficiency, η is 1.0 for SAW and 0.8 for SMAW and GMAW.

3. Predictive formula

It is known that a preferable correlation between the tensile strength and hardness holds. The following is one example[5]:

$$TS(MPa) = 3.0\,Hv + 22.3 \qquad (1)$$

In this study, a following predictive formula for base metal HAZ hardness[12] was employed for predicting weld metal hardness:

$$H_V = \frac{H_M + H_B}{2} - \frac{H_M - H_B}{2.2} arctan(x) \qquad (2)$$

$$x = 4\frac{log(t_{8/5} / t_M)}{log(t_B / t_M)} - 2 \qquad (3)$$

where, H_M: hardness of 100% martensite phase,

H_B: hardness of 0% martensite phase,

$t_{8/5}$: welding cooling times from 800°C to 500°C (s),

t_M: longest cooling time to get 100% martensite phase (s),

t_B: shortest cooling time to get 0% martensite phase (s).

The martensite hardness is determined solely by the carbon content and the following relation holds[12] in HAZ. It is assumed that the same relation holds in weld metals.

$$H_M = 884C + 294 \quad (4)$$

t_M is considered as an index for hardenability. In this study, t_M was give by Eq. (5) as a function of carbon equivalency of Eq. (6) which was obtained by a best fitting manner against the present database:

$$t_M = exp(10.6CE_I - 4.8) \quad (5)$$

$$CE_I = C + \frac{Si}{24} + \frac{Mn}{2.88(1+Mn)} + \frac{Ni}{30} + \frac{Cr}{16} + \frac{Mo}{8} \quad (6)$$

In Eq.(6), the effect of Mn is non-linear as indicated as Mn/(1+Mn). This means that activity of Mn decreases as a Mn content increases. Ni and Cr are considered to show the same tendency, but their effects were considered in this study to be linear for Ni less than 3.5% and Cr less than 1.25% as indicated by the present database. Cu was considered to not contribute to hardenablity but only to precipitation hardening. Thus, Cu was ignored in Eq.(6). The hardenablity effects of Mn, Cu, Ni, Cr, and Mo will be discussed later.

H_B is the hardness of 0% martensite phase plus that due to precipitation hardening which arises only when $t_{8/5}$ becomes long. That was given by Eq.(7) as a function of a carbon equivalency of Eq.(8) in which the effect of precipitation hardening elements of Cu, Mo, V, Nb, Ti are relatively high. The non-linear effect of Nb was considered as 2.2Nb/(1+5Nb) in Eq.(8). These effect will be discussed later.

$$H_B = 145 + 130\tanh(2.65CE_{II} - 0.69) \quad (7)$$

$$CE_{II} = C + \frac{Si}{24} + \frac{Mn}{2.16(1+Mn)} + \frac{Cu}{10} + \frac{Ni}{45} + \frac{Cr}{10} + \frac{Mo}{5} + 2V + \frac{2.2Nb}{(1+5Nb)} + \frac{Ti}{10} \quad (8)$$

t_B is the critical cooling time when martensite phases diminish and considered as an index of easiness of bainite formation. That was given by Eq.(9) as a function of carbon equivalency of Eq.(1):

$$t_B = exp(6.2CE_{III} + 0.74) \quad (9)$$

$$CE_{III} = C + \frac{Mn}{1.68(1+Mn)} + \frac{Ni}{15} + \frac{Cr}{10} + \frac{Mo}{8} \quad (10)$$

As described above, the weld metal tensile strength can be predicted through Eq.(1) from the hardness estimated through Eq. (2) as a function

of t8/5 (Appendix) and chemical compositions via Eqs. (3) to (10). The applicable range in the alloy element concentration is C<0.10%•Si<1.15%•Mn<2.0%•Cu<1.5%•Ni<3.5%•Cr<2.25%•Mo<1.2%•Nb<0.10%•V<0.10%, and that in the welding condition is 5s<$t_{8/5}$<160s.

4. Accuracy of prediction

$t_{8/5}$ must be estimated from the welding conditions (Appendix) before predicting the tensile strength. Accuracy of this prediction totally depends on that of $t_{8/5}$ estimation and the precision of $t_{8/5}$ estimation is described in Appendix. The plate thickness is not mentioned in the U. Cambridge database and 20mm thickness was considered for the whole data of U. Cambridge.

Figs. 1 to 5 show hardness estimated by the present predictive formula and that from the present database. The prediction in this study is considered satisfactory except for the data of higher strength weld metals of SAW of U. Cambridge database shown in Fig.2 and those of de-hydrogen heat-treated SMAW of U. Cambridge database shown in Fig.5. The SMAW weld metals shown in Fig. 5 were heat-treated at 200°C or 250°C for 10hrs or more for removing hydrogen from tensile test pieces. The duration of heat treatment seems too long for de-hydrogen. It is thus presumed that the measured values are considerably less than those predicted as shown in Fig.5.

In the database of solid wire GMAW for building constructions, welding conditions were varied considerably between 1.0kJ/mm and 4.0kJ/mm in arc energy (AE) and up to 450°C in inter-pass temperature (IP)[8]. The resultant $t_{8/5}$ was between 10s and 160s. Figs. 6, 7 and 8 shows the results of the prediction for GMAW weld metals, where solid lines were given only for the measured data. Accuracy of the prediction was between -10MPa and +50MPa, i.e., somewhat higher values were predicted under the wide range of welding conditions.

5. Discussion

The U. Cambridge database of SMAW include the effect of concentration of Mn, Cu, Ni, Cr, Mo, Nb and V on mechanical properties while keeping the welding condition and the concentration of other elements unchanged, although these data are available only for the weld metals de-hydrogen

treated with rather longer duration. Using these data this study investigated the validity of the significance of each element on hardenability and precipitation hardening, i.e., coefficients in carbon equivalent equations of Eqs.(6), (8), and (10).

Fig.9 shows the effect of Mn on both the predicted tensile strength and that (connected by solid lines or dotted lines) of the database. The database values increases in almost a linear manner while the predicted ones are lower in the low Mn region and higher in the high Mn region. This is because the Mn effect was considered as Mn/(1+Mn) in the carbon equivalents of Eqs. (6), (8), and (10). As far as the U. Cambridge SMAW database is concerned, the effect of Mn on weld metal strength seems to be linear.

However, accuracy of the prediction was considerably degraded for the SAW data, GMAW data, and SMAW data other than the U. Cambridge SMAW data if the Mn effect was considered linear. For example, the prediction and measurement was compared between when the Mn effect is linear and that is non-linear of Mn/(1+Mn) as shown in Fig.10. In the case of the linear effect, significantly lower values in the prediction resulted and in the non-linear case, preferable prediction resulted. In this study, therefore, the effect of Mn on weld metal tensile strength was considered non-linear.

Fig.10 shows the effect of Cu, which was considered in the present prediction to influence only precipitation hardening but not hardenability. Although higher values are predicted against weld metals with high Mn (long-time de-hydrogen treated), gradients of the tensile strength against the Cu contents preferably coincides between prediction and the database. It is reported that the Cu effect on the tensile strength emerges only when Cu is over 0.5%[13]. In fact, little effects of Cu not higher than 0.5% are seen in Fig.10.

Fig.11 shows the effect of Ni. Higher values are also predicted against weld metals with high Mn. It seems that the predicted effect of Ni is strong against the U. Cambridge data to some extent. However, the prediction against the other database was improved with the coefficients given in Eqs. (6), (8) and (10).

Fig.12 shows the effect of Cr. Although the higher prediction resulted against high Mn weld metals long-time de-hydrogen treated, the

gradients of the tensile strengths predicted vs. the Cr content satisfactorily coincided with those of the database.

Fig.13 shows the effect of V. In the prediction, V was considered to contribute only to precipitation hardening like Cu. Although the higher prediction resulted again against high Mn weld metals, the gradient of the tensile strengths vs. the V content satisfactorily coincided with those of the database.

Fig.14 shows the effect of Nb, which was considered to contribute only to precipitation hardening like Cu and V. In the U. Cambridge data, the effect of Nb on the tensile strength decreases with increasing Nb content. Therefore, the Nb terms in Eq.(8) was considered as Nb/(1+5Nb). As a result, the gradients of the tensile strengths predicted vs. the Nb content satisfactorily coincided with those of the database although the higher values were predicted against the high Mn weld metals.

6. Conclusion

The effect of alloying elements on hardness, hardenablity, and precipitation hardening of weld metals was investigated using the IIW IX-J database and the U. Cambridge database. Through this investigation, a formula predicting the hardness and tensile strength of a weld metal was proposed. This formula was verified to satisfactorily predict the hardness and tensile strength of weld metals from a mild steel grade to a TS1,000MPa high strength grade under the welding condition from 1.0kJ/mm to 14.0kJ/mm in arc energy and up to 450°C in inter-pass temperature.

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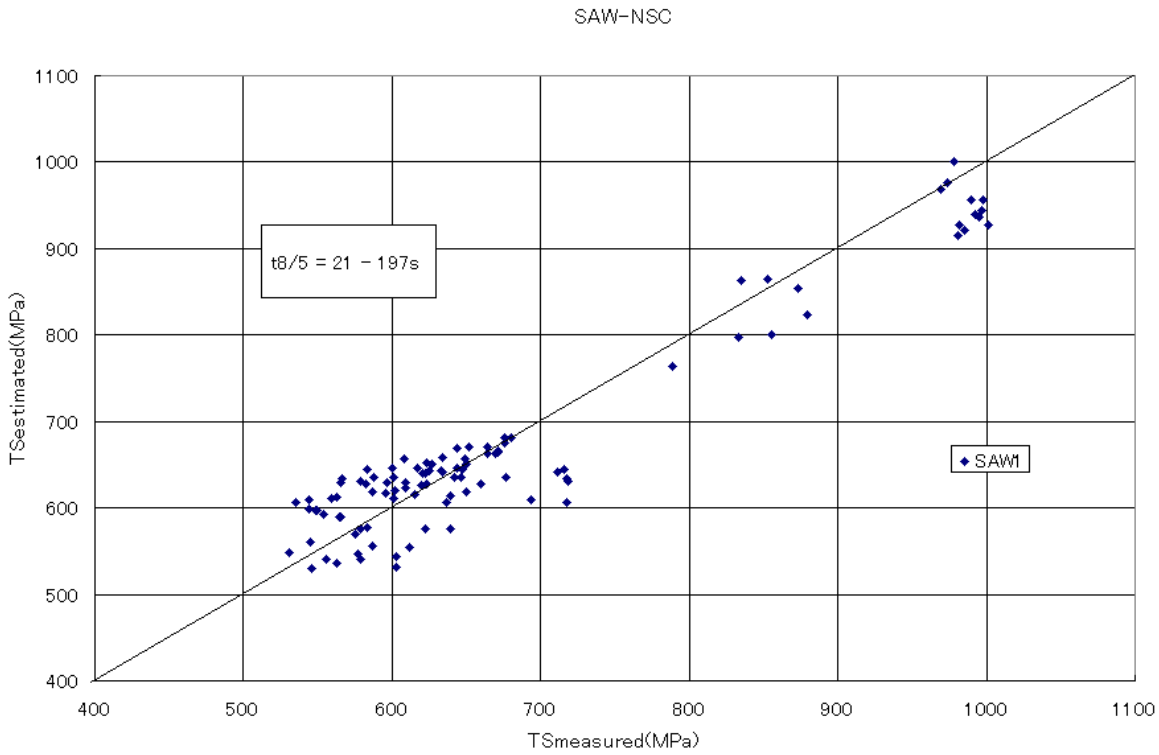

Fig. 1 SAW weld metal tensile strengths measured and predicted

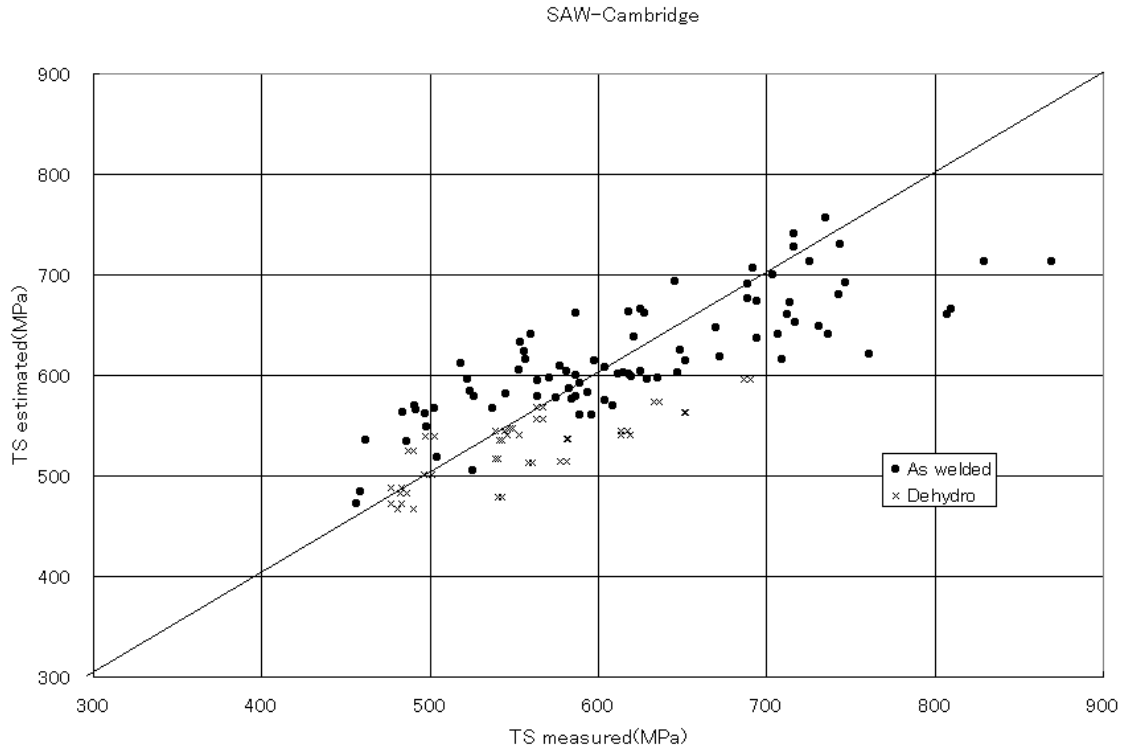

Fig.2 SAW (U. Cambridge) weld metal tensile strengths) measured and predicted

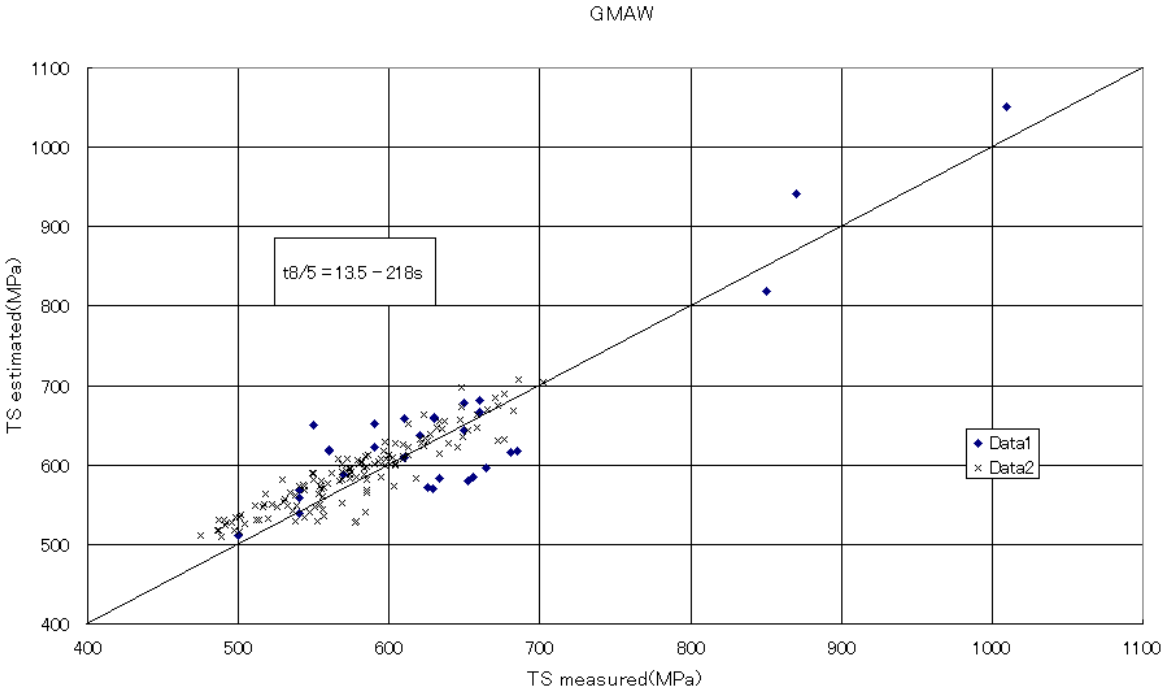

Fig.3 GMAW weld metal tensile strengths measured and predicted

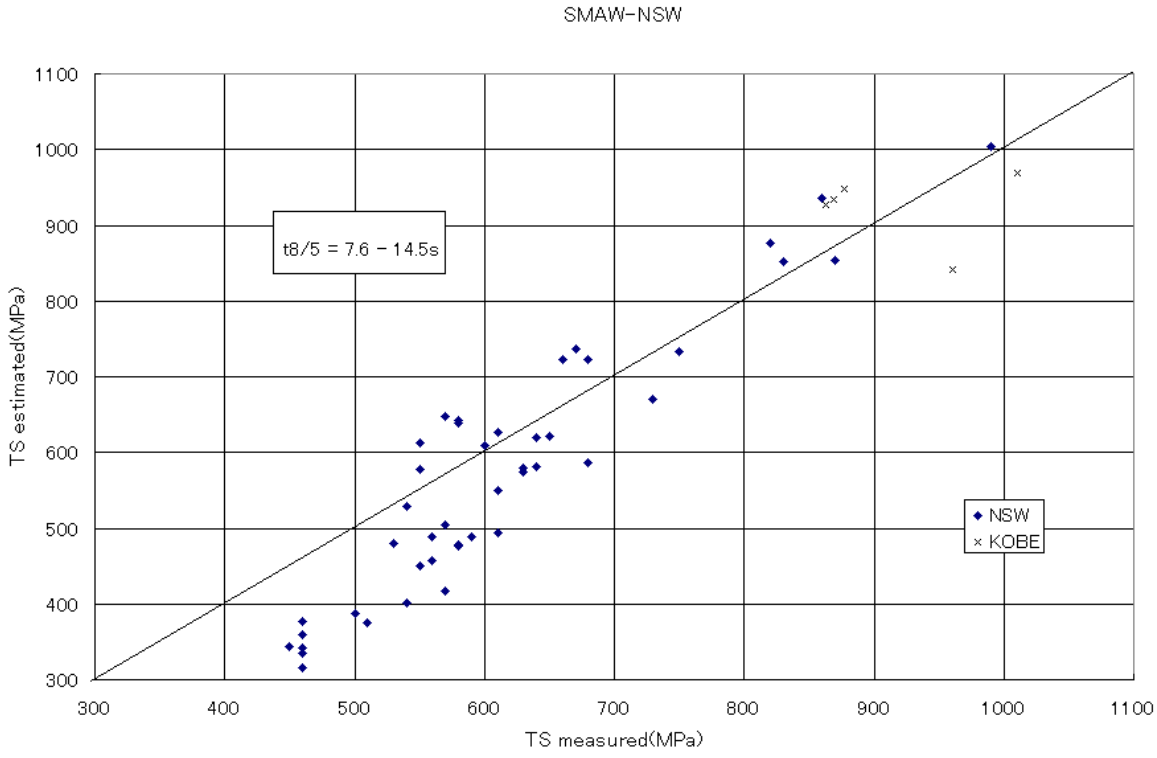

Fig.4 SMAW weld metal tensile strengths measured and predicted

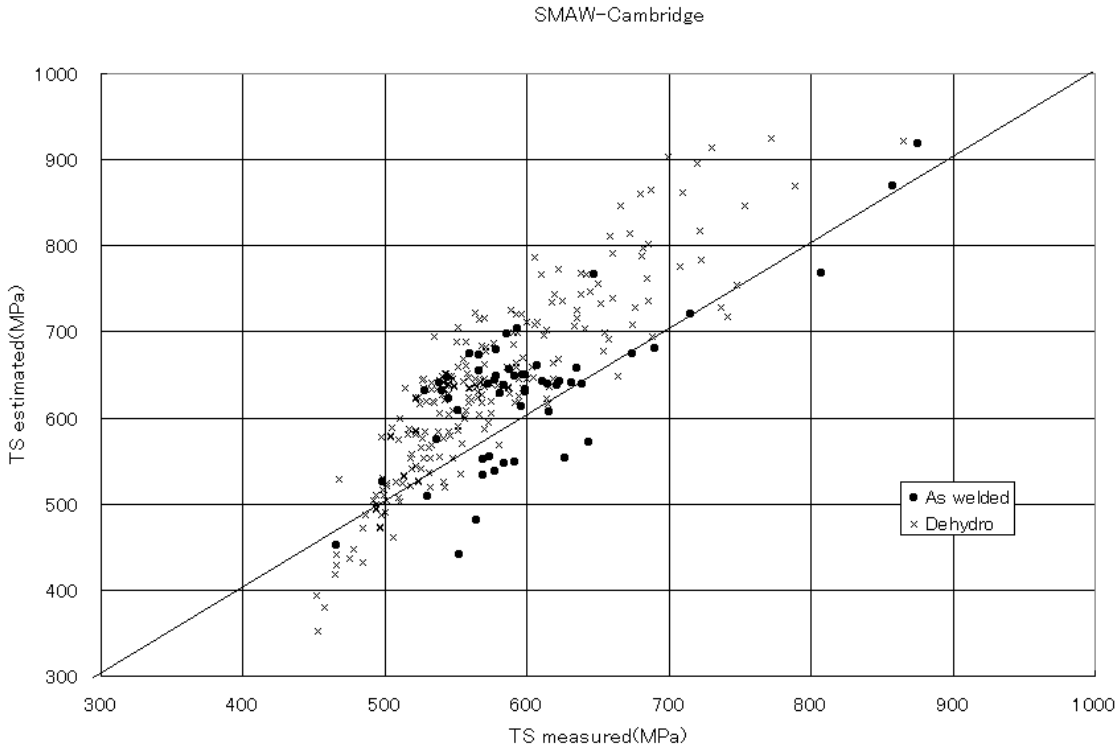

Fig.5 SMAW (U. Cambridge) weld metal tensile strengths measured and predicted

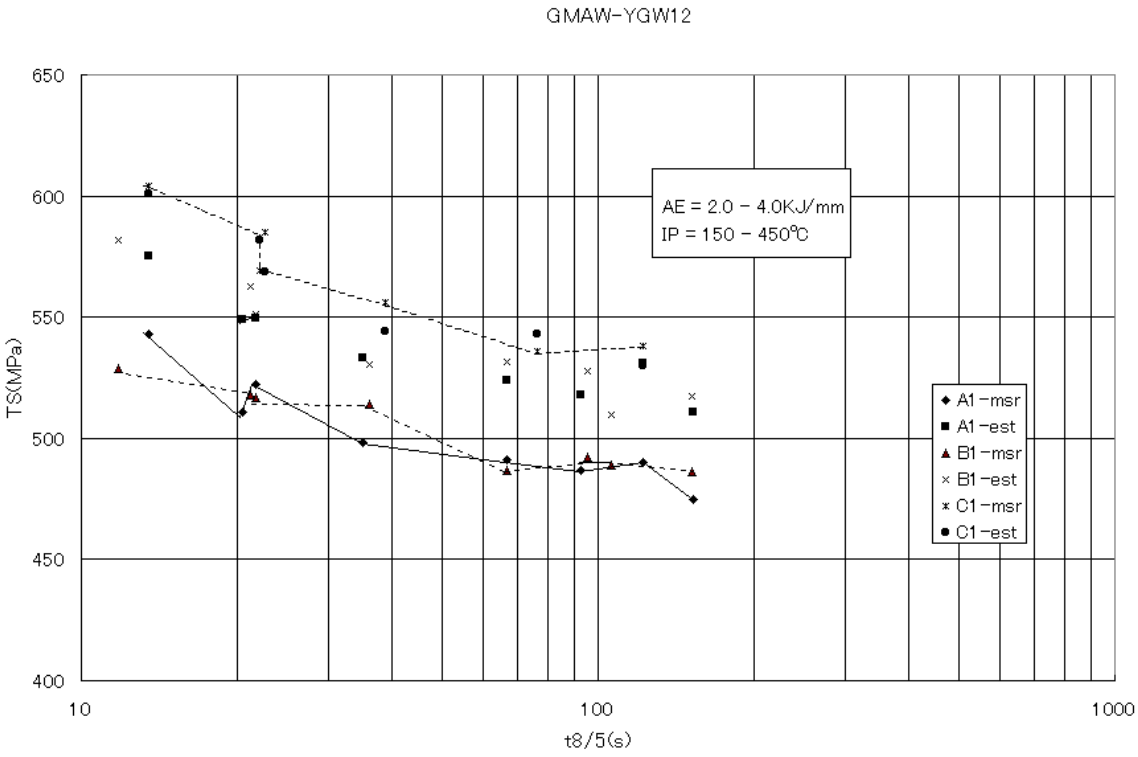

Fig.6 GMAW(YGW12) weld metal tensile strengths measured and predicted

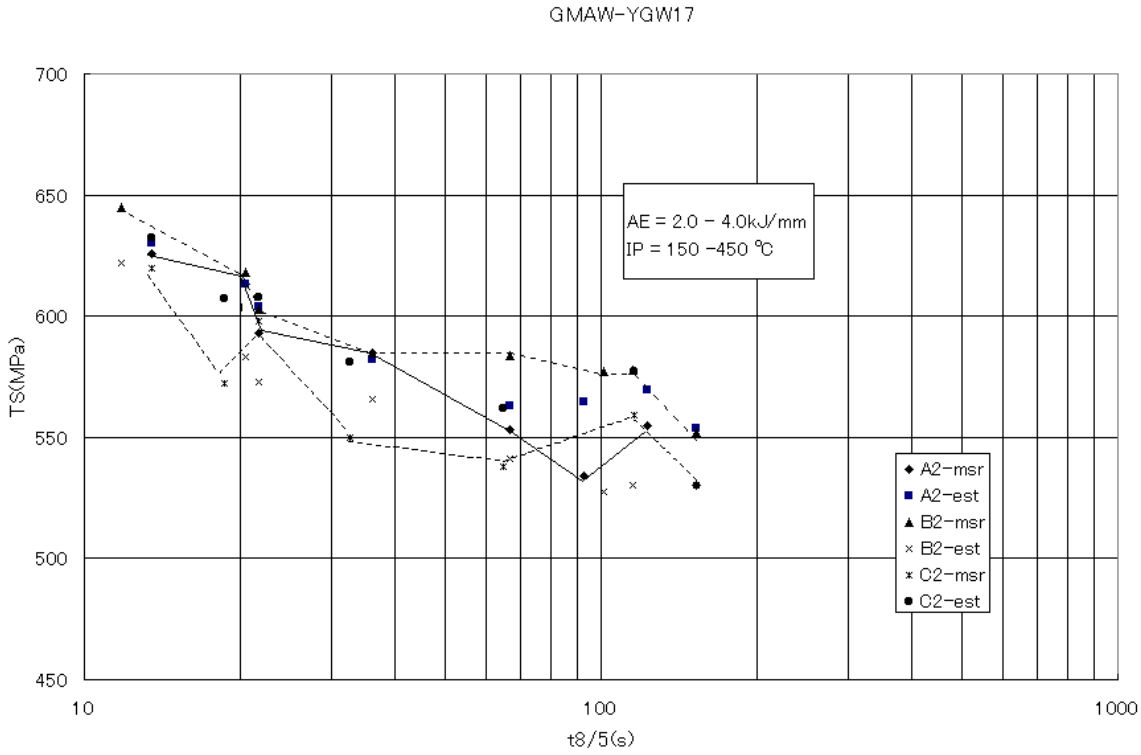

Fig.7 GMAW(YGW17) weld metal tensile strengths measured and predicted

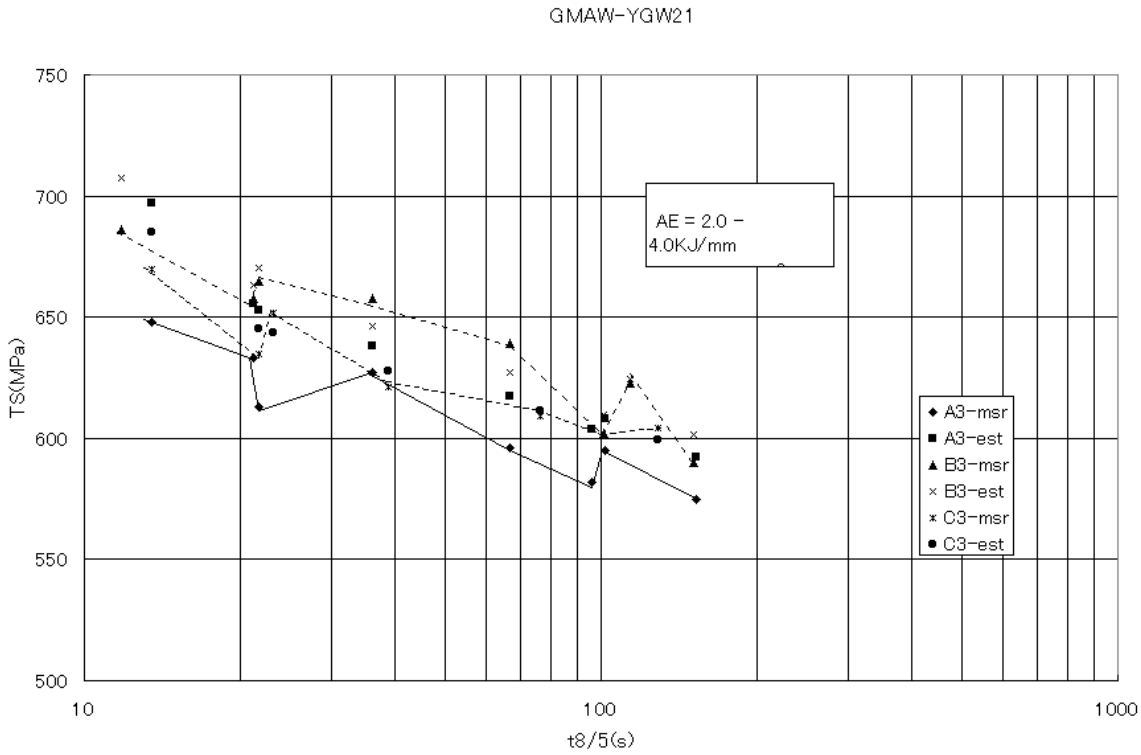

Fig.8 GMAW(YGW21) weld metal tensile strengths measured and predicted

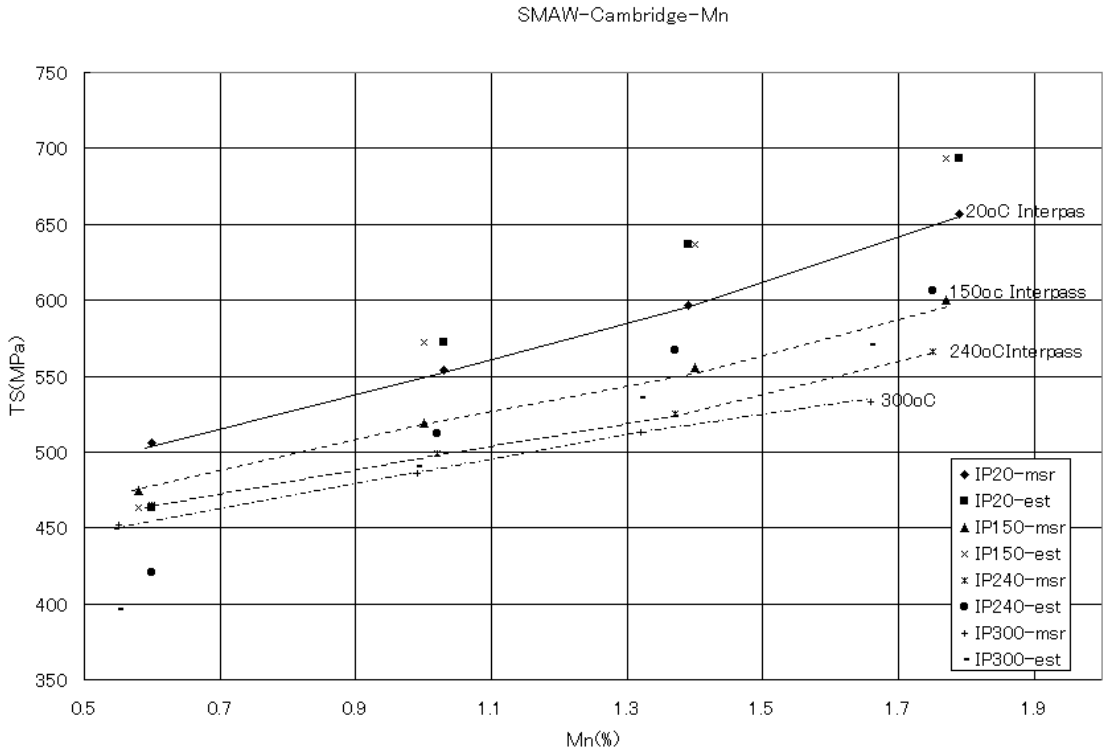

Fig.9 SMAW (U. Cambridge) tensile strengths measured and predicted against Mn content

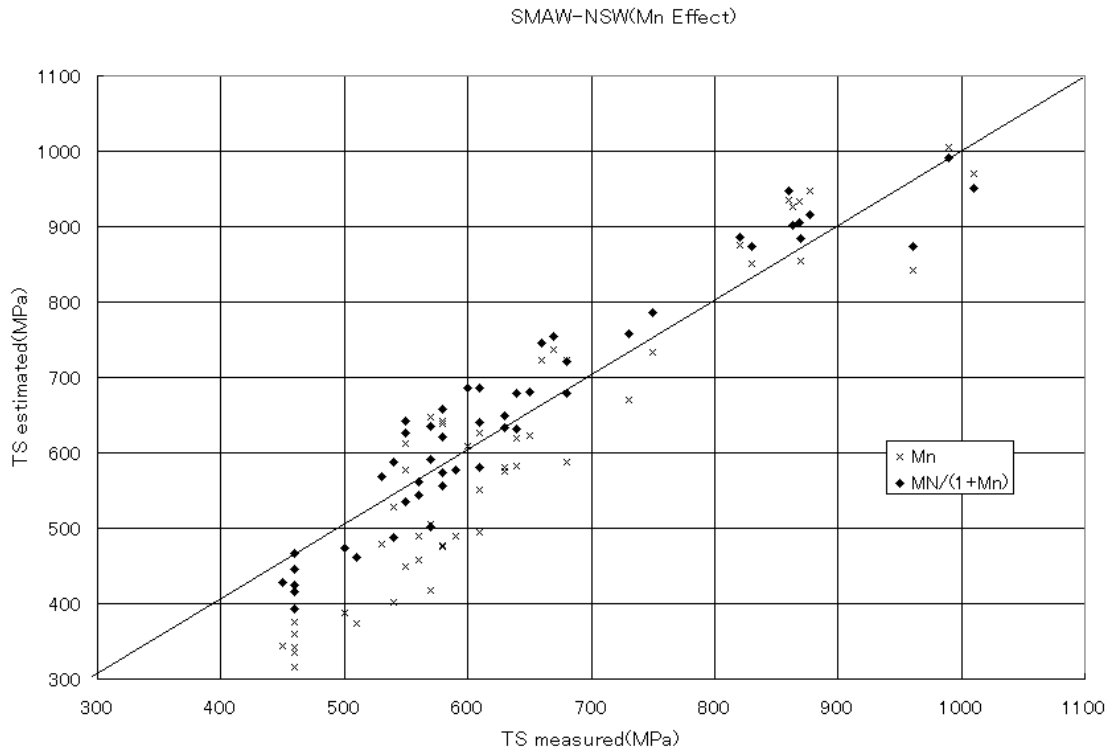

Fig.10 Predicted tensile strengths of SMAW (U. Cambridge) with linear and non-linear

Mn effect considered

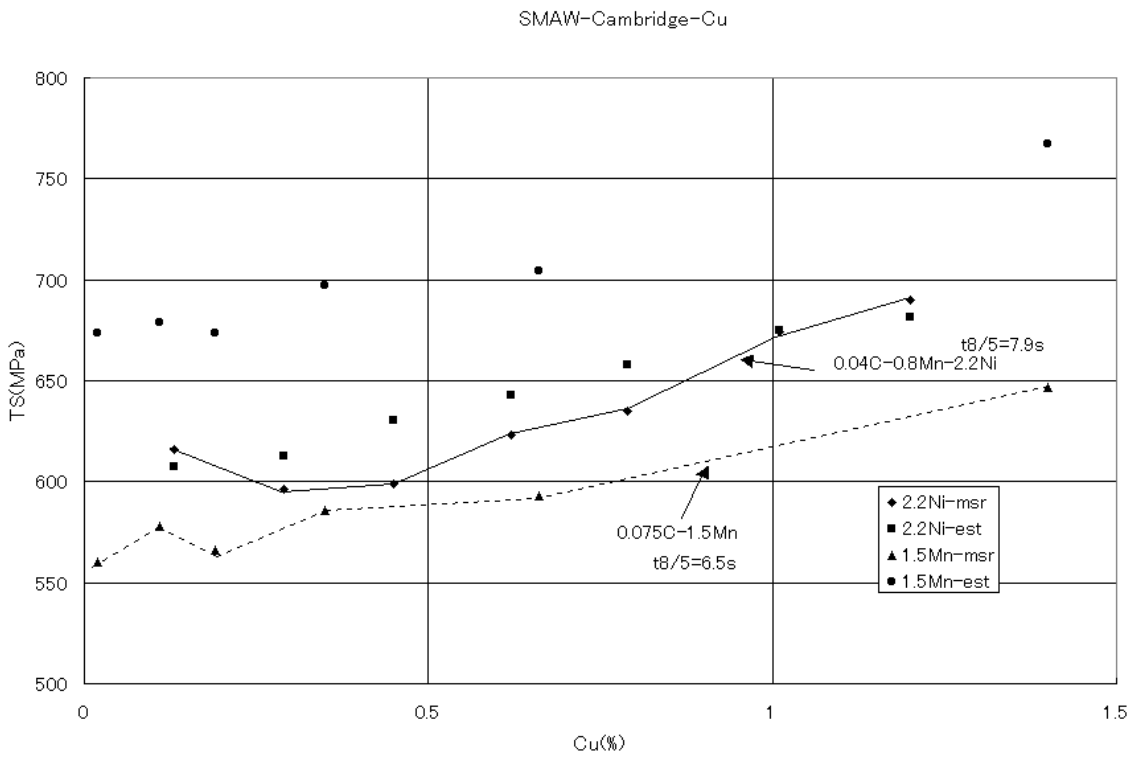

Fig.11 SMAW (U. Cambridge) tensile strengths measured and predicted against Cu content

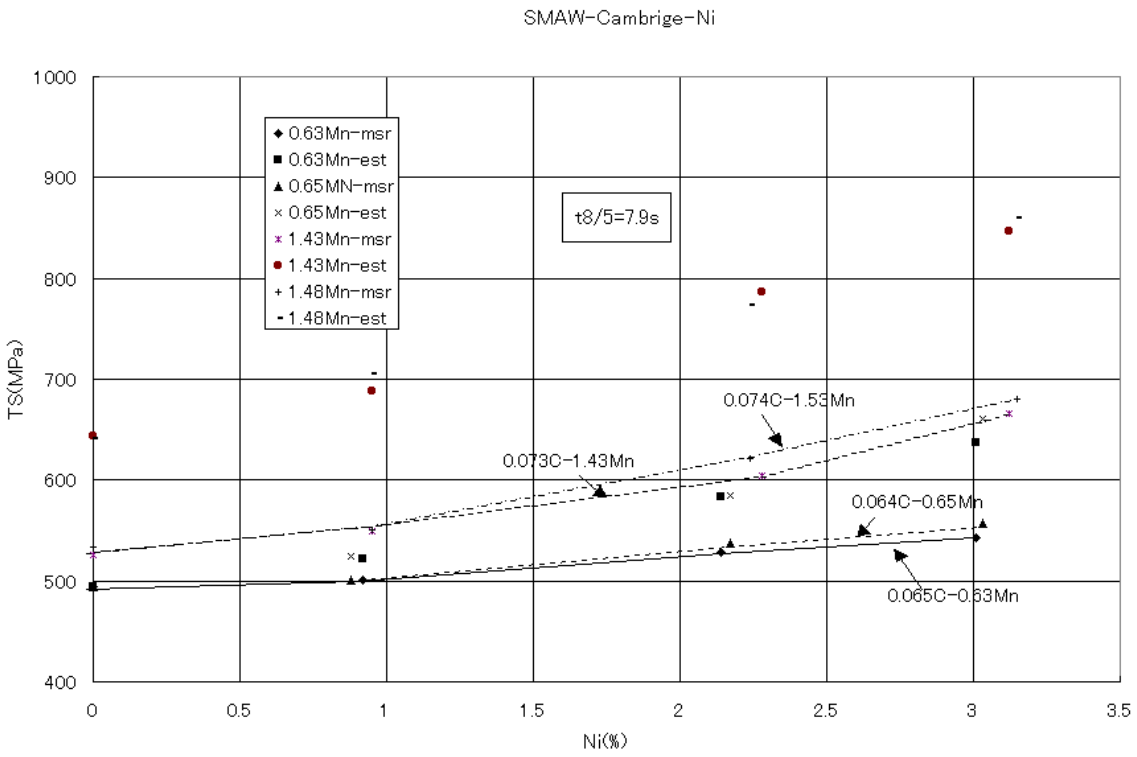

Fig.12 SMAW (U. Cambridge) tensile strengths measured and predicted against Ni content

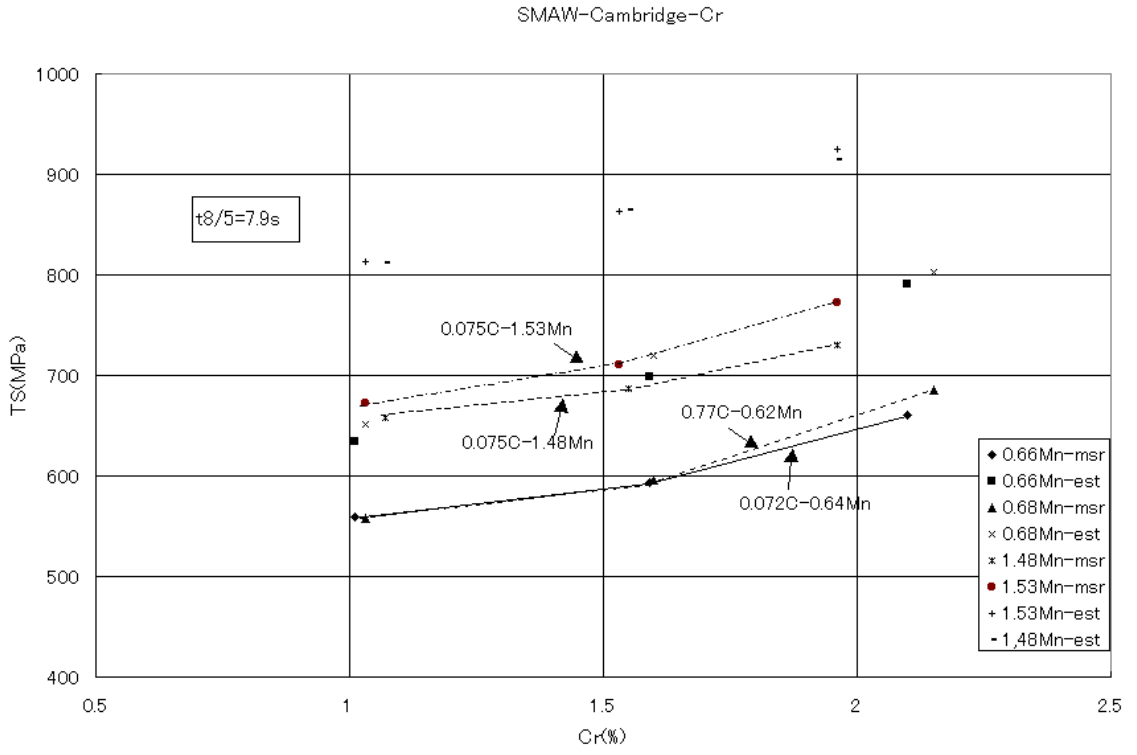

Fig.13 SMAW (U. Cambridge) tensile strengths measured and predicted against Cr content

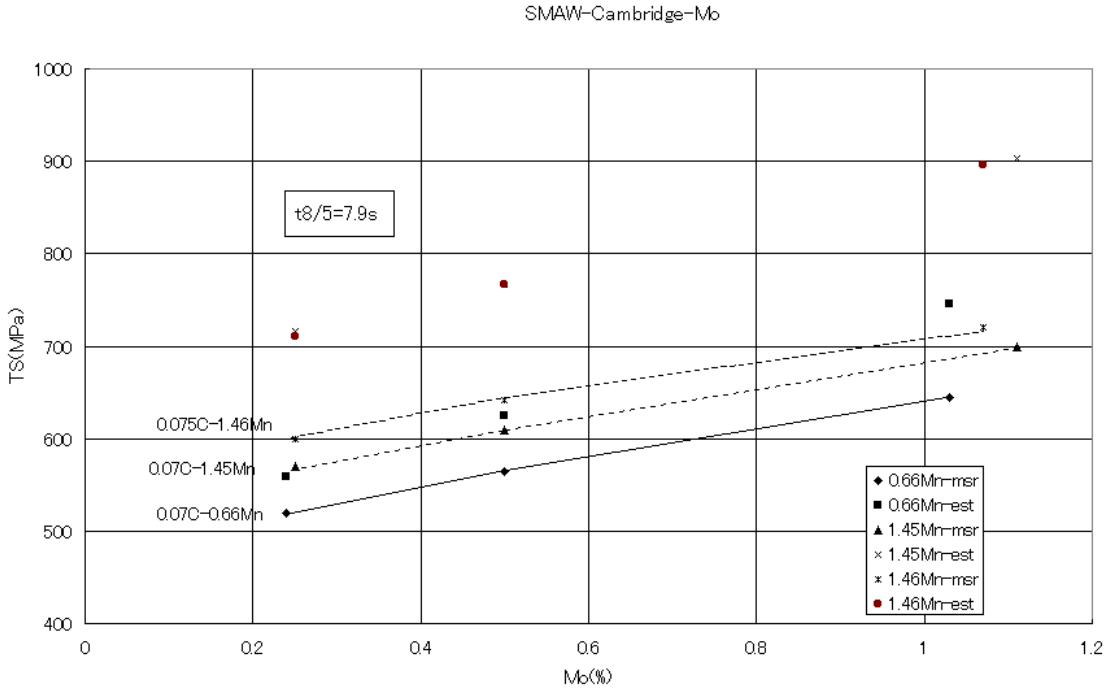

Fig.14 SMAW (U. Cambridge) tensile strengths measured and predicted against Mo content

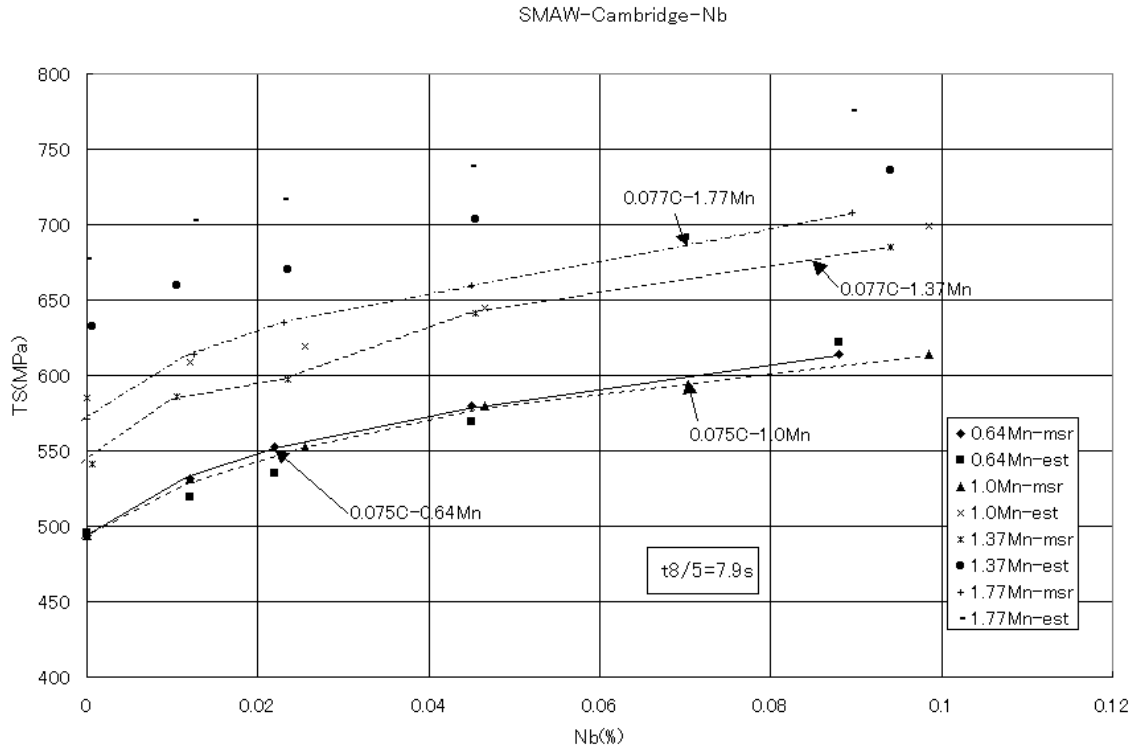

Fig.15 SMAW (U. Cambridge) tensile strengths measured and predicted against Nb content

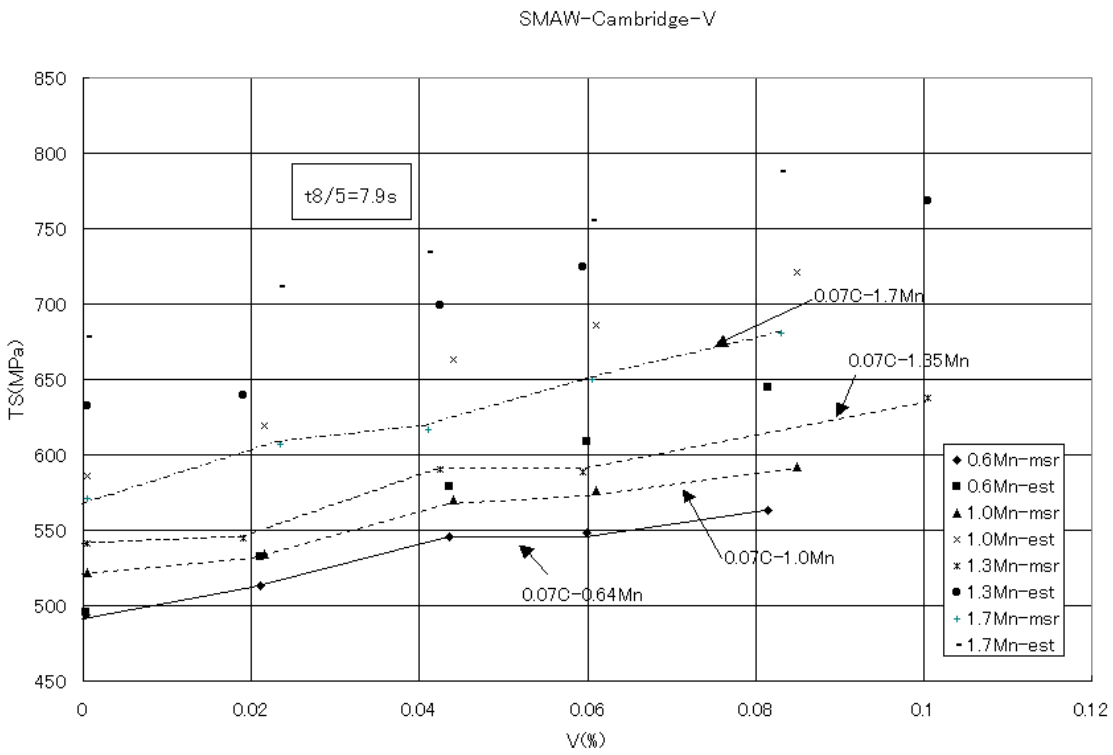

Fig.16 SMAW (U. Cambridge) tensile strengths measured and predicted against V content

Appendix Calculation of welding cooling time, $t_{8/5}$

It is important to precisely calculate welding cooling time, $t_{8/5}$ from welding conditions of arc energy, thickness and preheat and inter-pass temperature in order to predict the hardness and tensile strength of a weld metal with higher accuracy.

A1. Welding heat conduction equation

A welding heat conduction formula in the present study is based on a Rothenthal basic equation[A1)]. But the formula additionally includes the effect of the finite plate thickness, the preheating temperature and heat transfer from the surfaces of a weld and a plate as follows:

$$T = T_\infty + T_w \cdot exp\left\{(-\frac{\alpha_1}{\rho c})\cdot(\frac{2t}{h})\right\} + (T_{ph} - T_\infty)exp\left\{(-\frac{\alpha_2}{\rho c})(\frac{2t}{h})\right\} \quad \bullet A1 \bullet$$

$$T_w = \frac{Q_P}{2\pi\lambda} exp\left(\frac{-vw}{2\kappa}\right)\left[\frac{exp(-vR/2\kappa)}{R} + \sum_{n=1}^{\infty} r^n \left\{\frac{exp(-vR_n/2\kappa)}{R_n} + \frac{exp(-vR_n'/2\kappa)}{R_n'}\right\}\right] \quad \bullet A2 \bullet$$

where, T : temperature ($^\circ$C), T_{ph}: preheat and inter-pass temperature($^\circ$C), T_∞ : ambient temperature($^\circ$C), T_w: temperature increase due to moving point heat source($^\circ$C), x: co-ordinate in the welding direction(cm), z: co-ordinate in the plate thickness direction(cm), y: co-ordinate in the direction perpendicular to the welding direction (cm), t: time (s) after a point heat source passed at the point (x=y=z=0),

R: $R = \sqrt{w^2 + y^2 + z^2}$ Rn: $R_n = \sqrt{w^2 + y^2 + (2nh - z)^2}$ Rn': $R_n' = \sqrt{w^2 + y^2 + (2nh + z)^2}$

Q_p : Efficient energy of heat source = $0.24\,\eta AV$(cal/s), h: plate thickness (cm),

η: arc efficiency =1.0 (SAW), 0.80 (SMAW, GMAW),

$\alpha 1/\rho c$: surface heat transfer coefficient at a weld =0.0005 cm/s (SAW)
=0.0020cm/s (SMAW, GMAW),

$\alpha 2/\rho c$: surface heat transfer coefficient at a plate =0.0020 cm/s

r: heat reflection rate at the surface =0.90 (SAW), 0.80 (SMAW, GMAW),

λ: heat conduction=0.06+0.000012 HI (cal/cm s)

κ: heat diffusivity=0.042+0.000016 *HI* (cm cm/s)

E: arc energy= 60 *A V /v* (J/cm)

HI: Heat input = ηE (J/cm)

A: welding current(A)

V: welding voltage (V)

The heat conduction equation, Eq.(A2) includes a heat reflection term, r^n. Consequently, this equation does not satisfy the boundary condition of Eq. (A3) in a strict sense. If r=1.0 is considered, then the boundary condition is satisfied but the effect of the thickness becomes excessive resulting in unsatisfactory prediction of experimental data. So, r=0.90 for SAW and r=0.80 for SMAW and GMAW in this study.

$$\lambda \frac{\partial T}{\partial z} = -\alpha (T - T_\infty) \qquad \text{(A3)}$$

A2. Comparison of calculation and experiments

Table A1 shows the comparison of calculation and experiments[A2)] of $t_{8/5}$ in SMAW.

Table A1 $t_{8/5}$ calculated and measured in SMAW

Welding condition				Welding cooling time, $t_{8/5}$ (s)	
• (kJ/mm)	Welding condition	Thick(mm)	Preheat(°C)	Experiment	Calculation
8.0	120A,24V,21.5cpm	9	20	5.8	4.9
			100	6.7, 7.2, 7.6	7.8
			185	11.0, 12.6, 12.1	12.3
		16	20	3.1, 3.1, 3.3	3.6
			100	4.0, 4.0, 4.3	4.8
			200	6.6, 6.8, 6.5	7.1
		20	20	2.8, 3.1, 3.3	3.6
			100	4.0, 4.2, 4.2	4.8
			200	6.5, 6.6, 6.2	7.1
17	170A,25V,15cpm	9	20	16.4, 22.1, 21.5	19.8
			100	26.2, 33.0, 28.2	27.0
			200	34.2, 41.0, 37.0	38.2

		16	20	8.2, 10.6	7.7
			100	10.2, 11.6, 12.1	11.3
			200	18.2, 21.6, 20.7	18.9
		20	20	6.9, 7.1	6.8
			100	9.1, 9.9	8.7
			200	13.8, 15.0, 15.8	15.2
45	285A,29V,11cpm	9	20	62.0, 74.7	68.0
			100	75.3	81.6
			200		88.2
		16	20	31.1	46.3
			100	46.5	59.3
			200	59.0, 70.6	82.2
		20	20	20.7, 28.4	28.6
			100	40.2, 35.6	44.8
			200	53.6, 46.7	69.3

Table A2 shows $t_{8/5}$ calculated and measured for SAW.

Table A2 $t_{8/5}$ calculated and measured for SAW

Welding condition				Welding cooling time, $t_{8/5}$ (s)		
• (kJ/mm)	Welding condtion	Thick(mm)	Preheat(oC)	Measurement	Calculation	Reference
10	400A,25V,60cpm	7.5	20	21, 19	18.1	A2
		10		13, 11	10.6	
		20		4.8	5.1	
		25		4.2	5.1	
		30		4.2	5.1	
		40		4.2	5.1	
20	400A,25V,30cpm	10		49, 47	38.7	
		12.5		21	28.2	
		15		16	17.7	
		20		10	10.6	
		25		9	10.6	
		30		9	10.6	
		40		9	10.6	
30	400A,25V,20cpm	15		50, 43	43.1	
		17.5		33	31.0	
		20		27	21.2	
		25		18, 16	16.6	
		30		14	14.7	
10	400A,25V,60cpm	7.5	150	33	30.2	
		10		19	21.0	

		15		12	9.6	
		20		8	8.3	
		25		8	8.3	
20	400A,25V,30cpm	10		71, 63	56.2	
		15		38	37.4	
		20		22	20.5	
		25		15	16.5	
		30		15	16.5	
		40		15	16.5	
30	400A,25V,20cpm	15		70, 65	69.6	
		20		42	45.1	
		25		30, 28	28.5	
		30		23	25.7	
		40		23	22.9	
16		25	20	7	8.3	A3
29		25		18	14.7	
60		25		65	61.1	

Fig.A1 shows the comparison of measurements and experiments shown in Tables A1 and A2. Preferable coincidence was obtained. Consequently, the heat conduction formula and adopted thermal property values in the present study are considered satisfactory. A website is provided which enables to calculate easily $t_{8/5}$ based on the present equation[A5)].

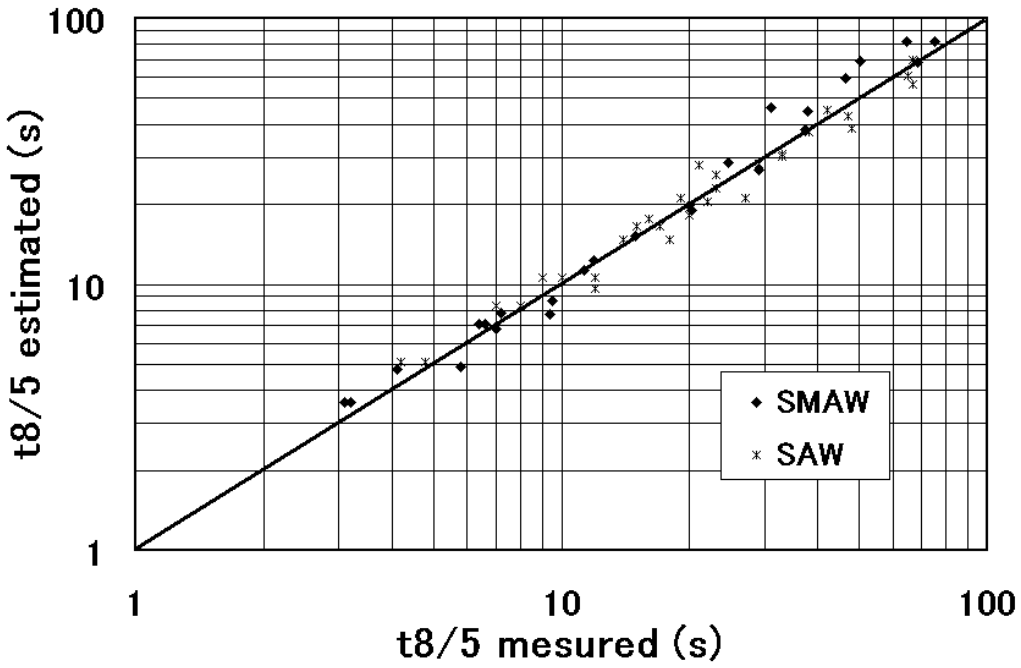

Fig. A1 Comparison of $t_{8/5}$ calculated and measured

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Table 1 Chemical Composition and Mechanical Properties of SAW

No	Exp.No	steel	welding p	Arc energ (kJ/mm)	Interpass Temp(℃)	location	Estimated t8/5(s)	YS (MPa)	TS (MPa)	Hv	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	T.Ti	T.Al	B (ppm)	N (ppm)	O (ppm)	CE(IIW)
1	NV12	SM41(20t)	SAW multi	4.5	150	final pas	88	509	612	187	0.089	0.22	1.49	0			0	0.002	0.004	0.023	0.005		33	142	0.338
2	NV22						88	521	622	189	0.084	0.21	1.49	0			0	0.002	0.018	0.020	0.005		30	158	0.336
3	NV32						88	530	639	206	0.088	0.23	1.55	0			0	0.002	0.034	0.021	0.006		28	178	0.353
4	NV42						88	613	694	227	0.085	0.24	1.54	0			0	0.033	0.004	0.023	0.004		31	180	0.342
5	NV52						88	613	717	232	0.089	0.24	1.51	0			0	0.051	0.005	0.023	0.004		26	161	0.342
6	NV62						88	608	715	233	0.087	0.23	1.65	0			0	0.035	0.019	0.021	0.003		28	153	0.366
7	No1	X-65(32t)	Each Side	3.5	150	final pass	27	564	609	193	0.076	0.21	1.14	0			0	0.015	0.037	0.020			43	298	0.273
8	C33	LCB(18.7t	Each Side	4.38	150	2nd side	90	611	718	222	0.075	0.24	1.77	0			0	0.044	0.005	0.021		16	50	325	0.371
9	C52			4.25			78	594	711	221	0.099	0.20	1.65	0			0.10	0.033	0	0.036		20	28	333	0.394
10	WT60	WT60(38t)	Each Side	3.9	150	final pass	28	582	669	215	0.087	0.23	1.20	0		0.05	0.28		0.030	0.023		50	49	337	0.359
11	F4Y4B	WT70(60t)		3.02-4.28	150	final pass	30	613	660	204	0.044	0.30	1.04	0.13		0.16	0.39		0.020	0.022		69	49	330	0.340
12	CT77	SHS40		4.15	150	f pass 1/4	30	469	549	185	0.077	0.19	1.38	0.08		0.01		0.005	0.015	0.018	0.006	41	30	223	0.317
13	CT78	(75t)		6.0			45	483	564	188	0.075	0.21	1.42	0.09		0.01		0.006	0.015	0.019	0.006	44	36	259	0.323
14	CO1	EH36-060	Each Side	10.9	150	f pass 1/4	176	494	597	195	0.075	0.22	1.51	0.21			0		0.050	0.011	0.009	33	40	284	0.351
15	CO2	(30t)					176	522	642	202	0.072	0.21	1.50	0.18			0.07		0.050	0.010	0.009	31	37	314	0.358
16	CO3						176	549	647	215	0.076	0.21	1.50	0.17			0.15		0.040	0.011	0.009	29	40	306	0.375
17	Cu1	SM41(20t)	SAW multi	4.5	150	final pas	88	449	546	175	0.085	0.19	1.35	0.06						0.022	0.006	48	30	244	0.314
18	Cu2						88	466	556	174	0.082	0.20	1.35	0.18						0.022	0.006	48	31	270	0.319
19	Cu3						88	481	577	189	0.083	0.17	1.32	0.29						0.016	0.006	44	31	203	0.322
20	Cu4						88	492	583	192	0.083	0.18	1.34	0.58						0.017	0.006	44	29	233	0.345
21	Cu5						88	521	637	207	0.082	0.20	1.33	0.92						0.020	0.006	44	29	248	0.365
22	Cu6						88	515	619	205	0.079	0.16	1.32	1.2						0.015	0.006	41	32	270	0.379
23	A517	ASTMA517	Each Side	2.9	150	final pass		640	908	285	0.090	0.22	1.57	0.08		0.51	0.51		0.018	0.013			47	306	0.692
24	HV1	SM41(20t)	SAW multi	4.5	150	final pas	88	562	676	220	0.098	0.24	1.39				0.42		0.007	0.002	0.016	1	75	166	0.415
25	HV2						88	482	587	190	0.088	0.24	1.35						0.013	0.024	0.007	41	39	201	0.316
26	HV3						88	617	717	221	0.108	0.23	1.79						0.012	0.025	0.011	43	30	177	0.409
27	HV4						88	549	639	209	0.092	0.18	1.66						0.010	0.014	0.011	38	26	107	0.371
28	HV5						88	553	603	198	0.038	0.13	2.15						0.005	0.010	0.012	9	27	172	0.397
29	HV6						88	456	563	192	0.041	0.08	2.00						0.005	0.006	0.010	8	31	245	0.375
30	HV7						88	554	601	200	0.040	0.16	2.15						0.039	0.013	0.010	13	23	188	0.406
31	HV8						88	517	579	192	0.040	0.21	1.98						0.005	0.018	0.010		37	219	0.371
32	HV9						88	499	603	200	0.037	0.15	1.94						0.005	0.012	0.009		62	203	0.361
33	HV10						88	524	602	196	0.042	0.21	2.07						0.044	0.019	0.012		40	119	0.396
34	HV11						88	515	650	213	0.086	0.12	1.55				0.33		0.007	0.010	0.012	6	34	310	0.412
35	**B57**	SHS40(75t	Each Side	4.48	150	final pass	36	535	575	200	0.079	0.20	1.32	0.00	0.04	0.00	0	0.003	0.011	0.027	0.003	52	27	253	0.304
36	58Q	SM58Q(50t)					32	540	579	183	0.077	0.20	1.25	0.00	0.00	0.00	0	0.007	0.014	0.024		50	29	249	0.288
37	30S	A516Gr70(30t)		7.06	150		98		531	165	0.110	0.20	1.38	0.00	0.00	0.00	0	0.000	0.000	0.02		38	30	250	0.340
38	G77	SHS40(75t)		4.15	150		30	477	549	185	0.077	0.19	1.38	0.08	0.00	0.01	0	0.005	0.015	0.018	0.006	41	30	223	0.318
39	CT78			6.0	150		45	521	565	188	0.075	0.21	1.42	0.09	0.00	0.01	0	0.006	0.015	0.019	0.006	44	36	259	0.323
40	TA			4.18	150		30	495	545	175	0.079	0.15	1.27	0.08	0.00	0.01	0	0.000	0.007	0.016		42	22	274	0.300
41	LTA	SM50B(25t	all depo	2.25	150	center	18.6	497	565	187	0.080	0.29	1.43	0.07	0.03	0.02	0.01	0.010	0.007	0.03		33	50	229	0.332
42	LTJ			4.61	150		67	471	544	173	0.090	0.25	1.49	0.07	0.03	0.02	0.01	0.010	0.008	0.03		41	50	213	0.353
43	JA2	WT80Mod(1	Each Side	3.7	150	final pass	18.6	783	835	280	0.070	0.23	1.40	0.09	2.20	0.50	0.58	0	0.010	0.03		0	40	350	0.674
44	JA1					1st side	18.6	807	853	287	0.070	0.27	1.41	0.10	2.20	0.50	0.58	0	0.010	0.02		0	50	354	0.676
45	N448D	WT80(25t)	all depo	3.4	150	center	37	648	789	267	0.054	0.24	1.32	0.08	2.23	0.49	0.56	0	0.010	0.005		0	43	410	0.640
46	N448A			3.6	150		40	701	855	278	0.080	0.24	1.39	0.07	2.23	0.50	0.56	0	0.010	0.007		0	40	289	0.679
47	N460D			3.4	150		37	666	879	281	0.092	0.30	1.37	0.08	2.19	0.48	0.56	0	0.011	0.007		0	47	326	0.682
48	N460A			3.6	150		40	814	973	330	0.110	0.29	1.44	0.07	2.23	0.48	0.56	0	0.010	0.01		0	38	138	0.713
49	M2D			3.4	150		37	658	833	268	0.070	0.22	1.47	0.08	2.21	0.49	0.56	0	0.011	0.007		0	43	352	0.680
50	M31	EH36(25t)	V-groove	8.36	20		114	530	623	200	0.074	0.20	1.42	0.17	0.43	0	0.01	0	0.045	0.014	0.010	27	36	249	0.361
51	M32	EH36-060(	Each Side	10.9	150	2nd side	177	497	596	190	0.079	0.19	1.38	0.18	0.42	0	0.01	0	0.042	0.013	0.009	28	36	237	0.359
52	M33						177	515	615	190	0.073	0.22	1.39	0.17	0.43	0	0.01	0	0.043	0.014	0.010	22	38	246	0.355
53	M41			11.1	150		182	530	623	200	0.078	0.20	1.46	0.18	0.39	0	0.16	0	0.045	0.015	0.008	29	33	199	0.400
54	M42						182	533	644	206	0.079	0.24	1.62	0.16	0.33	0	0.16	0	0.035	0.022	0.005	37	42	236	0.421
55	M43			10.9	150		177	536	625	193	0.078	0.19	1.40	0.17	0.36	0	0.17	0	0.042	0.014	0.008	27	37	239	0.389
56	M44						177	522	634	206	0.077	0.24	1.61	0.15	0.31	0	0.16	0	0.034	0.024	0.005	36	43	243	0.415
57	C42	EH36(25t)		8.36	150		162	497	587	190	0.086	0.19	1.25	0.20	0.18	0	0.12	0	0.036	0.015	0.007	27	30	230	0.351
58	C52						162	564	633	206	0.088	0.19	1.20	0.21	0.18	0	0.29	0	0.035	0.015	0.006	26	29	250	0.379
59	D32						162	438	535	170	0.084	0.22	1.39	0.20	0.17	0	0	0	0.035	0.016	0.008	27	31	221	0.347
60	D42						162	547	609	198	0.088	0.20	1.38	0.19	0.18	0	0.13	0	0.035	0.016	0.006	26	29	241	0.376
61	D52						162	593	650	207	0.091	0.19	1.38	0.20	0.21	0	0.26	0	0.033	0.014	0.006	23	31	232	0.407
62	D62						162	554	664	215	0.090	0.20	1.38	0.19	0.20	0	0.38	0	0.035	0.004	0.006	26	32	237	0.429

No	Exp.No	steel	welding p	Arc energ (kJ/mm)	Interpass Temp(°C)	location	Estimated t8/5(s)	YS (MPa)	TS (MPa)	Hv	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	T.Ti	T.Al	B (ppm)	N (ppm)	O (ppm)	CE(IIW)
63	C44	EH36(40t)	Each Side	13.7	150	2nd side	197	520	588	189	0.090	0.19	1.39	0.20	0.21	0	0.07	0.008	0.036	0.012	0.008	25	37	233	0.370
64	C54						197	560	634	207	0.091	0.18	1.31	0.21	0.19	0	0.22	0.009	0.038	0.012	0.008	25	38	246	0.388
65	D34						197	502	566	173	0.092	0.19	1.50	0.21	0.21	0	0	0.009	0.035	0.014	0.007	28	37	244	0.377
66	D44						197	536	608	198	0.096	0.19	1.49	0.21	0.20	0	0.12	0.009	0.037	0.013	0.007	28	36	241	0.403
67	D54						197	536	652	208	0.093	0.18	1.50	0.21	0.19	0	0.25	0.008	0.035	0.013	0.008	28	36	214	0.427
68	D64						197	550	676	217	0.092	0.18	1.42	0.21	0.22	0	0.36	0.008	0.036	0.012	0.008	28	37	238	0.437
69	E44						197	571	647	203	0.089	0.21	1.65	0.19	0.20	0	0.11	0	0.036	0.015	0.008	27	40	231	0.419
70	E54						197	570	676	212	0.092	0.21	1.67	0.21	0.21	0	0.21	0.008	0.036	0.014	0.009	28	39	233	0.448
71	M81	EH36(25t)		8.36	150		162	576	664	216	0.079	0.20	1.45	0.18	0.44	0	0.16	0.008	0.043	0.014	0.008	33	34	194	0.403
72	M82						162	571	671	217	0.077	0.20	1.47	0.18	0.42	0	0.16	0.008	0.045	0.014	0.007	45	36	195	0.403
73	M83						162	578	671	218	0.074	0.20	1.48	0.18	0.43	0	0.16	0.008	0.044	0.014	0.008	41	35	200	0.402
74	D72						162	485	582	187	0.083	0.21	1.39	0.19	0.19	0	0.08	0.005	0.035	0.014	0.009	29	33	223	0.363
75	D82						162	563	622	198	0.084	0.22	1.33	0.20	0.19	0	0.15	0.006	0.036	0.014	0.009	28	34	219	0.369
76	D74	EH36(40t)		13.6	150		197	492	601	188	0.092	0.20	1.49	0.21	0.19	0	0.06	0.005	0.035	0.013	0.008	28	38	212	0.386
77	D84						197	557	627	194	0.092	0.21	1.51	0.22	0.26	0	0.12	0.005	0.036	0.012	0.009	25	38	214	0.407
78	B42	EH36(25t)		8.36	150		162	489	563	180	0.081	0.19	1.07	0.20	0.20	0	0.12	0.004	0.040	0.012	0.008	25	32	258	0.318
79	B72						162	481	554	176	0.083	0.20	1.09	0.20	0.20	0	0.01	0.004	0.038	0.014	0.009	18	28	238	0.301
80	E32						162	486	579	182	0.082	0.24	1.60	0.18	0.20	0	0	0.004	0.037	0.015	0.01	28	29	212	0.381
81	E72						162	531	621	196	0.080	0.22	1.58	0.18	0.20	0	0.07	0.005	0.037	0.014	0.009	25	31	222	0.390
82	C62						162	563	644	210	0.080	0.19	1.18	0.20	0.20	0	0.45	0.004	0.036	0.012	0.008	21	27	263	0.401
83	B44	EH36(40t)		13.7	150		197	478	559	188	0.092	0.19	1.14	0.21	0.20	0	0.09	0.004	0.035	0.012	0.009	20	37	224	0.334
84	B74						197	471	544	172	0.086	0.19	1.18	0.22	0.20	0	0.06	0.004	0.037	0.012	0.009	22	36	248	0.330
85	E34						197	480	583	185	0.094	0.22	1.67	0.20	0.20	0	0	0.005	0.039	0.014	0.009	29	40	225	0.407
86	E74						197	521	617	195	0.090	0.23	1.64	0.20	0.20	0	0.06	0.004	0.037	0.012	0.009	21	40	227	0.409
87	B52	EH36(25t)		8.36	150		162	541	600	196	0.095	0.18	1.08	0.20	0.20	0	0.28	0.006	0.036	0.013	0.010	26	44	280	0.365
88	E42						162	532	649	207	0.083	0.23	1.62	0.18	0.20	0	0.11	0.009	0.037	0.015	0.010	26	31	222	0.408
89	E52						162	579	680	218	0.087	0.22	1.56	0.15	0.20	0	0.29	0.009	0.038	0.016	0.009	28	33	214	0.436
90	AY1	WT950(75t	V-groove	3.5	150	10mm	27	911	978	320	0.08	0.16	1.44	0.10	2.85	1.00	1.03	0.003	0.007	0.009	0.025	5	15	255	0.924
91	AU1					beneath	27	892	997	330	0.07	0.15	1.43	0.07	2.85	0.90	0.90	0.002	0.006	0.009	0.025	5	13	269	0.864
92	AY2						27	780	969	305	0.07	0.18	1.44	0.08	2.88	0.99	0.99	0.003	0.007	0.008	0.025	5	11	262	0.905
93	Au2						27	862	974	310	0.08	0.17	1.41	0.09	2.58	0.98	0.98	0.003	0.007	0.008	0.025	5	10	312	0.886
94	AY3			4.5	150		36	777	981	315	0.07	0.13	1.43	0.08	2.94	0.90	0.90	0.002	0.007	0.009	0.025	5	12	245	0.871
95	AU3						36	797	992	320	0.08	0.12	1.43	0.09	2.85	0.92	0.92	0.002	0.007	0.009	0.025	5	17	275	0.884
96	AY4			3.5	150		27	841	990	315	0.07	0.14	1.42	0.08	2.59	1.02	1.00	0.002	0.005	0.009	0.025	5	17	240	0.890
97	AY5			4.5	150		36	784	998	320	0.08	0.15	1.50	0.09	2.61	1.04	0.99	0.003	0.007	0.008	0.025	5	11	294	0.917
98	AY6			5.5	150		41	766	995	330	0.08	0.14	1.43	0.09	2.64	1.04	1.00	0.003	0.006	0.007	0.025	5	11	262	0.910
99	AY7						41	810	982	322	0.08	0.13	1.40	0.10	2.60	0.98	1.01	0.002	0.008	0.008	0.025	5	17	237	0.893
100	AY8			6.0	150		45	774	1001	330	0.08	0.14	1.43	0.08	2.64	1.06	1.00	0.003	0.006	0.008	0.025	5	14	236	0.913
101	AY9						45	898	985	325	0.08	0.15	1.39	0.08	2.59	1.01	1.03	0.002	0.005	0.008	0.025	5	15	230	0.899

Hatched: Estimated

Table 2 Chemical Composition and Mechanical Properties of SAW (U. Cambridge Data)

No	Weld ID	Process	ArcEnergy (kj/mm)	InterPass (oC)	t/8/5-est (s)	PWHT (oC)	PWHT (hr)	YS (MPa)	TS (MPa)	Hv	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	Ti	Al	B(ppm)	N(ppm)	O(ppm)	CE(IIW)
1	Kluket	SA	4.8	200	112	0	0	462	638		0.07	0.53	1.72	0.03	0.01	0.03	0.01		0.01	0.024	0.021	7	54	176	0.369
2	Kluket	SA	4.8	200	112	0	0	507	694		0.08	0.59	1.84	0.38	0.01	0.05	0.01		0.01	0.023	0.024	8	54	155	0.427
3	Kluket	SA	4.8	200	112	0	0	523	714		0.08	0.62	1.86	0.81	0.01	0.05	0.01		0.01	0.023	0.022	10	54	174	0.459
4	Kluket	SA	4.8	200	112	0	0	522	709		0.08	0.58	1.83	0.03	0.45	0.05	0.01		0.01	0.023	0.023	6	55	171	0.431
5	Kluket	SA	4.8	200	112	0	0	500	731		0.08	0.59	1.84	0.4	0.45	0.05	0.01		0.01	0.025	0.024	9	49	168	0.457
6	Kluket	SA	4.8	200	112	0	0	504	743		0.08	0.62	1.85	0.81	0.45	0.05	0.01		0.01	0.022	0.024	10	52	152	0.486
7	Kluket	SA	4.8	200	112	0	0	515	737		0.08	0.62	1.83	0.03	1.51	0.05	0.01		0.01	0.023	0.02	7	67	185	0.502
8	Kluket	SA	4.8	200	112	0	0	515	810		0.07	0.59	1.85	0.42	1.5	0.05	0.01		0.01	0.025	0.02	9	57	146	0.520
9	Kluket	SA	4.8	200	112	0	0	542	829		0.08	0.66	1.92	0.89	1.54	0.05	0.01		0.01	0.026	0.023	13	51	148	0.576
10	Kluket	SA	4.8	200	112	0	0	466	761		0.09	0.63	1.9	0.04	0.01	0.05	0.01		0.01	0.025	0.019	36	56	165	0.424
11	Kluket	SA	4.8	200	112	0	0	489	807		0.08	0.67	1.94	0.43	0.51	0.05	0.01		0.01	0.028	0.022	40	57	142	0.480
12	Kluket	SA	4.8	200	112	0	0	546	869		0.08	0.68	1.94	0.85	1.54	0.05	0.01		0.01	0.029	0.027	44	55	132	0.577
13	Cunh	SA	2.4	200	41.5	0	0	421	504	164	0.05	0.25	1.15	0.12	0	0	0	0.005	0.004	0.003	0.0105		140		0.250
14	Cunh	SA	2.4	200	41.5	0	0	631	726	265	0.1	0.18	1.6	0.14	0	0	0.5	0.01	0.004	0.002	0.008		110		0.477
15	Cunh	SA	2.4	200	41.5	0	0	541	646	226	0.09	0.28	1.52	0.1	0	0	0.5	0.005	0.005	0.008	0.0125		110		0.451
16	Cunh	SA	1.7	200	20.4	0	0	484	587	193	0.12	0.22	1.24	0.18	0	0	0	0.02	0	0	0.011		110		0.339
17	Cunh	SA	1.6	200	18.4	0	0	537	628	202	0.15	0.32	1.2	0	0	0	0	0	0	0	0.009		99		0.350
18	Cunh	SA	1.7	200	20.4	0	0	453	596	193	0.08	0.21	1.2	0	0	0	0	0.006	0	0	0.0128		100		0.280
19	Cunh	SA	1.7	200	20.4	0	0	520	594	172	0.1	0.12	1.2	0	0	0	0	0.006	0	0	0.0042		89		0.300
20	Pat	TundemSA	4.6	200	106	0	0	388	497	158(Hv30)	0.064	0.27	1.44	0.28			0.02		0.009				102	590	0.328
21	Pat	TundemSA	4.6	200	106	0	0	383	492	155(Hv30)	0.073	0.33	1.44	0.22			0.02		0.009				124	563	0.333
22	Pat	TundemSA	4.6	200	106	0	0	371	526	153(Hv30)	0.06	0.29	1.68	0.28			0.02		0.01				133	521	0.365
23	Pat	TundemSA	4.6	200	106	0	0	391	522	161(Hv30)	0.08	0.31	1.67	0.25			0.03		0.01				82	502	0.383
24	Pat	TundemSA	4.6	200	106	0	0	389	564	168(Hv30)	0.086	0.28	1.68	0.23			0.01		0.01				77	487	0.385
25	Pat	TundemSA	4.6	200	106	0	0	517	672	203(Hv30)	0.089	0.42	2.22	0.06			0.02		0.01				82	466	0.469
26	Pat	TundemSA	4.6	200	106	0	0	554	554	157(Hv30)	0.08	0.24	1.34	0.15			0.43		0.01				86	575	0.401
27	Pat	TundemSA	4.6	200	106	0	0	747	747	174(Hv30)	0.095	0.45	1.88	0.26			0.44		0.01				84	425	0.516
28	Pat	TundemSA	4.4	200	106	0	0	352	459	144(Hv30)	0.074	0.16	0.84	0.28			0.02		0.004				84	415	0.237
29	Pat	TundemSA	4.4	200	106	0	0	349	456	144(Hv30)	0.082	0.18	0.75	0.22			0.02		0.005				109	381	0.227
30	Pat	TundemSA	4.4	200	106	0	0	350	462	143(Hv30)	0.07	0.16	1.17	0.26			0.02		0.01				108	368	0.288
31	Pat	TundemSA	4.4	200	106	0	0	376	484	154(Hv30)	0.11	0.16	1.09	0.24			0.03		0.01				78	353	0.316
32	Pat	TundemSA	4.4	200	106	0	0	359	503	154(Hv30)	0.098	0.18	1.29	0.21			0.01		0.01				61	337	0.331
33	Pat	TundemSA	4.4	200	106	0	0	376	553	170(Hv30)	0.1	0.24	1.91	0.05			0.02		0.01				74	228	0.428
34	Pat	TundemSA	4.4	200	106	0	0	353	491	157(Hv30)	0.096	0.13	0.73	0.14			0.43		0.01				81	373	0.315
35	Pat	TundemSA	4.4	200	106	0	0	689	689	203(Hv30)	0.12	0.27	1.46	0.3			0.48		0.01				77	365	0.481
36	Wats	SA	3.6	100	48.7	0	0	429	537		0.094	0.31	1.32	0.11	0.05	0.04	0	0	0	0	0.014	0	95	233	0.333
37	Wats	SA	3.6	100	48.7	0	0	542	625		0.11	0.36	1.61	0.12	0.06	0.052	0.02	0.02	0.01	0	0.014	0	95	305	0.407
38	Wats	SA	3.6	100	48.7	0	0	493	618		0.1	0.28	1.42	0.15	0.09	0.08	0.04	0.03	0.01	0	0.015	0	150	430	0.379
39	Wats	SA	3.6	100	48.7	0	0	547	635		0.08	0.25	1.35	0.14	0.09	0.07	0	0.02	0	0	0.012	0	122	392	0.334
40	Wats	SA	3.6	100	48.7	0	0	498	621		0.1	0.31	1.37	0.15	0.08	0.06	0.02	0.03	0	0	0.013	0	99	336	0.360
41	Wats	SA	3.6	100	48.7	0	0	503	625		0.076	0.28	1.27	0.15	0.1	0.06	0.01	0.03	0	0	0.016	0	121	435	0.318
42	Wats	SA	3.6	100	48.7	0	0	380	486		0.094	0.18	1.05	0.11	0.1	0.05	0.01	0	0	0	0	0	100	511	0.295
43	Wats	SA	3.6	100	48.7	0	0	402	498		0.094	0.16	1.01	0.11	0.13	0.05	0.01	0.01	0	0	0	0	102	569	0.290
44	Wats	SA	3.6	100	48.7	0	0	427	518		0.09	0.15	1.18	0.14	0.13	0.08	0.03	0.02	0.01	0	0	0	131	621	0.329
45	Wats	SA	3.6	100	48.7	0	0	436	525		0.072	0.11	0.85	0.14	0.14	0.07	0.01	0.01	0	0	0	0	119	543	0.248
46	Wats	SA	3.6	100	48.7	0	0	451	545		0.081	0.16	0.97	0.19	0.15	0.07	0.02	0.02	0.01	0	0	0	95	584	0.285
47	Wats	SA	3.6	100	48.7	0	0	441	557		0.076	0.19	1.16	0.17	0.17	0.07	0.02	0.02	0.02	0	0	0	131	609	0.314
48	Stil	SA	7.9	300	215	0	0	505	589		0.125	0.26	1.34		0.07	0.05	0.003	0.018	0.005	0.0005			89	253	0.365
49	Stil	SA	7.9	300	215	0	0	530	620		0.13	0.3	1.4		0.07	0.06	0.005	0.018	0.002	0			95	430	0.381
50	Stil	SA	7.9	300	215	0	0	460	584		0.11	0.26	1.3		0.06	0.04	0.003	0.018	0.005	0.001			83	236	0.340
51	Stil	SA	7.9	300	215	0	0	471	575		0.105	0.28	1.46		0.08	0.02	0.005	0.016	0.002	0.0005			92	357	0.359
52	Stil	SA	7.9	300	215	0	0	473	609		0.115	0.22	1.3		0.13	0.05	0.005	0.016					99	255	0.351
53	Stil	SA	7.9	300	215	0	0	465	571		0.115	0.26	1.5		0.06	0.05	0.009	0.017	0.005	0.0005			100	455	0.382
54	Stil	SA	7.9	300	215	0	0	465	587		0.115	0.25	1.35		0.08	0.02	0.009	0.017	0.003				94	260	0.352
55	Stil	SA	7.9	300	215	0	0	423	564		0.105	0.3	1.5		0.08	0.03	0.011	0.015	0.0005				95	370	0.369
56	Stil	SA	7.9	300	215	0	0	504	589		0.1055	0.23	1.21		0.07	0.03	0.17		0.002	0.012		16	101	218	0.352
57	Stil	SA	7.9	300	215	0	0	496	604		0.105	0.24	1.39		0.07	0.03	0.15	0.019	0.003	0.01		20	103	411	0.378
58	Stil	SA	7.9	300	215	0	0	508	604		0.12	0.26	1.33		0.06	0.03	0.12		0.002	0.012		13	96	255	0.376
59	Stil	SA	7.9	300	215	0	0	549	629		0.105	0.26	1.32		0.06	0.03	0.125	0.018	0.002	0.01		22	101	362	0.360
60	Stil	SA	7.9	300	215	0	0	529	612		0.12	0.25	1.26		0.06	0.03	0.145	0.016	0.002	0.011		20	119	262	0.369
61	Stil	SA	7.9	300	215	0	0	460	583		0.1	0.26	1.38		0.07	0.03	0.14	0.01	0.002	0.012		22	116	416	0.369
62	Stil	SA	7.9	300	215	0	0	533	615		0.11	0.25	1.28		0.07	0.03	0.15	0.018	0.003	0.0115		21	107	253	0.365
63	Stil	SA	7.9	300	215	0	0	479	587		0.09	0.21	1.39		0.06	0.03	0.185	0.019	0.001	0.012		22	108	340	0.369
64	Gar	SA	3.3	300	105	0	0	500	707		0.08	0.3	1.35	0.043	0.03	0.03	0.005	0.015	0.046	0.005	0.023		90	420	0.326
65	Gar	SA	3.3	300	105	0	0	562	694		0.08	0.28	1.39	0.044	0.028	0.03	0.17	0.015	0.049	0.005	0.012		54	340	0.366
66	Gar	SA	3.3	300	105	0	0	562	692		0.08	0.29	1.33	0.053	0.032	0.03	0.43	0.015	0.05	0.005	0.01		95	450	0.409
67	Gar	SA	3.3	300	105	0	0	355	524		0.16	0.13	1.06	0.048	0.03	0.02	0.005	0.005	0.005	0.005	0.012		67	410	0.348

No	Weld ID	Process	ArcEnergy (kj/mm)	InterPass (oC)	t/8/5-est (s)	PWHT (oC)	PWHT (hr)	YS (MPa)	TS (MPa)	Hv	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	Ti	Al	B(ppm)	N(ppm)	O(ppm)	CE(IIW)
68	Gar	SA	3.3	300	105	0	0	522	689		0.12	0.26	1.4	0.106	0.057	0.05	0.009	0.005	0.056	0.005	0.014		138	420	0.387
69	Gar	SA	3.3	300	105	0	0	577	716		0.11	0.26	1.44	0.076	0.069	0.056	0.01	0.005	0.105	0.005	0.017		145	410	0.394
70	Gar	SA	3.3	300	105	0	0	405	577		0.16	0.12	1.04	0.041	0.027	0.02	0.15	0.005	0.005	0.005	0.009		67	420	0.373
71	Gar	SA	3.3	300	105	0	0	556	704		0.1	0.35	1.54	0.11	0.06	0.049	0.18	0.005	0.057	0.005	0.016		138	420	0.425
72	Gar	SA	3.3	300	105	0	0	556	716		0.11	0.27	1.47	0.072	0.07	0.054	0.22	0.005	0.095	0.005	0.022		139	480	0.438
73	Gar	SA	3.3	300	105	0	0	599	670		0.16	0.12	1	0.043	0.028	0.02	0.39	0.005	0.005	0.005	0.012		62	450	0.414
74	Gar	SA	3.3	300	105	0	0	574	744		0.12	0.33	1.47	0.11	0.06	0.05	0.39	0.005	0.055	0.005	0.015		136	400	0.475
75	Gar	SA	3.3	300	105	0	0	559	735		0.11	0.25	1.33	0.072	0.067	0.053	0.44	0.005	0.097	0.005	0.018		145	440	0.459
76	Gar	SA	3.3	300	105	0	0	426	652		0.12	0.3	1.4	0.25	0.14	0.11	0.025	0.005			0.015		50	210	0.406
77	Gar	SA	3.3	300	105	0	0	493	649		0.11	0.35	1.42	0.17	0.067	0.075	0.022	0.023			0.018		80	260	0.382
78	Gar	SA	1.9	300	48.8	0	0	420	560		0.11	0.33	1.41	0.19	0.065	0.082	0.016	0.018			0.024				0.382
79	Gar	SA	3.3	300	105	0	0	488	618		0.11	0.31	1.37	0.18	0.09	0.06	0.018	0.012			0.022				0.372
80	Gar	SA	7.6	300	215	0	0	432	598		0.15	0.31	1.23	0.15	0.06	0.065	0.02	0.02			0.025				0.386
81	Gar	SA	1.9	300	48.8	0	0	457	556		0.08	0.36	1.6	0.18	0.065	0.075	0.017	0.017			0.03				0.381
82	Gar	SA	3.3	300	105	0	0	507	647		0.09	0.4	1.6	0.11	0.04	0.055	0.015	0.015			0.027		80	400	0.381
83	Gar	SA	7.6	300	191	0	0	452	581		0.1	0.38	1.5	0.14	0.055	0.065	0.017	0.02			0.031				0.379
84	Gar	SA	3.3	300	191	0	0	544	717		0.12	0.29	1.5	0.19	0.085	0.075	0.3	0.01			0.019				0.463
85	Gar	SA	3.3	300	191	0	0	620	712		0.09	0.46	1.81	0.21	0.1	0.08	0.28	0.014			0.026		100	340	0.484
86	p	SA	2.025	250	40.4	200	1	408	501		0.095	0.35	0.9	0	0	0	0	0	0		0.017		54	269	0.245
87	p	SA	2.025	250	40.4	200	1	394	496		0.095	0.35	0.9	0	0	0	0	0	0		0.017		54	269	0.245
88	p	SA	2.475	250	53.6	200	1	390	486		0.093	0.32	0.86	0	0	0	0	0	0		0.018		54	236	0.236
89	p	SA	2.475	250	53.6	200	1	388	482		0.093	0.32	0.86	0	0	0	0	0	0		0.018		54	236	0.236
90	p	SA	2.925	250	73	200	1	370	481		0.096	0.3	0.8	0	0	0	0	0	0		0.017		47	265	0.229
91	p	SA	2.925	250	73	200	1	379	490		0.096	0.3	0.8	0	0	0	0	0	0		0.017		47	265	0.229
92	p	SA	4.8	100	81	200	1	337	477		0.1	0.28	0.82	0	0	0	0	0	0		0.02		45	258	0.237
93	p	SA	4.8	100	81	200	1	356	483		0.1	0.28	0.82	0	0	0	0	0	0		0.02		45	258	0.237
94	p	SA	2.025	250	40.4	200	1	456	563		0.088	0.35	1.38	0	0	0	0	0	0		0.02		109	268	0.318
95	p	SA	2.025	250	40.4	200	1	458	567		0.088	0.35	1.38	0	0	0	0	0	0		0.02		109	268	0.318
96	p	SA	2.475	250	53.6	200	1	428	539		0.089	0.32	1.36	0	0	0	0	0	0		0.018		85	237	0.316
97	p	SA	2.475	250	53.6	200	1	436	544		0.089	0.32	1.36	0	0	0	0	0	0		0.018		85	237	0.316
98	p	SA	2.925	250	73	200	1	439	543		0.092	0.31	1.33	0	0	0	0	0	0		0.017		84	252	0.314
99	p	SA	2.925	250	73	200	1	430	541		0.092	0.31	1.33	0	0	0	0	0	0		0.017		84	252	0.314
100	p	SA	4.8	100	81	200	1		539		0.09	0.33	1.19	0	0	0	0	0	0		0.02		78	234	0.288
101	p	SA	4.8	100	81	200	1	413	540		0.09	0.33	1.19	0	0	0	0	0	0		0.02		78	234	0.288
102	p	SA	2.025	250	40.4	200	1	405	497		0.075	0.47	1.31	0	0	0	0	0	0		0.019		49	465	0.293
103	p	SA	2.025	250	40.4	200	1	404	503		0.075	0.47	1.31	0	0	0	0	0	0		0.019		49	465	0.293
104	p	SA	2.475	250	53.6	200	1	383	487		0.078	0.44	1.24	0	0	0	0	0	0		0.022		61	479	0.285
105	p	SA	2.475	250	53.6	200	1	394	490		0.078	0.44	1.24	0	0	0	0	0	0		0.022		61	479	0.285
106	p	SA	2.925	250	73	200	1	386	483		0.08	0.36	1.02	0	0	0	0	0	0		0.023		51	513	0.250
107	p	SA	2.925	250	73	200	1	378	477		0.08	0.36	1.02	0	0	0	0	0	0		0.023		51	513	0.250
108	p	SA	2.025	250	40.4	200	1	456	567		0.077	0.44	1.61	0	0	0	0	0	0		0.018		105	434	0.345
109	p	SA	2.025	250	40.4	200	1	455	563		0.077	0.44	1.61	0	0	0	0	0	0		0.018		105	434	0.345
110	p	SA	2.475	250	53.6	200	1	439	549		0.071	0.4	1.55	0	0	0	0	0	0		0.02		81	423	0.329
111	p	SA	2.475	250	53.6	200	1	442	547		0.071	0.4	1.55	0	0	0	0	0	0		0.02		81	423	0.329
112	p	SA	2.925	250	73	200	1	435	546		0.073	0.39	1.55	0	0	0	0	0	0		0.022		72	463	0.331
113	p	SA	2.925	250	73	200	1	441	553		0.073	0.39	1.55	0	0	0	0	0	0		0.022		72	463	0.331
114	p	SA	2.025	250	40.4	200	1	473	582		0.068	0.9	1.2	0	0	0	0	0	0		0.027		27	789	0.268
115	p	SA	2.025	250	40.4	200	1	490	581		0.068	0.9	1.2	0	0	0	0	0	0		0.027		27	789	0.268
116	p	SA	2.475	250	53.6	200	1	469	561		0.066	0.8	1.12	0	0	0	0	0	0		0.033		26	774	0.253
117	p	SA	2.475	250	53.6	200	1	455	558		0.066	0.8	1.12	0	0	0	0	0	0		0.033		26	774	0.253
118	p	SA	2.925	250	73	200	1	449	540		0.06	0.68	1	0	0	0	0	0	0		0.04		27	821	0.227
119	p	SA	2.925	250	73	200	1	453	543		0.06	0.68	1	0	0	0	0	0	0		0.04		27	821	0.227
120	p	SA	2.025	250	40.4	200	1	530	636		0.07	1.14	1.45	0	0	0	0	0	0		0.023		37	699	0.312
121	p	SA	2.025	250	40.4	200	1	530	633		0.07	1.14	1.45	0	0	0	0	0	0		0.023		37	699	0.312
122	p	SA	2.475	250	53.6	200	1	516	613		0.064	0.95	1.33	0	0	0	0	0	0		0.028		42	765	0.286
123	p	SA	2.475	250	53.6	200	1	516	619		0.064	0.95	1.33	0	0	0	0	0	0		0.028		42	765	0.286
124	p	SA	2.925	250	73	200	1	481	577		0.073	0.76	1.14	0	0	0	0	0	0		0.035		46	711	0.263
125	p	SA	2.925	250	73	200	1	479	581		0.073	0.76	1.14	0	0	0	0	0	0		0.035		46	711	0.263
126	p	SA	2.025	250	40.4	200	1	592	690		0.072	1.08	1.71	0	0	0	0	0	0		0.032		65	609	0.357
127	p	SA	2.025	250	40.4	200	1	584	686		0.072	1.08	1.71	0	0	0	0	0	0		0.032		65	609	0.357
128	p	SA	2.475	250	53.6	200	1	560	652		0.071	0.84	1.53	0	0	0	0	0	0		0.031		72	720	0.326
129	p	SA	2.475	250	53.6	200	1	577	651		0.071	0.84	1.53	0	0	0	0	0	0		0.031		72	720	0.326
130	p	SA	2.925	250	73	200	1	516	613		0.077	0.64	1.43	0	0	0	0	0	0		0.033		75	646	0.315
131	p	SA	2.925	250	73	200	1	520	617		0.077	0.64	1.43	0	0	0	0	0	0		0.033		75	646	0.315

Table 3 Chemical Composition and Mechanical Properties of GMAW

No	Product	Steel	Welding Process	Arc Energ (kJ/mm	Interpas Temp(oC)	Estimated t8/5 (s)	YS (MPa)	TS (MPa)	YR (%)	Hv	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	T.Ti	T.Al	B (ppm)	N (ppm)	O (ppm)	CE(IIW)
1	YM26(NSW)		CO2, Multi	2	150	13.5	460	560	0.82		0.1	0.52	1.11	0.2											0.298
2	YM27(NSW)		CO2, Multi	2	150	13.5	490	560	0.88		0.1	0.45	1.12	0.2											0.3
3	YM28(NSW)		CO2, Multi	2	150	13.5	450	550	0.82		0.11	0.69	1.17	0.2											0.318
4	YM28(NSW)		CO2+20%Ar, Mul	2	150	13.5	510	610	0.84		0.09	0.75	1.46	0.2											0.347
5	YM25(NSW)		CO2, Multi	2	150	13.5	400	500	0.8		0.1	0.22	0.62	0.2											0.217
6	YM25(NSW)		CO2+20%Ar ,Mul	2	150	13.5	420	540	0.78		0.1	0.39	0.8	0.2											0.247
7	YM28S(NSW)		CO2+20%Ar, Mul	2	150	13.5	480	540	0.89		0.08	0.35	0.85	0.2											0.235
8	YM55A(NSW)		Ar+20%CO2, Mul	2	150	13.5	520	590	0.88		0.06	0.42	1.26	0.2			0.2								0.323
9	YM60C(NSW)		CO2, Multi	2	150	13.5	590	660	0.89		0.07	0.38	1.38	0.2			0.35								0.383
10	YM60A(NSW)		Ar+20%CO2, Mul	2	150	13.5	580	650	0.89		0.06	0.35	1.45	0.2			0.38								0.391
11	YM80C(NSW)		CO2, Multi	2	150	13.5	715	850	0.84		0.07	0.6	1.34	0.2	2.28		0.42								0.543
12	YM80A(NSW)		Ar+20%CO2, Mul	2	150	13.5	755	870	0.87		0.08	0.31	1.3	0.2	2.6	0.5	0.57								0.697
13	FGC55(NSW)		CO2, Multi	2	150	13.5	550	620	0.89		0.08	0.36	0.98	0.35		0.48									0.363
14	FGC55(NSW)		Ar+20%CO2, Mul	2	150	13.5	570	660	0.86		0.08	0.45	1.15	0.33		0.5									0.394
15	YM55W(NSW)		CO2, Multi	2	150	13.5	580	630	0.92		0.06	0.48	1.05	0.5	0.21	0.61									0.404
16	YM28E(NSW)		Ar+10%CO2, Mul	2.1	150	14.6	460	570	0.81		0.07	0.61	1.21	0.2											0.285
17	YM55H(NSW)		CO2, Multi	2	150	13.5	590	630	0.94		0.08	0.44	1.36	0.2			0.18								0.356
18	YM36E(NSW)		Ar+10%CO2, Mul	2	150	13.5	500	540	0.93		0.06	0.33	1.2	0.2							0.022		36		0.273
19	YM1N(NSW)		Ar+10%CO2, Mul	2	150	13.5	530	590	0.9		0.05	0.39	1.25	0.2	0.98		0.22								0.381
20	YM3N(NSW)		Ar+10%CO2, Mul	2	150	13.5	540	610	0.89		0.04	0.3	0.7	0.2	3.56										0.407
21	YM50WFR(NSW)		CO2, Multi	2	150	13.5	590	650	0.91		0.06	0.36	1.01	0.45	0.2	0.6									0.392
22	Q220	SM570B(25mmt)	CO2, Multi	2	200	17	644	685	0.94	221	0.07	0.49	1.5	0.22	0.03	0.016					0.056	<0.003		83	398	0.34
23	Q225	SM570B(25mmt)	CO2, Multi	2	250	21.8	623	681	0.91	217	0.075	0.5	1.53	0.23	0.03	0.017					0.056	<0.003		105	396	0.351
24	Q235	SM570B(25mmt)	CO2, Multi	2	350	41	564	652	0.87	204	0.071	0.47	1.47	0.22	0.03	0.016					0.052	<0.003		83	405	0.336
25	Q320	SM570B(25mmt)	CO2, Multi	3	200	26.6	584	664	0.88	217	0.072	0.48	1.49	0.21	0.04	0.018					0.042	<0.003		79	364	0.34
26	Q325	SM570B(25mmt)	CO2, Multi	3	250	36	564	656	0.86	212	0.073	0.47	1.46	0.22	0.03	0.017					0.051	<0.003		68	350	0.337
27	Q330	SM570B(25mmt)	CO2, Multi	3	300	49	537	629	0.85	198	0.072	0.45	1.43	0.22	0.03	0.017					0.049	<0.003		95	350	0.331
28	Q420	SM570B(25mmt)	CO2, Multi	4	200	41.9	551	633	0.87	215	0.075	0.47	1.5	0.2	0.05	0.02					0.036	<0.003		46	357	0.346
29	Q425	SM570B(25mmt)	CO2, Multi	4	250	54.4	510	626	0.81	211	0.074	0.46	1.46	0.21	0.04	0.019					0.034	<0.003		68	364	0.338
30	YM100A(NSW)		Ar+20%CO2, Mul	1.9	150	14.7	965	1010	0.96		0.08	0.42	1.8	0.2	2.78	1.14	0.69								250	0.945
31	A121	SN490B 25mm	CO2, 6layer9pas	2	150	13.5	459	543	0.85	182	0.06	0.45	1.2	0.2							0.048	0.006	6	50		0.273
32	A122	SN490B 25mm	CO2, 6layer9pas	2.07	250	21.8	426	522	0.82	172	0.06	0.44	1.17	0.2							0.045	0.006	7	60		0.268
33	A131	SN490B 25mm	CO2, 6layer7pas	3.01	150	20.5	412	511	0.81	164	0.07	0.39	1.07	0.2							0.043	0.005	6	50		0.262
34	A132	SN490B 25mm	CO2, 6layer7pas	3.04	250	35.1	387	498	0.78	161	0.07	0.4	1.09	0.2							0.044	0.005	6	50		0.265
35	A133	SN490B 25mm	CO2, 6layer7pas	2.97	350	66.8	371	491	0.76	156	0.07	0.42	1.13	0.2							0.05	0.005	6	60		0.272
36	A134	SN490B 25mm	CO2, 6layer7pas	2.91	450	122	371	490	0.76	156	0.08	0.44	1.2	0.2							0.052	0.006	7	50		0.293
37	A143	SN490B 25mm	CO2, 5layer6pas	3.96	350	92.6	346	487	0.71	150	0.08	0.38	1.08	0.2							0.038	0.005	6	50		0.273
38	A144	SN490B 25mm	CO2, 5layer6pas	3.96	450	153	343	475	0.72	146	0.08	0.38	1.09	0.2							0.039	0.005	6	50		0.275
39	B121	SN490B 25mm	CO2, 7layer10pa	1.95	150	11.8	438	529	0.83	186	0.07	0.45	1.09	0.2							0.051	0.005	2	60		0.265
40	B122	SN490B 25mm	CO2, 7layer10pa	1.99	250	21.8	421	517	0.81	168	0.07	0.44	1.09	0.2							0.043	0.005	2	70		0.265
41	B131	SN490B 25mm	CO2, 6layer7pas	2.97	150	21.2	420	518	0.81	172	0.08	0.42	1.08	0.2							0.048	0.006	2	60		0.273
42	B132	SN490B 25mm	CO2, 6layer7pas	2.93	250	36	409	514	0.8	172	0.07	0.42	1.06	0.2							0.055	0.005	2	90		0.26
43	B133	SN490B 25mm	CO2, 6layer7pas	2.95	350	66.8	382	487	0.78	154	0.08	0.43	1.11	0.2							0.048	0.006	2	60		0.278
44	B134	SN490B 25mm	CO2, 6layer7pas	2.91	423	106	381	489	0.78	160	0.07	0.43	1.08	0.2							0.054	0.005	3	70		0.263
45	B143	SN490B 25mm	CO2, 5layer6pas	3.93	346	95.5	385	492	0.78	174	0.08	0.45	1.13	0.2							0.055	0.005	2	90		0.282
46	B144	SN490B 25mm	CO2, 5layer6pas	4	450	152	372	486	0.77	146	0.08	0.43	1.12	0.2							0.047	0.005	2	70		0.28
47	C121	SN490B 25mm	CO2, 7layer10pa	2.08	150	13.5	509	604	0.84	209	0.08	0.51	1.15	0.2							0.064	0.008	2	90		0.285
48	C122	SN490B 25mm	CO2, 8layer11pa	2.08	250	22.7	486	585	0.83	189	0.08	0.5	1.11	0.2							0.064	0.007	2	110		0.278
49	C131	SN490B 25mm	CO2, 6layer7pas	3.29	150	22.2	473	569	0.83	188	0.09	0.48	1.12	0.2							0.057	0.007	2	60		0.29
50	C132	SN490B 25mm	CO2, 6layer7pas	3.24	250	38.7	457	556	0.82	180	0.08	0.47	1.08	0.2							0.059	0.007	2	70		0.273
51	C133	SN490B 25mm	CO2, 6layer7pas	3.19	350	76.1	430	536	0.8	170	0.09	0.49	1.12	0.2							0.062	0.008	2	60		0.29
52	C134	SN490B 25mm	CO2, 6layer7pas	3.04	448	122	424	538	0.79	168	0.09	0.47	1.1	0.2							0.056	0.007	2	90		0.287
53	C143	SN490B 25mm	CO2, 6layer6pas	4.03	350	101	356	469	0.76	148	0.09	0.31	0.84	0.2							0.034	0.005	2	60		0.243
54	C144	SN490B 25mm	CO2, 6layer6pas	4.07	450	152	338	456	0.74	144	0.09	0.32	0.84	0.2							0.035	0.006	2	80		0.243
55	D121	SN490B 25mm	CO2, 6layer10pa	2.02	149	13.5	487	582	0.84	203	0.07	0.51	1.27	0.2							0.081	0.007	1	70		0.295
56	D122	SN490B 25mm	CO2, 6layer9pas	2.11	249	21.3	466	562	0.83	184	0.08	0.48	1.26	0.2							0.067	0.007	1	80		0.303
57	D131	SN490B 25mm	CO2, 5layer7pas	2.93	149	21.2	450	555	0.81	189	0.08	0.43	1.2	0.2							0.063	0.006	1	110		0.293
58	D132	SN490B 25mm	CO2, 5layer7pas	3.02	249	35	456	557	0.82	173	0.08	0.48	1.26	0.2							0.077	0.007	1	70		0.303
59	D133	SN490B 25mm	CO2, 5layer7pas	3.09	349	70.9	438	551	0.79	179	0.08	0.45	1.23	0.2							0.066	0.007	1	130		0.298
60	D134	SN490B 25mm	CO2, 5layer7pas	3.01	429	113	433	544	0.8	176	0.08	0.44	1.21	0.2							0.061	0.007	1	120		0.295
61	D143	SN490B 25mm	CO2, 5layer5pas	3.91	349	95.8	451	557	0.81	176	0.07	0.48	1.24	0.2							0.085	0.008	1	200		0.29
62	D144	SN490B 25mm	CO2, 5layer5pas	4.02	432	141	389	496	0.78	160	0.08	0.43	1.17	0.2							0.072	0.008	1	100		0.288
63	E121	SN490B 25mm	CO2, 6layer8pas	2.13	150	14.6	513	600	0.86	205	0.08	0.59	1.26	0.2							0.062	0.008	5	100		0.303
64	E122	SN490B 25mm	CO2, 6layer8pas	2.27	250	24.9	480	578	0.83	197	0.08	0.6	1.24	0.2							0.058	0.008	5	150		0.3
65	E131	SN490B 25mm	CO2, 5layer6pas	2.98	150	21.2	472	574	0.82	200	0.08	0.55	1.2	0.2							0.051	0.008	5	160		0.293
66	E132	SN490B 25mm	CO2, 5layer6pas	2.96	249	35.9	462	569	0.81	182	0.07	0.56	1.19	0.2							0.054	0.007	5	140		0.282
67	E133	SN490B 25mm	CO2, 5layer6pas	3	350	66.8	414	531	0.78	168	0.09	0.51	1.22	0.2							0.05	0.008	4	80		0.307
68	E134	SN490B 25mm	CO2, 5layer6pas	3	390	92.2	433	547	0.79	177	0.08	0.55	1.21	0.2							0.052	0.008	5	130		0.295

No	Product	Steel	Welding Process	Arc Energy (kJ/mm)	Interpass Temp(oC)	Estimated t8/5 (s)	YS (MPa)	TS (MPa)	YR (%)	Hv	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	T.Ti	T.Al	B (ppm)	N (ppm)	O (ppm)	CE(IIW)
69	E143	SN490B 25mm	CO2, 4layer5pas	4.2	350	104	374	502	0.75	163	0.09	0.45	1.16	0.2						0.037	0.008	5	80		0.297
70	E144	SN490B 25mm	CO2, 4layer5pas	4.15	438	150	370	501	0.74	157	0.09	0.46	1.19	0.2						0.041	0.008	4	90		0.302
71	F121	SN490B 25mm	CO2, 6layer9pas	1.91	150	12.9	469	566	0.83	191	0.09	0.56	1.08	0.2						0.043	0.005	2	60		0.283
72	F122	SN490B 25mm	CO2, 6layer9pas	1.88	250	19.4	439	549	0.8	180	0.09	0.58	1.1	0.2						0.054	0.005	2	60		0.287
73	F131	SN490B 25mm	CO2, 6layer7pas	3.04	150	20.5	435	544	0.8	173	0.08	0.56	1.07	0.2						0.05	0.005	2	70		0.272
74	F132	SN490B 25mm	CO2, 6layer7pas	2.91	250	36	413	530	0.78	163	0.09	0.54	1.05	0.2						0.042	0.005	2	70		0.278
75	F133	SN490B 25mm	CO2, 6layer7pas	2.83	354	62.5	395	516	0.77	166	0.09	0.58	1.11	0.2						0.042	0.005	3	60		0.288
76	F134	SN490B 25mm	CO2, 6layer7pas	2.98	450	123	394	512	0.77	155	0.09	0.56	1.09	0.2						0.041	0.005	2	90		0.285
77	F143	SN490B 25mm	CO2, 5;auer6pas	4.14	350	97.3	383	504	0.76	156	0.09	0.53	1.04	0.2						0.034	0.005	2	70		0.277
78	F144	SN490B 25mm	CO2, 5layer6pas	4.14	450	156	381	504	0.76	160	0.09	0.56	1.08	0.2						0.044	0.005	2	80		0.283
79	G121	SN490B 25mm	CO2, 6layer9pas	1.98	150	11.8	485	579	0.84	194	0.08	0.57	1.11	0.2						0.06	0.003	1	70		0.278
80	G122	SN490B 25mm	CO2, 5layer7pas	2.06	250	21.8	475	574	0.83	195	0.09	0.58	1.19	0.2						0.062	0.004	1	60		0.302
81	G131	SN490B 25mm	CO2, 5layer6pas	3.05	150	20.5	462	567	0.81	201	0.08	0.54	1.15	0.2						0.059	0.003	1	70		0.285
82	G132	SN490B 25mm	CO2, 5layer6pas	3.03	250	35.1	425	533	0.8	175	0.08	0.48	1.1	0.2						0.052	0.003	1	60		0.277
83	G133	SN490B 25mm	CO2, 5layer6pas	3.09	350	71	425	539	0.79	174	0.09	0.51	1.16	0.2						0.054	0.003	1	60		0.297
84	G134	SN490B 25mm	CO2, 5layer6pas	3	450	122	403	520	0.78	172	0.09	0.5	1.12	0.2						0.052	0.003	1	60		0.29
85	G143	SN490B 25mm	CO2, 5layer5pas	4.04	350	101	384	501	0.77	163	0.08	0.47	1.05	0.2						0.045	0.004	1	70		0.268
86	G144	SN490B 25mm	CO2, 5layer5pas	4.08	450	152	378	497	0.76	157	0.09	0.44	1.05	0.2						0.04	0.003	1	60		0.278
87	A221	SN490B 25mm	CO2, 6layer9pas	2.01	150	13.5	554	626	0.88	219	0.07	0.6	1.51	0.2						0.045	0.006	13	40		0.335
88	A222	SN490B 25mm	CO2, 6layer9pas	1.99	250	21.8	508	593	0.86	188	0.07	0.59	1.51	0.2						0.043	0.007	13	40		0.335
89	A231	SN490B 25mm	CO2, 6layer7pas	3.02	150	20.5	533	613	0.87	210	0.08	0.56	1.46	0.2						0.04	0.007	12	80		0.337
90	A232	SN490B 25mm	CO2, 6layer7pas	2.91	250	36	491	585	0.84	200	0.07	0.58	1.48	0.2						0.047	0.006	13	40		0.33
91	A233	SN490B 25mm	CO2, 6layer7pas	2.9	350	66.8	433	553	0.78	185	0.07	0.57	1.46	0.2						0.043	0.007	12	50		0.327
92	A234	SN490B 25mm	CO2, 6layer7pas	2.89	450	123	379	555	0.68	176	0.08	0.61	1.55	0.2						0.049	0.007	13	40		0.352
93	A243	SN490B 25mm	CO2, 5layer6pas	3.96	350	92.6	391	534	0.73	183	0.08	0.54	1.47	0.2						0.037	0.007	11	60		0.338
94	A244	SN490B 25mm	CO2, 5layer6pas	3.94	450	153	369	530	0.7	174	0.08	0.53	1.45	0.2						0.038	0.007	11	80		0.335
95	B221	SN490B 25mm	CO2, 7layer10pa	1.98	150	11.8	573	645	0.89	225	0.08	0.58	1.22	0.2						0.07	0.007	42	60		0.297
96	B222	SN490B 25mm	CO2, 7layer10pa	1.95	250	21.8	517	603	0.86	208	0.07	0.57	1.2	0.2						0.07	0.007	43	60		0.283
97	B231	SN490B 25mm	CO2, 6layer7pas	3.03	150	20.5	535	618	0.87	213	0.08	0.54	1.17	0.2						0.071	0.006	39	60		0.288
98	B232	SN490B 25mm	CO2, 6layer7pas	2.97	250	36	490	585	0.84	199	0.08	0.56	1.2	0.2						0.069	0.006	40	100		0.293
99	B233	SN490B 25mm	CO2, 6layer7pas	2.89	350	66.8	463	584	0.79	207	0.07	0.57	1.2	0.2						0.082	0.007	43	60		0.283
100	B234	SN490B 25mm	CO2, 6layer7pas	2.97	441	115	461	578	0.8	187	0.07	0.56	1.2	0.2						0.074	0.006	40	50		0.283
101	B243	SN490B 25mm	CO2, 5layer6pas	4.09	350	101	450	577	0.78	182	0.07	0.54	1.18	0.2						0.058	0.006	41	50		0.28
102	B244	SN490B 25mm	CO2, 5layer6pas	3.97	448	153	409	552	0.74	174	0.08	0.55	1.17	0.2						0.069	0.006	42	50		0.288
103	C221	SN490B 25mm	CO2, 7layeer10p	2.05	150	13.5	537	620	0.87	205	0.08	0.61	1.39	0.2						0.042	0.007	26	70		0.325
104	C222	SN490B 25mm	CO2, 8layer11pa	2.05	250	21.8	505	598	0.84	205	0.08	0.61	1.41	0.2						0.047	0.007	24	80		0.328
105	C231	SN490B 25mm	CO2, 6layer7pas	2.89	150	18.7	486	572	0.85	193	0.09	0.5	1.26	0.2						0.039	0.007	22	60		0.313
106	C232	SN490B 25mm	CO2, 6layer7pas	2.85	250	32.6	452	550	0.82	186	0.09	0.5	1.25	0.2						0.038	0.007	21	60		0.312
107	C233	SN490B 25mm	CO2, 6layer7pas	2.81	350	64.6	428	538	0.8	178	0.09	0.51	1.27	0.2						0.035	0.007	21	70		0.315
108	C234	SN490B 25mm	CO2, 6layer7pas	2.76	450	116	444	559	0.79	186	0.09	0.66	1.5	0.2						0.055	0.008	26	60		0.353
109	C243	SN490B 25mm	CO2, 6layer6pas	4.1	350	101	370	486	0.76	153	0.08	0.43	1.11	0.2						0.031	0.006	20	80		0.278
110	C244	SN490B 25mm	CO2, 6layer6pas	4.13	450	152	368	482	0.76	148	0.09	0.42	1.09	0.2						0.031	0.005	20	70		0.285
111	D221	SN490B 25mm	CO2, 6layer10pa	1.97	149	13.4	531	623	0.85	202	0.09	0.71	1.47	0.2						0.068	0.008	44	170		0.348
112	D222	SN490B 25mm	CO2, 6layer9pas	2.01	249	21.7	525	613	0.86	199	0.08	0.72	1.5	0.2						0.072	0.008	44	110		0.343
113	D231	SN490B 25mm	CO2, 5layer7pas	3.01	149	20.4	500	597	0.84	202	0.09	0.67	1.43	0.2						0.06	0.006	42	230		0.342
114	D232	SN490B 25mm	CO2, 5layer7pas	3.07	249	35	470	569	0.83	198	0.09	0.63	1.4	0.2						0.065	0.007	39	140		0.337
115	D233	SN490B 25mm	CO2, 5layer7pas	3.16	349	70.9	445	550	0.81	175	0.1	0.63	1.42	0.2						0.064	0.007	38	140		0.35
116	D234	SN490B 25mm	CO2, 5layer7pas	3.05	446	122	442	544	0.81	173	0.09	0.64	1.45	0.2						0.07	0.007	37	120		0.345
117	D243	SN490B 25mm	CO2, 5layer5pas	3.84	347	89.4	441	554	0.8	173	0.09	0.62	1.4	0.2						0.066	0.007	37	120		0.337
118	D244	SN490B 25mm	CO2, 5layer5pas	3.98	442	144	427	540	0.79	169	0.1	0.63	1.41	0.2						0.065	0.007	37	120		0.348
119	F221	SN490B 25mm	CO2, 6layer9pas	1.93	150	11.8	512	586	0.87	198	0.09	0.28	1.15	0.2						0.032	0.005	24	50		0.295
120	F222	SN490B 25mm	CO2, 6layer9pas	2	250	21.8	501	583	0.86	187	0.08	0.35	1.32	0.2						0.049	0.005	27	50		0.313
121	F231	SN490B 25mm	CO2, 6layer7pas	2.87	150	18.7	494	585	0.84	208	0.08	0.35	1.33	0.2						0.049	0.005	26	60		0.315
122	F232	SN490B 25mm	CO2, 6layer7pas	2.93	250	36	512	595	0.86	197	0.09	0.36	1.37	0.2						0.046	0.005	26	50		0.332
123	F233	SN490B 25mm	CO2, 6layer7pas	2.97	350	66.8	438	554	0.79	171	0.08	0.35	1.32	0.2						0.04	0.005	27	60		0.313
124	F234	SN490B 25mm	CO2, 6layer7pas	2.87	450	116	409	533	0.77	166	0.09	0.34	1.32	0.2						0.051	0.005	26	50		0.323
125	F243	SN490B 25mm	CO2, 5layer6pas	3.94	350	96	436	556	0.78	188	0.09	0.38	1.39	0.2						0.05	0.005	27	60		0.335
126	F244	SN490B 25mm	CO2, 5layer6pas	3.98	450	149	367	526	0.7	170	0.09	0.35	1.34	0.2						0.046	0.005	26	60		0.327
127	A321	SN490B 25mm	CO2, 6layer9pas	2.03	150	13.5	579	648	0.89	219	0.08	0.42	1.37	0.2			0.34			0.04	0.006	9	60		0.39
128	A321	SN490B 25mm	CO2, 6layer9pas	2.03	250	21.8	529	613	0.86	205	0.08	0.4	1.34	0.2			0.29			0.037	0.007	7	50		0.375
129	A331	SN490B 25mm	CO2, 6layer7pas	2.97	150	21.2	556	633	0.88	211	0.08	0.41	1.35	0.2			0.29			0.041	0.006	7	60		0.376
130	A332	SN490B 25mm	CO2, 6layer7pas	2.95	250	36	536	627	0.85	209	0.08	0.42	1.36	0.2			0.31			0.048	0.007	8	60		0.382
131	A333	SN490B 25mm	CO2, 6layer7pas	2.93	350	66.8	479	596	0.8	193	0.08	0.41	1.34	0.2			0.31			0.044	0.007	6	60		0.379
132	A334	SN490B 25mm	CO2, 6layer7pas	2.85	420	102	434	595	0.73	198	0.08	0.41	1.32	0.2			0.32			0.042	0.006	8	80		0.377
133	A343	SN490B 25mm	CO2, 5layer6pas	3.87	350	96	444	582	0.76	197	0.08	0.4	1.35	0.2			0.28			0.039	0.007	7	70		0.374
134	A344	SN490B 25mm	CO2, 5lyaer6pas	3.93	450	153	405	575	0.7	192	0.08	0.39	1.32	0.2			0.28			0.037	0.006	6	60		0.369
135	B321	SN490B 25mm	CO2, 7layer10pa	1.96	150	11.8	625	686	0.91	229	0.07	0.5	1.52	0.2			0.32			0.06	0.008	4	90		0.401
136	B322	SN490B 25mm	CO2, 7layer10pa	1.97	250	21.8	586	665	0.88	215	0.07	0.5	1.5	0.2			0.34			0.059	0.008	3	100		0.401
137	B331	SN490B 25mm	CO2, 6layer7pas	2.96	150	21.2	574	658	0.87	221	0.07	0.48	1.46	0.2			0.32			0.057	0.008	3	80		0.391
138	B332	SN490B 25mm	CO2, 6layer7pas	2.95	250	36	563	658	0.86	221	0.08	0.48	1.47	0.2			0.29			0.05	0.008	3	100		0.396

No	Product	Steel	Welding Process	Arc Energy (kJ/mm)	Interpass Temp(oC)	Estimated t8/5 (s)	YS (MPa)	TS (MPa)	YR (%)	Hv	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	T.Ti	T.Al	B (ppm)	N (ppm)	O (ppm)	CE(IIW)
139	B333	SN490B 25mm	CO2, 6layer7pas	2.94	350	66.8	522	639	0.82	203	0.08	0.47	1.45	0.2			0.3			0.05	0.008	3	160		0.395
140	B334	SN490B 25mm	CO2, 6layer7pas	2.97	438	114	467	623	0.75	211	0.09	0.49	1.48	0.2			0.29			0.053	0.009	3	150		0.408
141	B343	SN490B 25mm	CO2, 5layer6pas	4.1	350	101	478	602	0.79	197	0.07	0.46	1.41	0.2			0.32			0.048	0.007	3	100		0.382
142	B344	SN490B 25mm	CO2, 5layer6pas	4.01	447	151	429	590	0.73	185	0.08	0.44	1.4	0.2			0.28			0.044	0.008	3	100		0.383
143	C321	SN490B 25mm	CO2, 7layer10pa	2.03	150	13.5	594	670	0.89	224	0.08	0.55	1.41	0.2			0.24			0.041	0.007	3	90		0.376
144	C322	SN490B 25mm	CO2, 8layer11pa	2.01	250	21.8	548	635	0.86	214	0.07	0.57	1.39	0.2			0.26			0.039	0.006	3	80		0.367
145	C331	SN490B 25mm	CO2, 6layer7pas	3.18	150	23.2	565	652	0.87	207	0.08	0.51	1.32	0.2			0.25			0.039	0.007	2	140		0.363
146	C332	SN490B 25mm	CO2, 6layer7pas	3.23	250	38.7	523	621	0.84	209	0.08	0.55	1.4	0.2			0.23			0.042	0.008	3	80		0.373
147	C333	SN490B 25mm	CO2, 6layer7pas	3.23	350	76.1	478	609	0.78	199	0.07	0.6	1.46	0.2			0.25			0.048	0.007	2	110		0.377
148	C334	SN490B 25mm	CO2, 6layer7pas	3.14	450	129	450	604	0.75	195	0.08	0.54	1.37	0.2			0.25			0.041	0.007	2	150		0.372
149	C343	SN490B 25mm	CO2, 6layer6pas	4.05	350	101	388	527	0.74	178	0.08	0.4	1.1	0.2			0.25			0.028	0.006	3	120		0.327
150	C344	SN490B 25mm	CO2, 6layer6pas	3.85	450	145	390	540	0.72	164	0.08	0.43	1.15	0.2			0.24			0.031	0.006	2	90		0.333
151	D321	SN490B 25mm	CO2, 6layer10pa	2	149	13.5	563	648	0.87	220	0.07	0.53	1.5	0.2			0.22			0.038	0.012	2	130		0.377
152	D322	SN490B 25mm	CO2, 6layer9pas	2.06	249	21.7	542	632	0.86	210	0.07	0.53	1.49	0.2			0.23			0.04	0.011	2	130		0.378
153	D331	SN490B 25mm	CO2, 5layer7pas	3.06	149	20.4	532	624	0.85	224	0.07	0.46	1.39	0.2			0.21			0.035	0.011	1	140		0.357
154	D332	SN490B 25mm	CO2, 5layer7pas	2.98	249	35.9	496	609	0.81	206	0.08	0.48	1.43	0.2			0.21			0.035	0.01	2	100		0.374
155	D333	SN490B 25mm	CO2, 5layer7pas	2.91	348	66.6	479	597	0.8	193	0.07	0.49	1.45	0.2			0.2			0.038	0.012	1	190		0.365
156	D334	SN490B 25mm	CO2, 5layer7pas	2.95	443	115	420	571	0.74	182	0.08	0.48	1.42	0.2			0.2			0.032	0.01	2	80		0.37
157	D343	SN490B 25mm	CO2, 5layer5pas	3.98	339	94.6	443	574	0.77	187	0.08	0.46	1.4	0.2			0.2			0.036	0.012	1	120		0.367
158	D344	SN490B 25mm	CO2, 5layer5pas	3.94	427	134	409	569	0.72	178	0.08	0.48	1.42	0.2			0.2			0.038	0.011	2	140		0.37
159	E321	SN490B 25mm	CO2, 6layer8pas	2.17	150	14.6	624	702	0.89	234	0.09	0.63	1.54	0.2			0.21			0.049	0.008	6	100		0.402
160	E322	SN490B 25mm	CO2, 6layer8pas	2.16	250	23.9	596	682	0.87	224	0.09	0.6	1.55	0.2			0.19			0.049	0.01	6	130		0.4
161	E331	SN490B 25mm	CO2, 5layer6pas	3.02	150	20.5	582	672	0.87	228	0.09	0.6	1.5	0.2			0.2			0.049	0.01	6	130		0.393
162	E332	SN490B 25mm	CO2, 5layer6pas	3.18	249	38.6	545	649	0.84	216	0.09	0.56	1.43	0.2			0.2			0.039	0.008	5	130		0.382
163	E333	SN490B 25mm	CO2, 5layer6pas	3	350	66.8	535	676	0.79	221	0.09	0.64	1.58	0.2			0.19			0.058	0.008	6	130		0.405
164	E334	SN490B 25mm	CO2, 5layer6pas	3	390	92.2	502	672	0.75	208	0.1	0.62	1.6	0.2			0.18			0.057	0.012	6	100		0.416
165	E343	SN490B 25mm	CO2, 4layer5pas	4.1	350	101	479	633	0.76	203	0.09	0.57	1.55	0.2			0.18			0.044	0.01	6	80		0.398
166	E344	SN490B 25mm	CO2, 4layer5pas	4.2	438	150	435	609	0.71	194	0.1	0.56	1.5	0.2			0.17			0.042	0.01	6	110		0.397
167	G321	SN490B 25mm	CO2, 6layer9pas	2.01	150	13.5	604	676	0.89	232	0.08	0.61	1.43	0.2			0.24			0.049	0.005	5	40		0.38
168	G322	SN490B 25mm	CO2, 5layer7pas	2.03	250	21.8	563	647	0.87	219	0.08	0.58	1.44	0.2			0.23			0.043	0.004	4	60		0.379
169	G331	SN490B 25mm	CO2, 5layer6pas	3.05	150	20.5	552	637	0.87	224	0.08	0.57	1.38	0.2			0.24			0.036	0.005	4	60		0.371
170	G332	SN490B 25mm	CO2, 5layer6pas	3.06	250	35.1	488	604	0.81	213	0.08	0.53	1.39	0.2			0.22			0.037	0.005	3	40		0.369
171	G333	SN490B 25mm	CO2, 5layer6pas	3.04	350	71	456	584	0.78	197	0.09	0.52	1.35	0.2			0.22			0.033	0.004	4	50		0.372
172	G334	SN490B 25mm	CO2, 5layer6pas	3.06	430	113	415	583	0.71	185	0.08	0.55	1.38	0.2			0.22			0.039	0.004	4	60		0.367
173	G343	SN490B 25mm	CO2, 5layer5pas	4.08	350	101	429	580	0.74	182	0.09	0.51	1.38	0.2			0.2			0.034	0.005	4	40		0.373
174	G344	SN490B 25mm	CO2, 5layer5pas	4.1	450	152	411	574	0.72	184	0.08	0.52	1.35	0.2			0.22			0.034	0.005	3	60		0.362

Table 4 Chemical Composition and Mechanical Properties of SMAW

No	Product	Steel	Welding Process	Arc Energy (kJ/mm)	Interpas Temp(degC)	Estimate t8/5 (s	YS (MPa)	TS (MPa)	YR (%)	EL (%)	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	T.Ti	T.Al	B (ppm)	N (ppm)	O (ppm)	CE(IIW)
1	G200(NSW)	All weld me	(Multi-run	1.30	100	7.6	390	450	0.87	31	0.070	0.08	0.46												0.147
2	B1(NSW)			1.30	100	7.6	410	460	0.89	31	0.090	0.10	0.42												0.160
3	A200(NSW)			1.30	100	7.6	410	460	0.89	30	0.080	0.12	0.40												0.147
4	G300(NSW)			1.30	100	7.6	400	460	0.87	32	0.080	0.13	0.53												0.168
5	A1(NSW)			1.30	100	7.6	400	460	0.87	30	0.060	0.18	0.38												0.123
6	EX-3A(NSW)			1.30	100	7.6	440	460	0.96	33	0.070	0.16	0.41												0.138
7	L16(NSW)			1.70	100	8.7	460	540	0.85	34	0.070	0.58	1.10												0.253
8	L16W(NSW)			1.60	100	8.3	480	580	0.83	32	0.070	0.61	0.90												0.220
9	L55(NSW)			1.70	100	8.7	480	550	0.87	32	0.070	0.62	1.18												0.267
10	L16LH(NSW)			1.70	100	8.7	440	510	0.86	34	0.050	0.48	0.64												0.157
11	L60(NSW)			1.70	100	8.7	540	640	0.84	29	0.070	0.42	1.12		0.73		0.22								0.349
12	L60S(NSW)			1.70	100	8.7	580	650	0.89	29	0.050	0.46	1.12		1.51		0.20								0.377
13	L62(NSW)			1.70	100	8.7	600	670	0.90	31	0.070	0.48	1.39		0.76		0.35								0.422
14	L60LT(NSW)			1.70	100	8.7	600	680	0.88	28	0.070	0.41	1.51		0.67		0.18			0.03		20			0.402
15	L80(NSW)			1.70	100	8.7	740	830	0.89	24	0.050	0.44	1.35		2.52	0.18	0.54								0.587
16	L80EL(NSW)			1.70	100	8.7	740	820	0.90	24	0.060	0.45	1.44		2.44	0.20	0.42								0.587
17	L80SN(NSW)			1.70	100	8.7	760	860	0.88	22	0.050	0.36	1.39		4.64		0.48								0.687
18	L60W(NSW)			1.70	100	8.7	550	630	0.87	31	0.070	0.6	1.02		0.51		0.19								0.312
19	L60G(NSW)			2.30	100	14.8	530	630	0.84	30	0.060	0.78	1.04		0.72		0.28								0.337
20	L62CF(NSW)			1.70	100	8.7	590	660	0.89	30	0.070	0.45	1.36		0.70		0.35								0.413
21	L70(NSW)			1.70	100	8.7	660	750	0.88	26	0.050	0.41	1.16		2.10		0.48								0.479
22	L85(NSW)			1.70	100	8.7	820	870	0.94	23	0.040	0.48	1.25		2.46	0.76	0.49								0.662
23	L100EL(NSW)			1.70	100	8.7	910	990	0.92	21	0.060	0.25	1.67		2.01	0.89	0.75								0.800
24	CT03Cr(NSW)			1.40	100	6.3	500	570	0.88	31	0.050	0.16	0.41	0.32	0.15	0.48									0.246
25	CT16Cr(NSW)			1.70	100	8.7	500	560	0.89	31	0.040	0.37	0.62	0.35	0.14	0.50									0.276
26	CT16VCr(NSW)			1.70	100	8.7	520	570	0.91	31	0.060	0.41	0.72	0.32	0.13	0.47									0.304
27	CT26GCr(NSW)			2.60	100	14.8	470	550	0.85	30	0.060	0.22	1.28	0.33	0.16	0.47									0.400
28	CT60Cr(NSW)			1.70	100	8.7	520	610	0.85	27	0.070	0.38	0.67	0.44	0.62	0.56									0.364
29	CT60GCr(NSW)			2.60	100	14.8	590	640	0.92	28	0.040	0.48	1.08	0.48	0.50	0.52									0.389
30	ST03(NSW)			1.40	100	8	440	500	0.88	30	0.070	0.10	0.50	0.35											0.177
31	ST16(NSW)			1.70	100	8.7	450	540	0.83	34	0.070	0.48	0.50	0.37											0.178
32	ST03Cr(NSW)			1.70	100	8.7	460	530	0.87	28	0.060	0.15	0.56	0.23		0.79									0.327
33	ST16Cr(NSW)			1.70	100	8.7	480	550	0.87	29	0.050	0.50	0.48	0.20		0.73									0.289
34	RS55(NSW)			1.70	100	8.7	500	590	0.85	28	0.050	0.53	0.57			1.00									0.345
35	RS55G(NSW)			1.70	100	8.7	540	610	0.89	26	0.050	0.62	0.52	0.18		0.73	0.13								0.321
36	L55SN(NSW)			1.70	100	8.7	530	580	0.91	30	0.070	0.42	1.41		0.57					0.02		20			0.343
37	N11(NSW)			1.70	100	8.7	540	610	0.89	31	0.070	0.49	1.15		1.62										0.370
38	N12(NSW)			1.70	100	8.7	520	600	0.87	30	0.060	0.44	1.02		2.38										0.389
39	N13(NSW)			1.70	100	8.7	500	580	0.86	31	0.050	0.42	0.46		3.35										0.350
40	N17(NSW)			1.70	100	8.7	670	730	0.92	21	0.040	0.14	0.26		7.91										0.611
41	N110(NSW)			1.70	100	8.7	520	570	0.91	31	0.070	0.21	1.57							0.03		30			0.332
42	L55S(NSW)			1.70	100	8.7	460	560	0.82	29	0.070	0.45	0.98												0.233
43	N16(NSW)			1.70	100	8.7	600	680	0.88	23	0.040	0.17	0.28		6.65										0.530
44	N118(NSW)			1.70	100	8.7	520	580	0.90	30	0.060	0.23	1.60							0.03		40			0.327
45	Tifree1(Kobe)			2.40	120	14.5	898	1010	0.889		0.049	0.38	1.72		2.5	0.87	0.85			0.003	0.008		130	170	0.846
46	Tifree2(Kobe)			1.73	120	10.1	729	869	0.839	22	0.041	0.58	1.77		2.71		0.78			0.002			120	260	0.673
47	Tibear1(Kobe)			1.73	120	10.1	727	863	0.842	23	0.040	0.52	1.73		2.78		0.79						150	220	0.672
48	Tibear2(Kobe)			2.40	120	14.5	873	961	0.908		0.048	0.4	1.25		2.51	0.74	0.64			0.015	0.005		180	210	0.700
49	Ti-B(Kobe)			1.73	120	10.1	793	877	0.904	24	0.039	0.64	1.84		2.83		0.82			0.016		34	100	220	0.698

Table 5 Chemical Composition and Mechanical Properties of SMAW (U. Cambridge Data)

No	Weld ID	Process	Arc Eneg (kJ/mm)	IP (oC)	t/8/5-est (s)	PWHT (oC)	PWHT (hr)	YS (MPa)	TS (MPa)	Hv	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	Ti	Al	B (ppm)	N (ppm)	O (ppm)	CE(IIW)
1	Evans	MMA	1	200	7.9	250	14	392	466		0.037	0.3	0.65		0										0.145
4	Evans	MMA	1	200	7.9	250	14	413	498		0.037	0.31	1.03		0										0.209
7	Evans	MMA	1	200	7.9	250	14	468	551		0.044	0.35	1.43		0										0.282
10	Evans	MMA	1	200	7.9	250	14	514	588		0.045	0.33	1.85		0										0.353
13	Evans	MMA	1	200	7.9	250	14	411	484		0.039	0.32	0.66		0.53										0.184
15	Evans	MMA	1	200	7.9	250	14	464	522		0.041	0.33	1.01		0.49										0.242
18	Evans	MMA	1	200	7.9	250	14	509	568		0.051	0.32	1.4		0.47										0.316
20	Evans	MMA	1	200	7.9	250	14	547	618		0.049	0.33	1.85		0.51										0.391
23	Evans	MMA	1	200	7.9	250	14	423	497		0.038	0.31	0.63		1.09										0.216
26	Evans	MMA	1	200	7.9	250	14	475	541		0.043	0.33	1		1.1										0.283
29	Evans	MMA	1	200	7.9	250	14	498	569		0.049	0.35	1.37		1.06										0.348
32	Evans	MMA	1	200	7.9	250	14	566	641		0.053	0.35	1.83		1.06										0.429
35	Evans	MMA	1	200	7.9	250	14	466	538		0.041	0.3	0.62		2.38										0.303
38	Evans	MMA	1	200	7.9	250	14	489	567		0.044	0.31	0.96		2.38										0.363
41	Evans	MMA	1	200	7.9	250	14	567	635		0.049	0.32	1.41		2.32										0.439
44	Evans	MMA	1	200	7.9	250	14	621	684		0.046	0.32	1.81		2.33										0.503
47	Evans	MMA	1	200	7.9	250	14	479	561		0.037	0.3	0.65		3.5										0.379
50	Evans	MMA	1	200	7.9	250	14	525	605		0.041	0.31	0.98		3.46										0.435
53	Evans	MMA	1	200	7.9	250	14	621	682		0.048	0.33	1.4		3.47										0.513
56	Evans	MMA	1	200	7.9	250	14	692	753		0.051	0.36	1.79		3.42										0.577
59	WJ59	MMA	1	150	6.5	0	0	484	560		0.074	0.36	1.51	0.02						0.004				400	0.327
61	WJ59	MMA	1	150	6.5	0	0	502	578		0.075	0.36	1.48	0.11						0.004				390	0.329
63	WJ59	MMA	1	150	6.5	0	0	488	566		0.074	0.32	1.42	0.19						0.004				380	0.323
65	WJ59	MMA	1	150	6.5	0	0	504	586		0.076	0.33	1.48	0.35						0.004				400	0.346
67	WJ59	MMA	1	150	6.5	0	0	513	593		0.068	0.32	1.49	0.66						0.004				390	0.360
69	WJ59	MMA	1	150	6.5	0	0	568	647		0.076	0.36	1.49	1.4						0.004				410	0.418
71	Evans	MMA	1	200	7.9	250	14	431	527		0.074	0.29	1.49							0.0005	0.0006		72	471	0.322
75	Evans	MMA	1	200	7.9	250	14	444	542		0.081	0.29	1.43							0.0005	0.006		54	461	0.319
79	Evans	MMA	1	200	7.9	250	14	437	527		0.076	0.34	1.36							0.0005	0.015		57	476	0.303
83	Evans	MMA	1	200	7.9	250	14	437	538		0.079	0.39	1.37							0.0005	0.025		47	446	0.307
87	Evans	MMA	1	200	7.9	250	14	469	545		0.078	0.44	1.4							0.0005	0.042		44	436	0.311
91	Evans	MMA	1	200	7.9	250	14	466	551		0.081	0.48	1.42							0.0004	0.066		46	444	0.318
95	Evans	MMA	1	200	7.9	250	14	468	529		0.069	0.3	1.36							0.0037	0.0005		68	432	0.296
99	Evans	MMA	1	200	7.9	250	14	478	540		0.08	0.33	1.41							0.0043	0.0078		55	432	0.315
103	Evans	MMA	1	200	7.9	250	14	485	549		0.076	0.37	1.36							0.0036	0.019		53	422	0.303
107	Evans	MMA	1	200	7.9	250	14	491	564		0.078	0.44	1.31							0.0036	0.034		50	431	0.296
111	Evans	MMA	1	200	7.9	250	14	485	560		0.076	0.51	1.3							0.0043	0.049		48	423	0.293
115	Evans	MMA	1	200	7.9	250	14	491	570		0.079	0.57	1.32							0.0038	0.061		52	422	0.299
119	Evans	MMA	1	200	7.9	250	14	484	547		0.074	0.32	1.5							0.0099	0.0008		89	375	0.324
122	Evans	MMA	1	200	7.9	250	14	442	514		0.074	0.27	1.41							0.0088	0.0047		70	407	0.309
125	Evans	MMA	1	200	7.9	250	14	481	545		0.071	0.39	1.36							0.0092	0.016		52	381	0.298
128	Evans	MMA	1	200	7.9	250	14	474	540		0.069	0.45	1.36							0.0063	0.028		44	374	0.296
131	Evans	MMA	1	200	7.9	250	14	466	533		0.069	0.51	1.39							0.0069	0.048		41	379	0.301
134	Evans	MMA	1	200	7.9	250	14	486	555		0.072	0.57	1.4							0.008	0.064		38	360	0.305
137	Evans	MMA	1	200	7.9	250	14	502	555		0.081	0.34	1.54							0.018	0.0003		80	312	0.338
141	Evans	MMA	1	200	7.9	250	14	452	535		0.072	0.24	1.32							0.018	0.0047		68	397	0.292
145	Evans	MMA	1	200	7.9	250	14	467	522		0.072	0.34	1.33							0.019	0.015		57	427	0.294
149	Evans	MMA	1	200	7.9	250	14	514	570		0.074	0.41	1.36							0.026	0.032		49	418	0.301
153	Evans	MMA	1	200	7.9	250	14	522	580		0.066	0.46	1.41							0.024	0.044		49	407	0.301
157	Evans	MMA	1	200	7.9	250	14	522	591		0.066	0.44	1.33							0.024	0.068		49	454	0.288
161	Evans	MMA	1	200	7.9	250	14	535	594		0.069	0.43	1.49							0.046	0.0001		77	294	0.317
165	Evans	MMA	1	200	7.9	250	14	522	583		0.071	0.36	1.44							0.046	0.0067		94	373	0.311
169	Evans	MMA	1	200	7.9	250	14	531	587		0.071	0.42	1.39							0.042	0.015		65	446	0.303
173	Evans	MMA	1	200	7.9	250	14	538	604		0.071	0.52	1.44							0.046	0.03		67	466	0.311
181	Evans	MMA	1	200	7.9	250	14	547	616		0.067	0.57	1.4							0.045	0.05		60	451	0.300
220	Evans	MMA	1	200	7.9	250	14	413	498		0.037	0.31	1.03			0									0.209
223	Evans	MMA	1	200	7.9	250	14	468	551		0.044	0.35	1.43			0									0.282
226	Evans	MMA	1	200	7.9	250	14	514	588		0.045	0.33	1.85			0									0.353
229	Evans	MMA	1	200	7.9	250	14	422	496		0.038	0.3	0.65			0.22									0.190
231	Evans	MMA	1	200	7.9	250	14	463	532		0.041	0.32	1.01			0.24									0.257
234	Evans	MMA	1	200	7.9	250	14	500	575		0.044	0.32	1.45			0.24									0.334
236	Evans	MMA	1	200	7.9	250	14	567	622		0.048	0.33	1.85			0.26									0.408
239	Evans	MMA	1	200	7.9	250	14	446	510		0.04	0.33	0.6			0.51									0.242
242	Evans	MMA	1	200	7.9	250	14	494	545		0.043	0.31	0.95			0.53									0.307
245	Evans	MMA	1	200	7.9	250	14	543	603		0.047	0.33	1.42			0.53									0.390
248	Evans	MMA	1	200	7.9	250	14	617	674		0.051	0.33	1.83			0.52									0.460
251	Evans	MMA	1	200	7.9	250	14	472	531		0.041	0.3	0.59			1									0.339

No	Weld ID	Process	Arc Eneg (kJ/mm)	IP (oC)	t/8/5-est (s)	PWHT (oC)	PWHT (hr)	YS (MPa)	TS (MPa)	Hv	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	Ti	Al	B (ppm)	N (ppm)	O (ppm)	CE(IIW)
254	Evans	MMA	1	200	7.9	250	14	531	592		0.045	0.32	0.97			1.04									0.415
257	Evans	MMA	1	200	7.9	250	14	626	676		0.048	0.33	1.37			1.08									0.492
260	Evans	MMA	1	200	7.9	250	14	692	723		0.052	0.33	1.81			1.1									0.574
263	Evans	MMA	1	200	7.9	250	14	587	652		0.041	0.27	0.59			2.34									0.607
266	Evans	MMA	1	200	7.9	250	14	655	722		0.046	0.3	0.93			2.38									0.677
269	Evans	MMA	1	200	7.9	250	14	738	789		0.05	0.31	1.29			2.32									0.729
272	Evans	MMA	1	200	7.9	250	14	808	865		0.054	0.33	1.72			2.36									0.813
275	Evans	MMA	1	200	7.9	250	14	468	529		0.069	0.3	1.36					0	0	0.0037	0	0	67	432	0.296
282	Evans	MMA	1	200	7.9	250	14	475	536		0.073	0.33	1.39					0	0	0.0039	0.002	0	66	427	0.305
287	Evans	MMA	1	200	7.9	250	14	478	541		0.078	0.32	1.39					0	0	0.0042	0.0044	0	66	436	0.310
293	Evans	MMA	1	200	7.9	250	14	478	540		0.08	0.33	1.41					0	0	0.0043	0.0078	0	61	432	0.315
300	Evans	MMA	1	200	7.9	250	14	480	543		0.08	0.37	1.42					0	0	0.0043	0.012	0	54	439	0.317
306	Evans	MMA	1	200	7.9	250	14	485	549		0.076	0.37	1.36					0	0	0.0036	0.019	0	54	422	0.303
313	Evans	MMA	1	200	7.9	250	14	491	564		0.078	0.44	1.31					0	0	0.0036	0.034	0	52	431	0.296
320	Evans	MMA	1	200	7.9	250	14	485	560		0.076	0.51	1.3					0	0	0.0043	0.049	0	50	423	0.293
327	Evans	MMA	1	200	7.9	250	14	491	570		0.079	0.57	1.32					0	0	0.0038	0.061	0	48	422	0.299
334	Evans	MMA	1	200	7.9	250	14	402	494		0.073	0.35	0.64					0	0.0003	0.0038	0	0	77	428	0.180
337	Evans	MMA	1	200	7.9	250	14	436	513		0.071	0.36	0.63					0.0005	0.021	0.0043	0	0	78	435	0.180
340	Evans	MMA	1	200	7.9	250	14	478	546		0.071	0.4	0.64					0.0005	0.0435	0.0036	0	0	88	411	0.186
343	Evans	MMA	1	200	7.9	250	14	488	548		0.074	0.36	0.63					0.0005	0.06	0.0031	0	0	75	432	0.191
346	Evans	MMA	1	200	7.9	250	14	490	563		0.072	0.36	0.64					0.0005	0.0815	0.0034	0	0	84	436	0.195
349	Evans	MMA	1	200	7.9	250	14	443	522		0.077	0.35	1.02					0.0005	0.0004	0.0041	0	0	75	399	0.247
352	Evans	MMA	1	200	7.9	250	14	456	534		0.076	0.34	1.01					0.0005	0.0215	0.0037	0	0	75	426	0.249
355	Evans	MMA	1	200	7.9	250	14	505	570		0.078	0.31	1.04					0.0005	0.044	0.0032	0	0	48	429	0.260
358	Evans	MMA	1	200	7.9	250	14	509	576		0.076	0.33	1.04					0.0005	0.061	0.0031	0	0	70	429	0.262
361	Evans	MMA	1	200	7.9	250	14	538	592		0.077	0.32	1.05					0.0005	0.085	0.0034	0	0	72	400	0.269
364	Evans	MMA	1	200	7.9	250	14	463	541		0.077	0.31	1.33					0.0006	0.0004	0.0038	0	0	80	419	0.299
367	Evans	MMA	1	200	7.9	250	14	486	545		0.072	0.33	1.22					0.0005	0.019	0.0029	0	0	85	447	0.279
370	Evans	MMA	1	200	7.9	250	14	536	590		0.077	0.26	1.36					0.0005	0.0425	0.0029	0	0	79	410	0.312
373	Evans	MMA	1	200	7.9	250	14	521	589		0.078	0.3	1.35					0.0005	0.0595	0.003	0	0	76	405	0.315
376	Evans	MMA	1	200	7.9	250	14	599	638		0.076	0.26	1.36					0.0005	0.1005	0.0029	0	0	83	407	0.323
379	Evans	MMA	1	200	7.9	250	14	500	571		0.076	0.29	1.74					0.0006	0.0004	0.0035	0	0	92	415	0.366
382	Evans	MMA	1	200	7.9	250	14	543	607		0.077	0.26	1.73					0.0005	0.0235	0.0027	0	0	72	423	0.370
385	Evans	MMA	1	200	7.9	250	14	578	617		0.077	0.26	1.72					0.0005	0.041	0.0025	0	0	74	423	0.372
388	Evans	MMA	1	200	7.9	250	14	589	650		0.076	0.25	1.72					0.0005	0.0605	0.0025	0	0	86	405	0.375
391	Evans	MMA	1	200	7.9	250	14	639	681		0.08	0.26	1.74					0.0005	0.083	0.0025	0	0	90	411	0.387
394	Evans	MMA	1	200	7.9	250	14	402	494		0.073	0.35	0.64					0	0.0003	0.0038	0	0	77	428	0.180
397	Evans	MMA	1	200	7.9	250	14	450	532		0.073	0.34	0.64					0.012	0.0003	0.0041	0	0	80	431	0.180
400	Evans	MMA	1	200	7.9	250	14	474	553		0.075	0.33	0.62					0.022	0.0003	0.0042	0	0	85	429	0.178
403	Evans	MMA	1	200	7.9	250	14	522	580		0.07	0.33	0.64					0.045	0.0007	0.0042	0	0	85	413	0.177
406	Evans	MMA	1	200	7.9	250	14	549	614		0.074	0.33	0.64					0.088	0.0003	0.0039	0	0	110	460	0.181
409	Evans	MMA	1	200	7.9	250	14	443	522		0.077	0.35	1.02					0	0.0004	0.0041	0	0	75	399	0.247
412	Evans	MMA	1	200	7.9	250	14	480	557		0.078	0.35	1.02					0.012	0.0004	0.0036	0	0	83	368	0.248
415	Evans	MMA	1	200	7.9	250	14	513	594		0.074	0.34	1					0.0255	0.0005	0.0037	0	0	86	424	0.241
418	Evans	MMA	1	200	7.9	250	14	553	618		0.074	0.33	0.99					0.0465	0.0004	0.0037	0	0	88	393	0.239
421	Evans	MMA	1	200	7.9	250	14	615	655		0.075	0.34	1.02					0.0985	0.0005	0.0037	0	0	79	417	0.245
424	Evans	MMA	1	200	7.9	250	14	463	541		0.077	0.31	1.33					0.0006	0.0004	0.0038	0	0	80	419	0.299
427	Evans	MMA	1	200	7.9	250	14	505	586		0.079	0.33	1.37					0.0105	0.0004	0.0034	0	0	97	417	0.307
430	Evans	MMA	1	200	7.9	250	14	540	597		0.076	0.3	1.36					0.0235	0.0004	0.0033	0	0	84	370	0.303
433	Evans	MMA	1	200	7.9	250	14	586	641		0.077	0.34	1.39					0.0455	0.0004	0.0032	0	0	99	409	0.309
436	Evans	MMA	1	200	7.9	250	14	610	685		0.076	0.3	1.36					0.094	0.0005	0.0033	0	0	91	432	0.303
439	Evans	MMA	1	200	7.9	250	14	500	571		0.076	0.29	1.74					0	0.0004	0.0035	0	0	92	415	0.366
442	Evans	MMA	1	200	7.9	250	14	540	614		0.077	0.32	1.77					0.0125	0.0004	0.0031	0	0	89	418	0.372
445	Evans	MMA	1	200	7.9	250	14	575	635		0.078	0.3	1.76					0.023	0.0004	0.0032	0	0	110	433	0.371
448	Evans	MMA	1	200	7.9	250	14	606	660		0.077	0.29	1.77					0.045	0.0004	0.0031	0	0	97	432	0.372
451	Evans	MMA	1	200	7.9	250	14	654	708		0.079	0.29	1.79					0.0895	0.0004	0.0033	0	0	105	406	0.377
454	Evans	MMA	2	200	19.1	250	14	427	512		0.062	0.22	1.17										120	330	0.257
455	Evans	MMA	2	200	19.1	250	14	440	523		0.06	0.26	1.2										150	320	0.260
456	Evans	MMA	2	200	19.1	250	14	443	508		0.06	0.25	1.19										110	353	0.258
457	Evans	MMA	2	200	19.1	250	14	468	531		0.062	0.31	1.24										110	366	0.269
458	Evans	MMA	1	200	7.9	250	14	435	510		0.055	0.33	1.39										70	323	0.287
459	Evans	MMA	1	200	7.9	250	14	430	505		0.049	0.34	1.39										65	339	0.281
460	Evans	MMA	1	200	7.9	250	14	433	504		0.048	0.31	1.34										75	371	0.271
461	Evans	MMA	1	200	7.9	250	14	465	526		0.048	0.36	1.3										70	401	0.265
462	Evans	MMA	1	200	7.9	250	14	442	524		0.059	0.29	1.49										110	305	0.307
463	Evans	MMA	1	200	7.9	250	14	497	559		0.051	0.31	1.64										60	330	0.324
464	Evans	MMA	1	200	7.9	250	14	487	555		0.069	0.53	1.17										120	365	0.264
465	Evans	MMA	1	200	7.9	250	14	494	569		0.068	0.36	1.56										90	396	0.328
466	Evans	MMA	1	200	7.9	580	2	373	448		0.043	0.3	0.69												0.158

No	Weld ID	Process	Arc Eneg (kJ/mm)	IP (oC)	t/8/5-est (s)	PWHT (oC)	PWHT (hr)	YS (MPa)	TS (MPa)	Hv	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	Ti	Al	B (ppm)	N (ppm)	O (ppm)	CE(IIW)
580	Evans	ShMA	1	200	7.9	250	14	482	548		0.073	0.34	1.49							0.0016			84	396	0.321
584	Evans	ShMA	1	200	7.9	250	14	497	563		0.071	0.36	1.46							0.0022			85	400	0.314
588	Evans	ShMA	1	200	7.9	250	14	474	538		0.061	0.33	1.36							0.0028			81	419	0.288
592	Evans	ShMA	1	200	7.9	250	14	488	549		0.07	0.32	1.48							0.0055			75	373	0.317
596	Evans	ShMA	1	200	7.9	250	14	466	542		0.068	0.32	1.38							0.0077			74	376	0.298
600	Evans	ShMA	1	200	7.9	250	14	499	569		0.068	0.35	1.51							0.01			87	351	0.320
604	Evans	ShMA	1	200	7.9	250	14	513	579		0.065	0.39	1.53							0.014			93	351	0.320
608	Evans	ShMA	1	200	7.9	250	14	515	592		0.07	0.48	1.64							0.021			102	290	0.343
612	Evans	ShMA	1	200	7.9	250	14	588	654		0.075	0.29	1.75							0.0255			96	272	0.367
616	Evans	MMA	1	200	7.9	250	14	404	494		0.074	0.35	0.63					0	0	0.0008	0	0	66	472	0.179
619	Evans	MMA	1	200	7.9	250	14	402	494		0.074	0.35	0.65					0	0	0.0036	0	0	73	426	0.182
622	Evans	MMA	1	200	7.9	250	14	396	492		0.075	0.35	0.66					0	0	0.0096	0	0	71	396	0.185
625	Evans	MMA	1	200	7.9	250	14	410	494		0.076	0.38	0.67					0	0	0.016	0	0	70	362	0.188
628	Evans	MMA	1	200	7.9	250	14	440	523		0.078	0.44	0.71					0	0	0.0225	0	0	76	306	0.196
631	Evans	MMA	1	200	7.9	250	14	409	504		0.077	0.3	1					0	0	0.0007	0	0	83	464	0.244
634	Evans	MMA	1	200	7.9	250	14	443	522		0.076	0.35	1.01					0	0	0.0041	0	0	74	401	0.244
637	Evans	MMA	1	200	7.9	250	14	427	516		0.075	0.31	1.03					0	0	0.0092	0	0	79	394	0.247
640	Evans	MMA	1	200	7.9	250	14	434	517		0.075	0.35	1.05					0	0	0.014	0	0	82	361	0.250
643	Evans	MMA	1	200	7.9	250	14	456	545		0.078	0.43	1.1					0	0	0.019	0	0	73	329	0.261
646	Evans	MMA	1	200	7.9	250	14	420	523		0.075	0.3	1.31					0	0	0.0005	0	0	81	441	0.293
649	Evans	MMA	1	200	7.9	250	14	463	541		0.077	0.32	1.33					0	0	0.0036	0	0	83	422	0.299
652	Evans	MMA	1	200	7.9	250	14	450	522		0.073	0.3	1.32					0	0	0.0075	0	0	77	401	0.293
655	Evans	MMA	1	200	7.9	250	14	464	544		0.079	0.33	1.35					0	0	0.014	0	0	78	375	0.304
658	Evans	MMA	1	200	7.9	250	14	485	559		0.08	0.39	1.37					0	0	0.0215	0	0	90	320	0.308
661	Evans	MMA	1	200	7.9	250	14	458	568		0.077	0.28	1.79					0	0	0.0007	0	0	82	439	0.375
664	Evans	MMA	1	200	7.9	250	14	500	571		0.078	0.31	1.75					0	0	0.0036	0	0	94	417	0.370
667	Evans	MMA	1	200	7.9	250	14	484	577		0.077	0.29	1.76					0	0	0.0105	0	0	81	396	0.370
670	Evans	MMA	1	200	7.9	250	14	510	590		0.075	0.32	1.83					0	0	0.017	0	0	82	346	0.380
673	Evans	MMA	1	200	7.9	250	14	536	612		0.079	0.37	1.82					0	0	0.0255	0	0	81	324	0.382
676	Kocak	MMA	1	200	7.9	0	0	445	528		0.074	0.25	1.4							0.0001			79	475	0.307
677	Kocak	MMA	1	200	7.9	0	0	471	544		0.077	0.27	1.46							0.0028			81	459	0.320
678	Kocak	MMA	1	200	7.9	0	0	478	540		0.073	0.26	1.41							0.009			83	392	0.308
679	Kocak	MMA	1	200	7.9	0	0	480	538		0.074	0.3	1.45							0.012			84	337	0.316
680	Kocak	MMA	1	200	7.9	0	0	509	578		0.072	0.38	1.5							0.026			77	291	0.322
681	Kocak	MMA	1	200	7.9	0	0	504	577		0.069	0.45	1.47							0.041			77	282	0.314
682	Kocak	MMA	1	200	7.9	0	0	530	597		0.07	0.45	1.5							0.055			75	294	0.320
683	Kocak	MMA	1	200	7.9	0	0	473	566		0.074	0.28	1.58							0			145	404	0.337
684	Kocak	MMA	1	200	7.9	0	0	482	545		0.068	0.28	1.4							0.0031			148	409	0.301
685	Kocak	MMA	1	200	7.9	0	0	522	584		0.069	0.31	1.5							0.0051			160	400	0.319
686	Kocak	MMA	1	200	7.9	0	0	513	573		0.07	0.29	1.5							0.012			164	341	0.320
687	Kocak	MMA	1	200	7.9	0	0	546	611		0.068	0.39	1.51							0.03			166	278	0.320
688	Kocak	MMA	1	200	7.9	0	0	584	639		0.066	0.47	1.48							0.041			164	285	0.313
689	Kocak	MMA	1	200	7.9	0	0	535	599		0.07	0.45	1.5							0.059			155	297	0.320
690	Kocak	MMA	1	200	7.9	0	0	505	607		0.073	0.27	1.66							0			235	399	0.350
691	Kocak	MMA	1	200	7.9	0	0	492	581		0.069	0.26	1.45							0.0029			226	391	0.311
692	Kocak	MMA	1	200	7.9	0	0	538	591		0.073	0.29	1.53							0.0046			243	419	0.328
693	Kocak	MMA	1	200	7.9	0	0	523	599		0.07	0.28	1.45							0.012			239	315	0.312
694	Kocak	MMA	1	200	7.9	0	0	546	621		0.067	0.4	1.48							0.032			253	286	0.314
695	Kocak	MMA	1	200	7.9	0	0	578	631		0.068	0.47	1.46							0.045			249	297	0.311
696	Kocak	MMA	1	200	7.9	0	0	552	615		0.066	0.43	1.47							0.069			240	322	0.311
697	Evans	MMA	1	150	6.5	0	0	392	466		0.035	0.3	0.66										70	490	0.145
699	Evans	MMA	1	150	6.5	0	0	413	498		0.038	0.3	1										100	460	0.205
701	Evans	MMA	1	150	6.5	0	0	468	551		0.049	0.34	1.42										90	410	0.286
703	Evans	MMA	1	150	6.5	0	0	514	588		0.051	0.34	1.82										90	390	0.354
705	Surian	MMA	2.1	107	12.8	0	0	665	715		0.05	0.25	1.21	0.06	1.84	0.05	0.34		0.01				143	444	0.458
707	Surian	MMA	2.1	107	12.8	0	0	768	807		0.07	0.26	1.24	0.06	1.9	0.05	0.34		0.01				119	365	0.487
709	Surian	MMA	2.1	107	12.8	0	0	798	858		0.1	0.34	1.42	0.05	1.92	0.05	0.35		0.01				87	345	0.550
711	Surian	MMA	2.1	107	12.8	0	0	808	875		0.12	0.33	1.41	0.05	1.88	0.05	0.34		0.01				99	329	0.564
713	Alekseev	MMA	1	200	7.9	0	0	481	616		0.04	0.24	0.84	0.13	2.2					0.015				300	0.335
714	Alekseev	MMA	1	200	7.9	0	0	471	596		0.04	0.22	0.81	0.29	2.19					0.012				300	0.340
715	Alekseev	MMA	1	200	7.9	0	0	498	599		0.04	0.23	0.83	0.45	2.19					0.014				280	0.354
716	Alekseev	MMA	1	200	7.9	0	0	525	623		0.04	0.24	0.82	0.62	2.2					0.015				300	0.365
717	Alekseev	MMA	1	200	7.9	0	0	536	635		0.04	0.23	0.83	0.79	2.21					0.014				320	0.378
718	Alekseev	MMA	1	200	7.9	0	0	566	674		0.04	0.23	0.83	1.01	2.21					0.013				320	0.393
719	Alekseev	MMA	1	200	7.9	0	0	573	690		0.04	0.2	0.8	1.2	2.2					0.014				370	0.400
733	Raiter	MMA	1.8	100	10.9	250	16	449	542		0.05	0.46	0.96	0.02	0.03		0.01						84	443	0.215
735	Raiter	MMA	1.8	100	10.9	250	16	494	570		0.045	0.48	0.97	0.02	0.03		0.32						107	430	0.274
737	Raiter	MMA	1.8	100	10.9	250	16	514	594		0.05	0.41	0.92	0.02	0.02		0.51						114	450	0.308
739	Raiter	MMA	1.8	100	10.9	250	16	550	615		0.06	0.44	1.6	0.02	0.03		0.01						102	395	0.332

No	Weld ID	Process	Arc Eneg (kJ/mm)	IP (oC)	t/8/5-est (s)	PWHT (oC)	PWHT (hr)	YS (MPa)	TS (MPa)	Hv	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	Ti	Al	B (ppm)	N (ppm)	O (ppm)	CE(IIW)
741	Raiter	MMA	1.8	100	10.9	250	16	612	688		0.06	0.46	1.63	0.02	0.02		0.34						106	407	0.402
743	Raiter	MMA	1.8	100	10.9	250	16	673	737		0.055	0.48	1.62	0.02	0.02		0.54						93	371	0.436
745	Raiter	MMA	1.8	100	10.9	250	16	583	664		0.06	0.42	2	0.02	0.02		0.01						117	371	0.398
747	Raiter	MMA	1.8	100	10.9	250	16	677	741		0.06	0.39	1.95	0.02	0.02		0.34						125	395	0.456
749	Raiter	MMA	1.8	100	10.9	250	16	701	748		0.055	0.39	1.99	0.02	0.02		0.54						102	364	0.497
908	Cunh	MMA	2.7	250	40	0	0	456.2	529.8	180	0.07	0.34	0.95	0	0	0	0	0.006	0.006	0.007	0.0035		90		0.230
910	Cunh	MMA	2.2	250	29	0	0	475.8	564.1	220	0.06	0.28	0.55	0.02	1.26	0	0	0.006	0.01	0.007	0.0035		70		0.239
912	Cunh	MMA	2.5	250	36	0	0	491.5	573.9	193	0.09	0.42	0.93	0.08	0	0	0.02	0.012	0.004	0.014	0.004		160		0.255
914	Cunh	MMA	2.4	250	33	0	0	503.3	591.5	213	0.08	0.33	0.65	0.02	0.5	0.35	0.008	0.015	0.004	0.02	0.0045		140		0.295
916	Cunh	MMA	2.8	250	43	0	0	479.7	583.7	189	0.07	0.61	1.07	0	0	0	0	0.004	0.014	0.0064	0.007		94		0.251
918	Cunh	MMA	2.6	250	40	0	0	463	552.3	181	0.07	0.21	0.75	0	0	0	0	0	0	0	0.0069		190		0.195
920	Cunh	MMA	1.8	150	12.9	0	0	486.8	569.3	183	0.09	0.44	0.9	0	0	0	0	0	0	0.02	0.0088		70		0.240
922	Cunh	MMA	1.8	140	12.5	0	0	453.8	536.3	184	0.08	0.35	0.65	0	1.2	0	0	0	0.02	0.004	0.015		100		0.272
924	Cunh	MMA	1.8	150	12.9	0	0	553.3	626.9	194	0.06	0.53	1.15	0	0	0.02	0	0	0	0	0.0057		100		0.256
926	Cunh	MMA	1.8	150	12.9	0	0	478.5	569.3	180	0.07	0.47	0.85	0	0	0	0	0	0.01	0.008	0.0043		120		0.214
928	Cunh	MMA	1.9	140	14.2	0	0	561.1	643.5	216	0.07	0.47	1.1	0	0	0	0	0	0.01	0.02	0.0053		190		0.255
930	Cunh	MMA	1.9	150	14.7	0	0	486.8	577.5	191	0.08	0.49	0.9	0	0	0.05	0	0	0	0.005	0.0108		170		0.240
1037	EvHtIp	MMA	0.6	200	5	250	14	445	496		0.044	0.32	0.62												
1039	EvHtIp	MMA	0.6	200	5	250	14	479	527		0.046	0.31	0.96												
1041	EvHtIp	MMA	0.6	200	5	250	14	511	575		0.05	0.38	1.42												
1043	EvHtIp	MMA	0.6	200	5	250	14	587	633		0.055	0.35	1.93												
1045	EvHtIp	MMA	1	200	7.9	250	14	401	466		0.037	0.29	0.6												
1047	EvHtIp	MMA	1	200	7.9	250	14	438	501		0.039	0.29	0.94												
1049	EvHtIp	MMA	1	200	7.9	250	14	479	551		0.048	0.35	1.41												
1051	EvHtIp	MMA	1	200	7.9	250	14	507	587		0.051	0.32	1.8												
1053	EvHtIp	MMA	2.2	200	21.3	250	14	389	457		0.038	0.24	0.55												
1055	EvHtIp	MMA	2.2	200	21.3	250	14	400	478		0.036	0.24	0.89												
1057	EvHtIp	MMA	2.2	200	21.3	250	14	438	518		0.042	0.28	1.37												
1059	EvHtIp	MMA	2.2	200	21.3	250	14	456	548		0.045	0.26	1.69												
1061	EvHtIp	MMA	4.3	200	66	250	14	341	453		0.043	0.2	0.52												
1063	EvHtIp	MMA	4.3	200	66	250	14	376	484		0.042	0.2	0.93												
1065	EvHtIp	MMA	4.3	200	66	250	14	405	500		0.043	0.24	1.37												
1067	EvHtIp	MMA	4.3	200	66	250	14	437	541		0.047	0.25	1.73												
1085	Evans-IP	MMA	1	20	4.5	250	14	450	506		0.036	0.31	0.6												
1086	Evans-IP	MMA	1	20	4.5	250	14	495	554		0.043	0.3	1.03												
1087	Evans-IP	MMA	1	20	4.5	250	14	542	597		0.046	0.31	1.39												
1088	Evans-IP	MMA	1	20	4.5	250	14	604	657		0.05	0.31	1.79												
1089	Evans-IP	MMA	1	150	6.5	250	14	411	475		0.039	0.28	0.58												
1090	Evans-IP	MMA	1	150	6.5	250	14	454	519		0.047	0.31	1												
1091	Evans-IP	MMA	1	150	6.5	250	14	486	556		0.046	0.31	1.4												
1092	Evans-IP	MMA	1	150	6.5	250	14	525	600		0.049	0.31	1.77												
1093	Evans-IP	MMA	1	240	10	250	14	390	465		0.037	0.28	0.6												
1094	Evans-IP	MMA	1	240	10	250	14	427	499		0.042	0.32	1.02												
1095	Evans-IP	MMA	1	240	10	250	14	448	525		0.047	0.31	1.37												
1096	Evans-IP	MMA	1	240	10	250	14	501	566		0.047	0.32	1.75												
1097	Evans-IP	MMA	1	300	15.6	250	14	371	452		0.042	0.25	0.55												
1098	Evans-IP	MMA	1	300	15.6	250	14	410	486		0.045	0.3	0.99												
1099	Evans-IP	MMA	1	300	15.6	250	14	431	513		0.047	0.27	1.32												
1100	Evans-IP	MMA	1	300	15.6	250	14	446	533		0.047	0.28	1.66												
1464	RC81033	MMA	1.0925	250	10.9	200	1	437	509		0.029	0.55	1.08	0	0	0	0	0	0				72	342	
1465	RC81033	MMA	1.0925	250	10.9	200	1	449	525		0.061	0.53	1.01	0	0	0	0	0	0				79	307	
1466	RC81033	MMA	1.0925	250	10.9	200	1	492	573		0.08	0.58	1.15	0	0	0	0	0	0				52	310	
1467	RC81033	MMA	1.0925	250	10.9	200	1	507	575		0.1	0.55	1.02	0	0	0	0	0	0				62	262	
1488	EvansLette	MMA	1	200	7.9	250	14	404	494		0.073	0.34	0.64	0	0	0	0	0	0	0.0007		0	63	450	
1491	EvansLette	MMA	1	200	7.9	250	14	423	501		0.064	0.3	0.63	0	0.92	0	0	0	0	0.0005		0	70	473	
1494	EvansLette	MMA	1	200	7.9	250	14	443	528		0.065	0.26	0.61	0	2.14	0	0	0	0	0.0005		0	86	488	
1497	EvansLette	MMA	1	200	7.9	250	14	457	543		0.062	0.29	0.62	0	3.01	0	0	0	0	0.0006		0	72	500	
1500	EvansLette	MMA	1	200	7.9	250	14	433	518		0.07	0.31	0.66	0	0	0	0.24	0	0	0.0005		0	79	430	
1503	EvansLette	MMA	1	200	7.9	250	14	470	559		0.073	0.34	0.66	0	0	0	0.5	0	0	0.0005		0	75	454	
1506	EvansLette	MMA	1	200	7.9	250	14	528	619		0.075	0.3	0.63	0	0	0	1.03	0	0	0.0005		0	80	438	
1509	EvansLette	MMA	1	200	7.9	250	14	481	559		0.07	0.35	0.65	0	0	1.01	0	0	0	0.0005		0	78	504	
1512	EvansLette	MMA	1	200	7.9	250	14	494	593		0.074	0.25	0.58	0	0	1.59	0	0	0	0.0004		0	89	500	
1515	EvansLette	MMA	1	200	7.9	250	14	565	660		0.076	0.28	0.64	0	0	2.1	0	0	0	0.0008		0	81	492	
1518	EvansLette	MMA	1	200	7.9	250	14	391	468		0.068	0.28	0.62	0.5	0	0	0	0	0	0.0005		0	73	477	
1521	EvansLette	MMA	1	200	7.9	250	14	439	509		0.065	0.3	0.62	1.03	0	0	0	0	0	0.0004		0	72	519	
1524	EvansLette	MMA	1	200	7.9	250	14	504	565		0.064	0.32	0.64	1.6	0	0	0	0	0	0.0004		0	60	498	
1527	EvansLette	MMA	1	200	7.9	250	14	402	494		0.073	0.35	0.64	0	0	0	0	0	0	0.0038		0	77	428	
1530	EvansLette	MMA	1	200	7.9	250	14	423	501		0.063	0.31	0.65	0	0.88	0	0	0	0	0.0038		0	85	472	
1533	EvansLette	MMA	1	200	7.9	250	14	461	537		0.064	0.27	0.61	0	2.17	0	0	0	0	0.0032		0	91	454	

No	Weld ID	Process	Arc Eneg (kJ/mm)	IP (oC)	t/8/5-est (s)	PWHT (oC)	PWHT (hr)	YS (MPa)	TS (MPa)	Hv	C	Si	Mn	Cu	Ni	Cr	Mo	Nb	V	Ti	Al	B (ppm)	N (ppm)	O (ppm)	CE(IIW)
1536	EvansLette	MMA	1	200	7.9	250	14	477	557		0.067	0.3	0.65	0	3.03	0	0	0	0	0.0036		0	72	460	
1539	EvansLette	MMA	1	200	7.9	250	14	436	519		0.069	0.33	0.68	0	0	0	0.24	0	0	0.0036		0	67	395	
1542	EvansLette	MMA	1	200	7.9	250	14	483	565		0.073	0.34	0.66	0	0	0	0.5	0	0	0.0042		0	70	433	
1545	EvansLette	MMA	1	200	7.9	250	14	565	644		0.072	0.32	0.66	0	0	0	1.03	0	0	0.004		0	76	411	
1548	EvansLette	MMA	1	200	7.9	250	14	490	558		0.077	0.32	0.66	0	0	1.03	0	0	0	0.0034		0	75	457	
1551	EvansLette	MMA	1	200	7.9	250	14	509	596		0.078	0.26	0.62	0	0	1.6	0	0	0	0.0029		0	100	472	
1554	EvansLette	MMA	1	200	7.9	250	14	598	685		0.078	0.28	0.64	0	0	2.15	0	0	0	0.0042		0	95	482	
1557	EvansLette	MMA	1	200	7.9	250	14	417	498		0.063	0.3	0.64	0.53	0	0	0	0	0	0.0043		0	74	453	
1560	EvansLette	MMA	1	200	7.9	250	14	429	497		0.064	0.3	0.63	1.05	0	0	0	0	0	0.0042		0	65	456	
1563	EvansLette	MMA	1	200	7.9	250	14	516	568		0.066	0.37	0.67	1.44	0	0	0	0	0	0.0051		0	55	453	
1566	EvansLette	MMA	1	200	7.9	250	14	434	526		0.078	0.26	1.43	0	0	0	0	0	0	0.0005		0	86	481	
1569	EvansLette	MMA	1	200	7.9	250	14	470	550		0.073	0.28	1.39	0	0.95	0	0	0	0	0.0005		0	76	454	
1572	EvansLette	MMA	1	200	7.9	250	14	512	605		0.071	0.26	1.48	0	2.28	0	0	0	0	0.0005		0	87	460	
1575	EvansLette	MMA	1	200	7.9	250	14	573	666		0.073	0.24	1.43	0	3.12	0	0	0	0	0.0005		0	77	460	
1578	EvansLette	MMA	1	200	7.9	250	14	474	570		0.076	0.28	1.53	0	0	0	0.25	0	0	0.0005		0	84	444	
1581	EvansLette	MMA	1	200	7.9	250	14	523	610		0.076	0.25	1.45	0	0	0	0.5	0	0	0.0005		0	78	457	
1584	EvansLette	MMA	1	200	7.9	250	14	594	699		0.076	0.24	1.41	0	0	0	1.11	0	0	0.0005		0	85	447	
1587	EvansLette	MMA	1	200	7.9	250	14	570	658		0.08	0.28	1.48	0	0	1.07	0	0	0	0.0005		0	94	436	
1590	EvansLette	MMA	1	200	7.9	250	14	591	687		0.075	0.28	1.48	0	0	1.55	0	0	0	0.0005		0	86	466	
1593	EvansLette	MMA	1	200	7.9	250	14	637	730		0.076	0.28	1.44	0	0	1.96	0	0	0	0.0005		0	84	476	
1596	EvansLette	MMA	1	200	7.9	250	14	453	535		0.08	0.24	1.47	0.55	0	0	0	0	0	0.0005		0	96	455	
1599	EvansLette	MMA	1	200	7.9	250	14	492	566		0.075	0.24	1.41	1.06	0	0	0	0	0	0.0005		0	89	484	
1602	EvansLette	MMA	1	200	7.9	250	14	559	638		0.074	0.22	1.36	1.63	0	0	0	0	0	0.0005		0	110	484	
1605	EvansLette	MMA	1	200	7.9	250	14	460	533		0.074	0.28	1.46	0	0	0	0	0	0	0.0035		0	79	443	
1608	EvansLette	MMA	1	200	7.9	250	14	498	551		0.076	0.25	1.48	0	0.95	0	0	0	0	0.0033		0	81	417	
1611	EvansLette	MMA	1	200	7.9	250	14	555	622		0.068	0.27	1.46	0	2.24	0	0	0	0	0.0034		0	78	436	
1614	EvansLette	MMA	1	200	7.9	250	14	604	680		0.075	0.26	1.46	0	3.15	0	0	0	0	0.0032		0	72	418	
1617	EvansLette	MMA	1	200	7.9	250	14	560	600		0.076	0.26	1.49	0	0	0	0.25	0	0	0.0034		0	89	412	
1620	EvansLette	MMA	1	200	7.9	250	14	596	642		0.075	0.26	1.46	0	0	0	0.5	0	0	0.0031		0	86	429	
1623	EvansLette	MMA	1	200	7.9	250	14	650	720		0.075	0.25	1.44	0	0	0	1.07	0	0	0.0031		0	83	432	
1626	EvansLette	MMA	1	200	7.9	250	14	624	672		0.079	0.3	1.56	0	0	1.03	0	0	0	0.0027		0	98	431	
1629	EvansLette	MMA	1	200	7.9	250	14	650	710		0.073	0.29	1.53	0	0	1.53	0	0	0	0.0027		0	79	438	
1632	EvansLette	MMA	1	200	7.9	250	14	706	772		0.078	0.29	1.48	0	0	1.96	0	0	0	0.0028		0	82	438	
1635	EvansLette	MMA	1	200	7.9	250	14	495	557		0.076	0.27	1.48	0.53	0	0	0	0	0	0.0022		0	81	454	
1638	EvansLette	MMA	1	200	7.9	250	14	487	563		0.077	0.25	1.43	1.08	0	0	0	0	0	0.0019		0	92	456	
1641	EvansLette	MMA	1	200	7.9	250	14	570	625		0.069	0.25	1.37	1.6	0	0	0	0	0	0.0023		0	75	475	