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Results and Analysis of The ASTM Round Robin On Reconstitution

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ABSTRACT

In 1992, the American Society for Testing and Materials (ASTM) initiated a Round Robin on Reconstitution (RRR) to contribute to the review of ASTM E1253 Guide on Charpy specimen reconstitution. The purpose of this RRR is to study the influence of parameters, such as the reconstitution technique, the insert length, the hammer tup geometry and the material. Ten laboratories participated in the RRR and performed Charpy specimen reconstitution on unirradiated material according to a pre-defined test matrix with both 10- and 14-mm inserts. All Charpy impact tests were conducted by the U.S. Nuclear Regulatory Commission sponsored Heavy-Section Steel Irradiation Program. Comparison of the absorbed energy and lateral expansion before and after reconstitution demonstrates that the loss due to reconstitution can be characterized by the combination of the insert length, the welding method, and the tup geometry used. In general, stud and upset-butt welding combined with the ASTM tup show the highest difference in energy whereas electron-beam welding with the ISO tup indicates the least. The variations among welding techniques and laboratories are also described. It is concluded that reconstitution does not affect any characteristic loads in the instrumented load-time traces, and that the 10-mm insert length should not be used in the upper shelf or mid-transition temperature region.

KEYWORDS: surveillance, Charpy, reconstitution, absorbed energy, insert, welding technique, instrumented Charpy impact test, load diagram

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FOREWORD

The work reported here was performed at the Oak Ridge National Laboratory (ORNL) under the Heavy-Section Steel Irradiation (HSSI) Program, T. M. Rosseel, Program Manager. The program is sponsored by the Office of Nuclear Regulatory Research of the U.S. Nuclear Regulatory Commission (NRC). The technical monitor for the NRC is C. J. Fairbanks.

This report is designated HSSI Report 28. Reports in this series are listed below:

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1 INTRODUCTION

Charpy specimen reconstitution is used by many organizations around the world as a tool to enhance or supplement reactor pressure vessel surveillance programs. The American Society for Testing and Materials (ASTM) Standard Guide on the Reconstitution of Irradiated Charpy Specimens (E1253) provides guidelines to reconstitute an irradiated broken Charpy V-notch impact specimen. This guide was written with the technical knowledge of reconstitution welding, impact testing of reconstituted specimens and analysis of test results available at that time [1-3]. Only one set of results on irradiated materials were available at that time [4]. The underlying principles in the development of ASTM E1253 are: 1) no deformation from prior testing would be allowed in the central test section because prior deformation in this region would obviously affect the results of the reconstituted specimen; 2) to preclude annealing the irradiation damage, the temperature of the central 10 mm portion in the reconstituted specimen could not exceed the irradiation temperature; 3) the reconstitution process must be qualified so that specimens will provide satisfactory results (this was done by comparing results from the reconstituted specimens with those of the virgin specimens); and 4) the plastic deformation of the reconstituted specimens must be contained within the heat-affected-zones (HAZs) of the reconstitution welds.

The 14 mm requirement was established through hardness measurements, direct measurements of plastic zones, and calculated plastic zone size using slip line theory for Charpy specimens with the highest absorbed energy. The standard allows a smaller central test section if it can be established that the plastic zone will be within the HAZs of the reconstitution welds. In 1992, ASTM initiated a Round Robin on Reconstitution (RRR) to provide more data on reconstitution variables and to evaluate variability of results from Charpy specimens reconstituted in accordance with ASTM E1253. The RRR specifically addressed the effects of the reconstitution technique, the insert length and the tup geometry on the results of Charpy-V impact tests on unirradiated materials. Ten laboratories world-wide participated in the RRR by reconstituting Charpy specimens according to a well defined test matrix using broken Charpy specimens. The results of the RRR and the analysis of this report will potentially guide changes to ASTM E1253. A comprehensive review of the status of reconstitution technique can be found in reference [5].

This report presents a summary of the RRR and the analysis of the RRR data, and compares the data obtained from reconstituted specimens prepared by the participants.

2 PROGRAM DESCRIPTION

2.1 Procedure and Test Matrix

Table 1 gives the test matrix specifying the number of specimens, insert length, test temperature, material, and tup. The parameters in this testing program are the material, the insert length and the hammer tup geometry used to perform the Charpy impact tests.

Table 1– Test matrix of the ASTM Round-Robin on Reconstitution.

(a) Reconstitution

Material	HSST-03		Linde 80	
Insert length	10 mm	14 mm	10 mm	14 mm
No. of specimens	12	12	12	12
Total of specimens	48			

(b) Charpy testing for each 12-specimen set

Tup geometry	ASTM-tup		ISO-tup	
Test temperature	-12 °C	93 °C	2 °C	93 °C
No. of specimens	4	2	4	2

Two materials were selected for the RRR; 1) a high upper shelf plate*1 (HSST-03) and 2) a low upper shelf weld*2 (Linde 80). These materials were selected to assess the effect of absorbed energy on the results of reconstituted Charpy specimens. The cutting diagrams with the location of each specimen within each block can be found in Appendix A. The virgin Charpy V-notch specimens were tested under the U.S. Nuclear Regulatory Commission-sponsored Heavy-Section Steel Irradiation Program at Oak Ridge National Laboratory (ORNL). The hammer tup geometries used are the ASTM type according to ASTM Test Methods for Notched Bar Impact Testing of Metallic Materials (E23) with 8 mm radius and the ISO type [6] with 2 mm radius. It is known that the shape of the tup affects the absorbed energy and the lateral expansion. Because some countries use the ISO tup as a standard and others ASTM, both types of tup were used to characterize the effect of tup geometry on reconstituted test specimens. Twenty-four halves of broken Charpy specimens of each material were distributed to each participant. To characterize the reconstitution welding, the measurements of temperature history in a dummy insert and hardness distribution across the weldment were performed at each participating laboratory. Each participant was given nuclear grade material*3 (18MND5) to be used for end tabs. This material has a similar chemical composition and almost equivalent tensile properties as the program materials.

*1 supplied courtesy ORNL
*2 supplied courtesy B&W Owners Group
*3 supplied courtesy SCK•CEN

The insert lengths chosen are 10 mm and 14 mm. The 10 mm insert allows specimen reorientation if justified by this program, while the 14 mm insert provides less constraint of plastic deformation. These insert lengths were selected to evaluate whether the dimensional requirements of the central portion of the reconstituted specimen could be relaxed in ASTM E1253. Six specimens for each condition, a combination of material and insert length, were reconstituted at each laboratory. Consequently, forty-eight Charpy specimens were prepared at each laboratory for the RRR. The reconstituted Charpy-V specimens were sent to ORNL, where instrumented Charpy impact tests were conducted.

ORNL performed all instrumented Charpy impact tests on both the virgin and the reconstituted specimens with the same machine to avoid any inter-laboratory testing bias. Four specimens out of six were tested in the transition range around the 41 J level, and two specimens were tested at upper shelf temperature. Appendix B provides all details of the test matrix, materials, and reconstitution procedure.

2.2 Brief Description of Reconstitution Techniques applied during the RRR

Stud welding

The stud-welding (SW) technique can be applied to simple geometries like Charpy-V specimens or tensile specimens. The equipment is based on a commercial stud gun, is moderately priced and can easily be installed in a hot-cell [7-9]. An arc is initiated between the end tab (stud) and the insert piece, melting the surfaces of both pieces. Subsequently, the stud is projected onto the insert and both materials fuse. This process takes place in an argon atmosphere or employs an aluminum ball to avoid oxidation of the weld. Since the input energy is a few kJ in about 100 ms, additional cooling of the insert piece is required. To ensure proper alignment and square sectional welds, the stud is slightly oversized; therefore, the reconstituted specimen needs mechanical finishing. An example of stud-insert arrangement can be found in reference [10]. The welds are symmetric, have a maximum width of approximately 2mm and may contain small gas bubbles. The HAZ extends about 1mm to either side of the weld.

Electron beam welding

Electron beam welding (EBW) is the most versatile reconstitution technique, although it is the most expensive. The electron beam with energy densities up to 10^8 W/cm^2 allows deep penetration and creates homogeneous narrow V-shaped welds (for Charpy-V specimens the weld width varies between 0.3 and 1mm, while the HAZ has similar dimensions on either side of the weld) [11, 12]. Small weld widths and HAZs are important in small insert applications. By preference, the specimens should be welded from two sides - each time to half the thickness of the material - to avoid bending of the specimen. Since EBW is performed in a vacuum chamber, hot-cell application is difficult and needs a lot of space. Precautions, also due to the vacuum conditions, must be taken to keep the insert temperature low enough during and after the welding: a cooled sample clamping system and a time gap between the two reconstitution welds are necessities [12].

Upset butt welding

An upset butt-welding (UBW) technique has been used for the reconstitution of Charpy specimens [13, 14]. The results are similar to those of the SW technique. A welding cycle consists of three steps, that can be adjusted in time: preloading (~ 350 kg/cm^2), preheating and fusing. The total energy input for preheating and fusing is approximately 30kJ in 400 ms (75kVA transformer) [14]. Cooling is assured by liquid nitrogen cooled copper clamps. Oversized end tabs are used to assure final alignment of the reconstituted specimen. The welds are very homogeneous, as was demonstrated with X-ray photography [15]. Although the energy input is very high, the temperature distribution within the insert is similar to those of the other welding techniques. The equipment can be readily installed into a hot-cell.

3 TEST RESULTS

3.1 Results for Virgin Specimens

A 326-J (240-ft-lb) capacity pendulum-type impact machine, Baldwin Model SI1C, was used to conduct the Charpy impact tests [16]. The machine is equipped with a semi-automated specimen thermal conditioning and transfer system where the system positions the specimen in the thermal conditioning system. This system has a calibrated contact thermocouple for temperature measurement, and heats the specimen by contact with graphite electrodes or cools the specimen with cold nitrogen gas. The system allows transfer of the specimen to the anvils and testing in less than 5 seconds after removal from the conditioning chamber. Both the 8-mm and 2-mm tups were instrumented with strain gages to provide a load-time record. All reported energy values are dial energies. The percent shear fracture was visually measured and the lateral expansion was determined with a device similar to that described in ASTM E23. Calibration specimens were tested prior to use of each tup for the RRR testing.

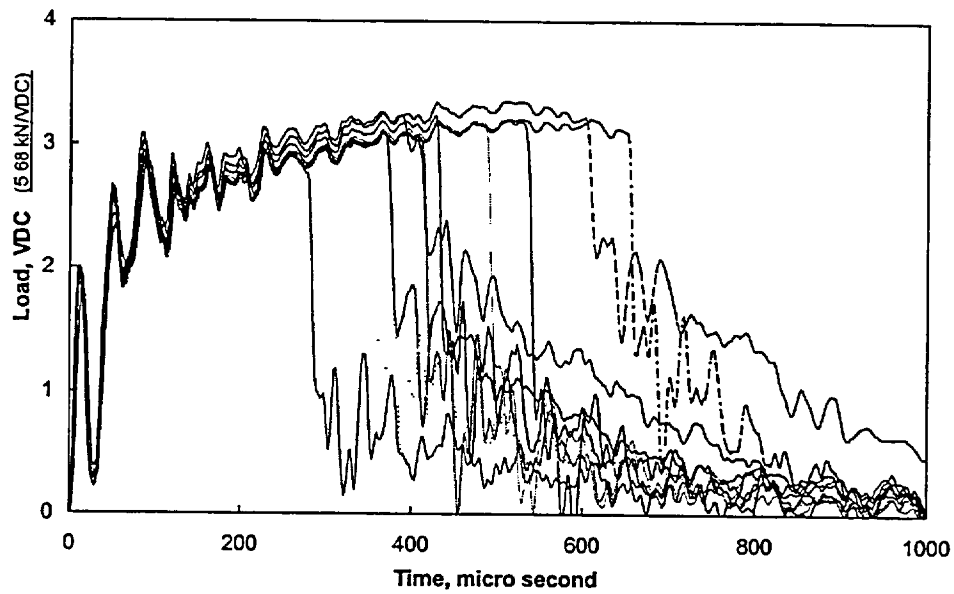
Table 2 shows the average value and standard deviation of Charpy impact test results for each baseline test condition for both materials. Appendix C contains all test data.

Material	Test Temp.	Tup used	Number of Specimen	Absorbed Energy		Lateral Expansion		Shear Area	
				Average	Std. dev.	Average	Std. dev.	Average	Std. dev.
	°C			J	J	mm	mm	%	%
HSST-03	-12	ASTM	46	40.9	9.7	0.65	0.17	10.0	0.0
		ISO	46	38.1	8.9	0.63	0.13	10.0	0.0
	93	ASTM	23	163.6	7.0	2.04	0.04	100.0	0.0
		ISO	23	151.4	5.5	2.27	0.09	100.0	0.0
Linde 80	2	ASTM	46	43.9	8.1	0.75	0.12	32.5	11.5
		ISO	46	42.1	6.8	0.82	0.13	35.3	10.9
	93	ASTM	23	94.5	2.7	1.66	0.06	99.0	0.9
		ISO	23	93.4	3.4	1.78	0.09	99.3	0.5

Table 2—Summary of baseline data from virgin specimens for the ASTM Round-Robin on Reconstitution.

Figure 1 shows typical instrumented signals from original specimens of Linde 80 weld tested in the transition temperature range.

(a)



(b)

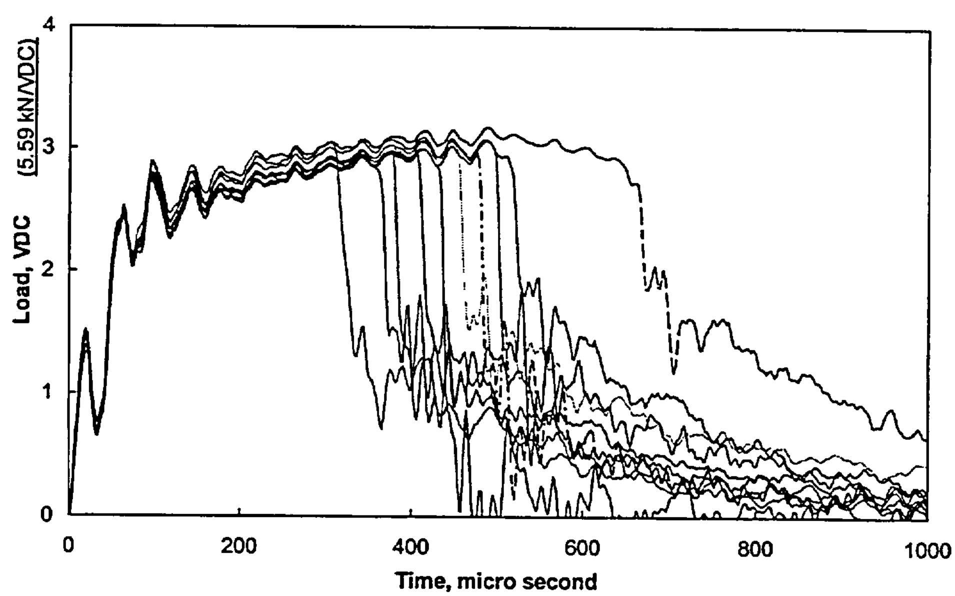


FIG. 1--Instrumented Charpy signals obtained from original Linde 80 specimens tested at 1.7°C with (a) the ASTM tup and (b) the ISO tup.

The large scatter in the curves is primarily caused by the difference in cleavage initiation point. This result is also reflected in the scatter of the shear area, as indicated in Table 2. Figure 2 shows examples of typical instrumented Charpy signals obtained from the original specimens tested at upper shelf temperature, 93.3°C. Except for a few specimens in each condition, good agreement between these curves was obtained. This figure demonstrates the effect of the tup geometry on the load-deflection signals. The ASTM tup gives a higher maximum load than the ISO tup. This load difference continues up to large deflection in case of HSST-03, and represents the effect of the tup shape. This is the Brinell type deformation at the impact side of the specimen and is caused by the interaction of the tup edge with the bending specimen.

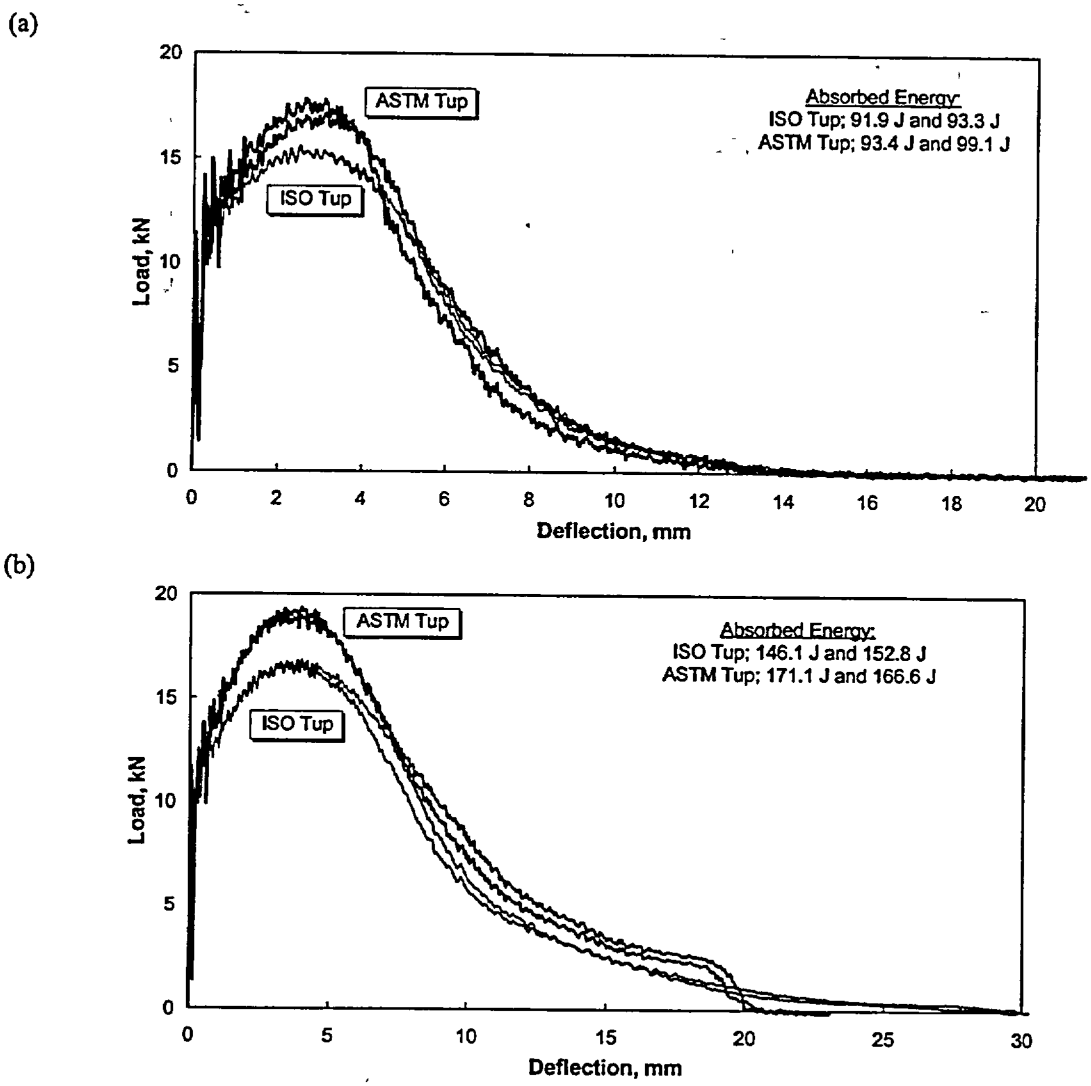


FIG. 2--Typical examples of instrumented Charpy signals obtained from virgin specimens of (a) Linde 80 and (b) HSST-03 tested at 93°C with the ASTM tup and the ISO tup.

3.2 Results for Reconstituted Specimens

Table 3 lists the welding methods with some typical welding parameters, used by the participants in the Round-Robin. Ten participants joined the Round-Robin with three welding techniques: upset butt welding (UBW, Lab. #1), electron beam welding (EBW, Labs. #2, #5, and #10) and arc stud welding (SW, all other Labs.). Table 4 summarizes the conventional Charpy impact test results obtained from the specimens reconstituted by the 10 participants . All Charpy impact data for the reconstituted specimens can be found in Appendix D.

TABLE 3--Welding parameters used and maximum temperature during welding.

Lab. #	Welding Method	Welding Parameters	Heat Input** (kJ)	Tmax, u A		
				Distance from welding surface, mm		
				2	4	others
1	UBW	75 kVA, 15kA, 0.2 s, 500 kgf	15	635	340	
2	EBW	50 kV, 40 mA, 750 mm/min	1.6	245	183.2	
3*	SW	700 A, 20V, 90 ms	1.26	303	198	168
4	SW	1000 A, 23 V, 0.24 s	5.52	427.2	235.5	
5	EBW	140 kV, 20 mA, 20 mm/s	1.4	214	161	
6	SW	1300 A, 23 V, 0.07 s	2.09	390	280	
7	SW	-	-	-	-	
8	SW	850 A, 1 s	-	220	170	
9	SW	420 A, 75 V, 0.2 s	6.3	314.4	281.6	
10	EBW	90 kV, 33.5 mA, 720 mm/min	2.51	300	250	

*: Lab #3: Temp. measured at 2.7, 4.7, 5.4 mm
**: Heat Input = (Voltage) * (Current) * (time)

TABLE 4-- Charpy impact test results. (a) Low Upper Shelf Weld (Linde 80)

ASTM TUP

Laboratory Identifier	Insert: 10mm					Insert: 14mm				
	2 °C			93 °C		2 °C			93 °C	
#	Energy	Lat Exp	Shear	Energy	Lat. Exp.	Energy	Lat. Exp	Shear	Energy	Lat Exp
	J	mm	%	J	mm	J	mm	%	J	mm
1	37.2	0.77	41.3	78.7	1.66	52.4	1.00	46.3	87.5	1.68
2	34.1	0.76	28.8	74.9	1.55	43.5	0.87	25.0	90.2	1.78
3	37.1	0.53	27.5	86.1	1.63	41.6	0.70	27.5	98.7	1.80
4	38.7	0.74	31.3	84.6	1.59	39.0	0.64	22.5	94.3	1.69
5	46.3	0.98	45.0	89.3	1.75	45.1	0.95	41.3	92.0	1.75
6	48.0	0.96	45.0	88.0	1.45	54.6	0.99	32.5	96.0	1.28
7	33.1	0.52	22.5	61.9	1.31	43.2	0.74	40.0	80.2	1.44
8	71.1	1.11	65.0	91.5	1.75	48.7	0.83	47.5	96.7	1.61
9	41.7	0.76	31.7	79.3	1.63	55.6	0.95	35.0	89.7	1.60
10	40.7	0.67	33.3	83.4	1.46	56.6	0.86	41.7	96.3	1.56
Total Ave.	41.8	0.78	34.0	81.0	1.58	47.6	0.89	36.3	92.1	1.62
Tot.Std.Dev	11.5	0.23	16.7	9.5	0.17	8.6	0.14	11.5	6.4	0.26
	Baseline Data					**Baseline Data**				
Total Ave.	43.9	0.75	32.5	94.6	1.66	43.9	0.75	32.5	94.6	1.66
Tot.Std.Dev	8.1	0.13	11.4	2.7	0.06	8.1	0.13	11.4	2.7	0.06

ISO TUP

Laboratory Identifier	Insert: 10mm					Insert: 14mm				
	2 °C			93 °C		2 °C			93 °C	
#	Energy	Lat. Exp.	Shear	Energy	Lat Exp	Energy	Lat. Exp	Shear	Energy	Lat. Exp
	J	mm	%	J	mm	J	mm	%	J	mm
1	35.7	0.76	41.3	81.4	1.61	48.5	0.96	43.8	96.6	1.80
2	39.0	0.86	35.0	79.7	1.69	38.9	0.71	32.5	95.6	1.87
3	41.2	0.77	35.0	86.8	1.59	45.8	0.80	27.5	90.7	1.68
4	36.9	0.69	32.5	88.2	1.57	42.0	0.80	33.8	89.2	1.45
5	43.8	0.97	45.0	88.8	1.71	48.1	1.03	51.3	88.5	1.70
6	47.4	0.98	50.0	90.6	1.50	52.9	1.01	43.8	99.3	1.92
7	34.9	0.76	38.3	69.4	1.49	33.6	0.62	30.0	95.3	1.84
8	53.9	1.21	50.0	113.1	2.10	51.0	0.79	48.8	100.5	1.78
9	44.7	0.82	36.3	89.2	1.96	47.6	0.89	42.5	99.0	1.80
10	42.1	0.69	40.0	86.1	1.47	51.0	0.86	41.3	89.7	1.59
Total Ave.	41.5	0.83	39.9	87.3	1.67	45.9	0.85	38.9	94.4	1.74
Tot.Std.Dev	8.6	0.20	12.7	11.0	0.23	9.2	0.18	13.2	5.5	0.16
	Baseline Data					**Baseline Data**				
Total Ave.	42.1	0.82	35.3	93.4	1.78	42.1	0.82	35.3	93.4	1.78
Tot.Std.Dev	6.8	0.13	10.8	3.4	0.09	6.8	0.13	10.8	3.4	0.09

Table 4-- Charpy impact test results (continued).
(b) High Upper Shelf Plate (HSST-03).

ASTM TUP

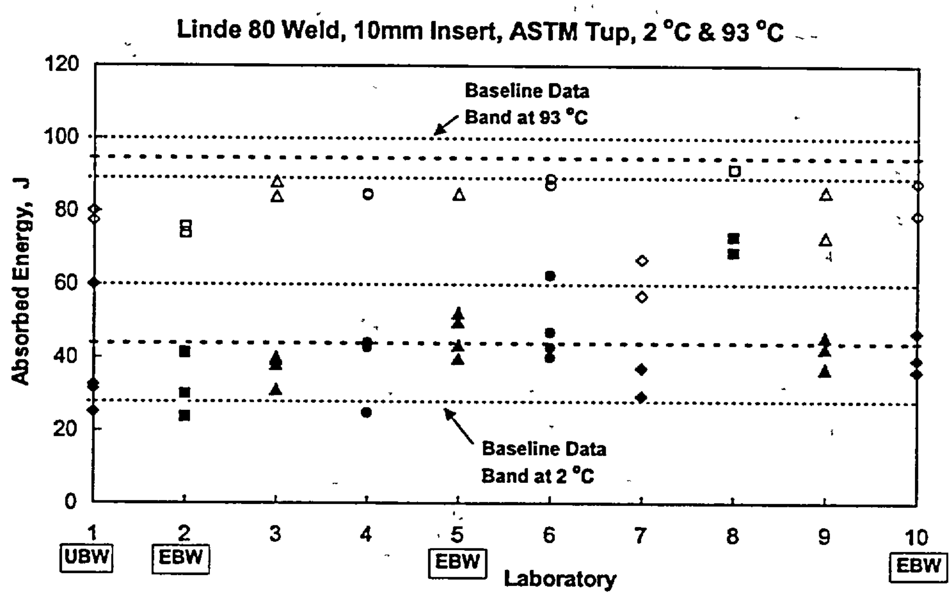
Laboratory Identifier	Insert: 10mm					Insert: 14mm				
	-12 °C			93 °C		-12 °C			93 °C	
#	Energy	Lat. Exp.	Shear	Energy	Lat. Exp.	Energy	Lat. Exp.	Shear	Energy	Lat. Exp.
	J	mm	%	J	mm	J	mm	%	J	mm
1	34.7	0.65	5.0	123.4	1.94	51.1	0.84	11.3	151.1	2.15
2	18.5	0.39	10.0	130.7	2.17	16.9	0.37	13.8	154.0	2.20
3	35.6	0.58	15.0	144.4	1.94	41.6	0.61	21.3	160.0	2.10
4	29.4	0.48	12.5	124.6	1.84	31.0	0.46	8.8	153.2	2.06
5	29.1	0.53	12.5	142.4	2.12	31.8	0.55	15.0	150.5	2.13
6	27.2	0.47	10.0	122.4	1.94	39.1	0.63	10.0	143.8	2.11
7	22.2	0.38	5.0	107.1	1.75	36.1	0.56	10.0	146.1	2.03
8	57.6	1.22	20.0	194.0	2.03	42.3	0.61	8.8	164.1	2.13
9	33.0	0.54	10.0	126.6	2.04	38.8	0.60	11.3	157.6	2.30
10	29.1	0.40	10.0	139.3	1.98	39.3	0.55	10.0	159.7	2.08
Total Ave.	30.1	0.52	10.3	137.0	1.99	36.8	0.58	12.0	154.4	2.13
Tot.Std.Dev	8.2	0.16	4.6	25.0	0.15	10.4	0.14	6.5	7.4	0.10
	Baseline Data					Baseline Data				
Total Ave.	40.9	0.65	10.0	163.6	-	40.9	0.65	10.0	163.6	-
Tot.Std.Dev	9.7	0.17	0.0	7.0	-	9.7	0.17	0.0	7.0	-

ISO TUP

Laboratory Identifier	Insert: 10mm					Insert: 14mm				
	-12 °C			93 °C		-12 °C			93 °C	
#	Energy	Lat. Exp.	Shear	Energy	Lat. Exp.	Energy	Lat. Exp.	Shear	Energy	Lat. Exp.
	J	mm	%	J	mm	J	mm	%	J	mm
1	27.7	0.54	10.0	126.8	2.02	41.3	0.68	15.0	143.0	2.03
2	17.9	0.41	6.3	138.8	2.05	27.7	0.57	8.8	154.6	2.36
3	35.5	0.61	11.3	143.7	2.17	45.8	0.76	16.3	146.8	1.85
4	31.5	0.47	10.0	132.1	1.73	34.2	0.55	10.0	148.1	2.17
5	27.9	0.54	13.8	143.6	2.03	33.2	0.64	13.8	156.6	2.22
6	33.7	0.60	10.0	131.9	1.83	42.3	0.74	10.0	147.1	2.34
7	25.6	0.49	8.8	105.1	1.40	34.0	0.60	8.8	156.3	2.07
8	40.3	0.84	10.0	146.4	2.03	42.6	0.61	12.5	152.0	2.20
9	34.8	0.61	15.0	137.5	2.04	49.3	0.78	11.3	147.5	2.08
10	30.6	0.46	18.3	141.0	1.88	50.3	0.76	21.3	150.0	2.04
Total Ave.	29.5	0.54	11.2	135.7	1.94	40.1	0.67	12.8	150.2	2.14
Tot.Std.Dev	7.4	0.11	4.4	10.0	0.20	9.1	0.12	4.7	5.6	0.16
	Baseline Data					Baseline Data				
Total Ave.	38.1	0.63	10.0	151.4	2.27	37.4	0.63	10.0	151.4	2.27
Tot.Std.Dev	8.9	0.13	0.0	5.5	0.09	8.9	0.13	0.0	5.5	0.09

For the absorbed energy, Figures 3 and 4 compare the values for the 10 mm insert of Linde 80 weld and HSST-03 plate before and after reconstitution. In these figures, the baseline data are shown by the average value with two standard deviations. Large variations among the results of the participants can be seen. The loss of absorbed energy after reconstitution at upper shelf test temperature occurs for almost all laboratories. Even at transition temperature range, i.e. at lower energy level, the loss of energy is seen for some laboratories. It is noted that Lab. #8 provided considerably higher energy values than the baseline data in some cases.

(a)



(b)

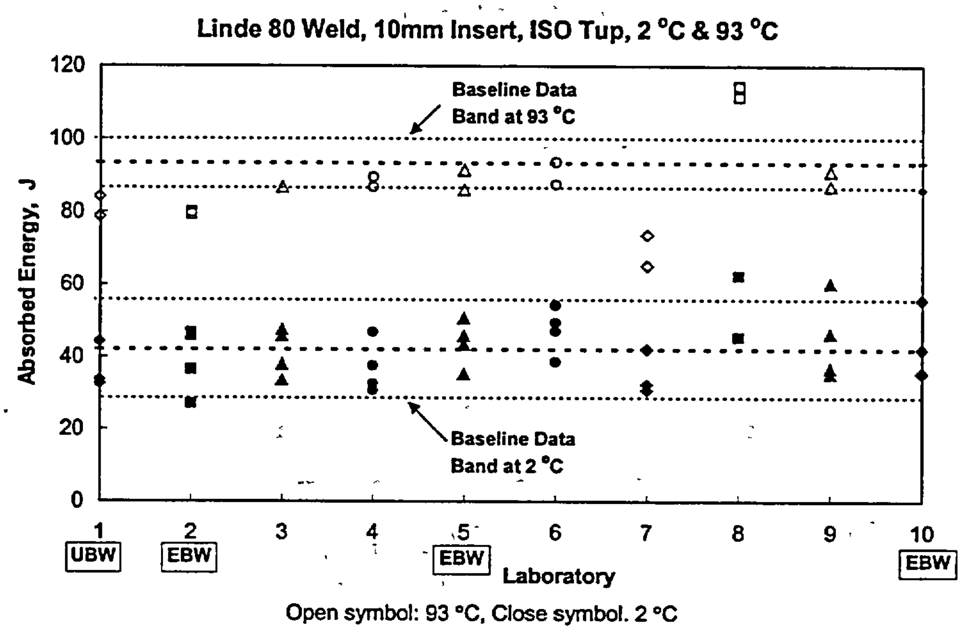
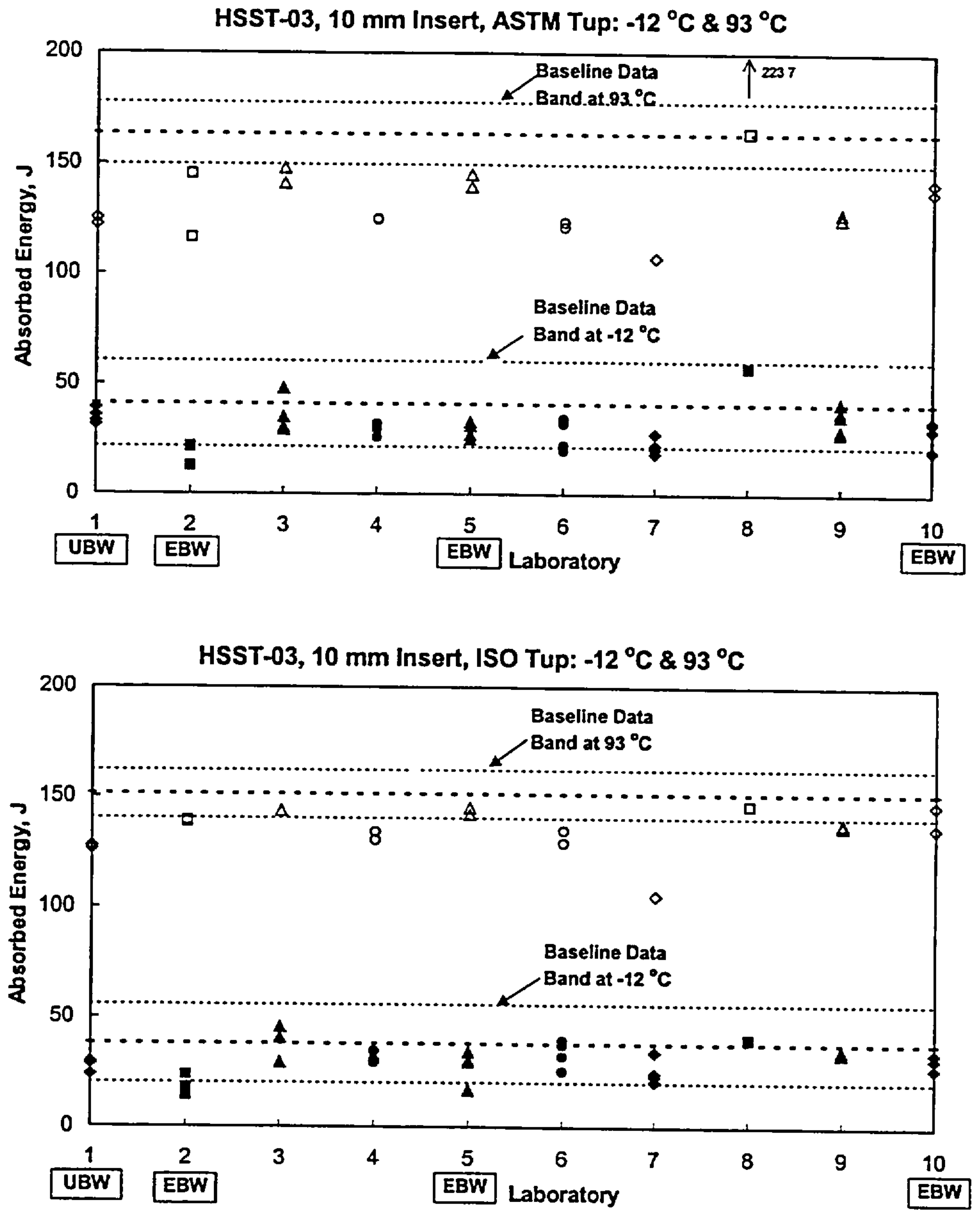


FIG. 3--Comparison of absorbed energy between virgin and reconstituted specimens having 10 mm insert of Linde 80 tested with (a) the ASTM tup and (b) the ISO tup.

(a)

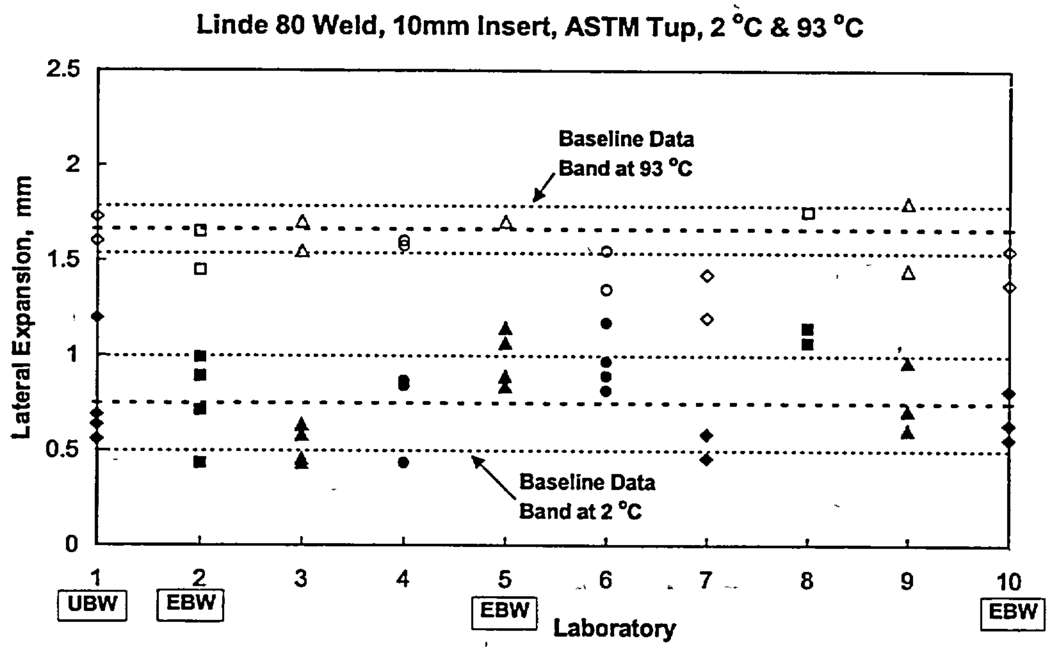


(b)

FIG. 4--Comparison of absorbed energy between virgin and reconstituted specimens having 10 mm insert of HSST-03 tested with (a) the ASTM tup and (b) the ISO tup.

Figure 5 shows an example of the lateral expansion data before and after reconstitution with a 10 mm insert of Linde 80 material. Since the lateral expansion data from original specimens of HSST-03 with the ASTM tup were missing, the comparison of lateral expansion data for HSST-03 specimens was excluded. For upper shelf temperature data, the loss of lateral expansion after reconstitution seems to be similar to the loss of absorbed energy. In the transition temperature data, many lateral expansion data fall within the baseline data scatter band. One exception is again the data from Lab. #8 which show in some cases a larger expansion.

(a)



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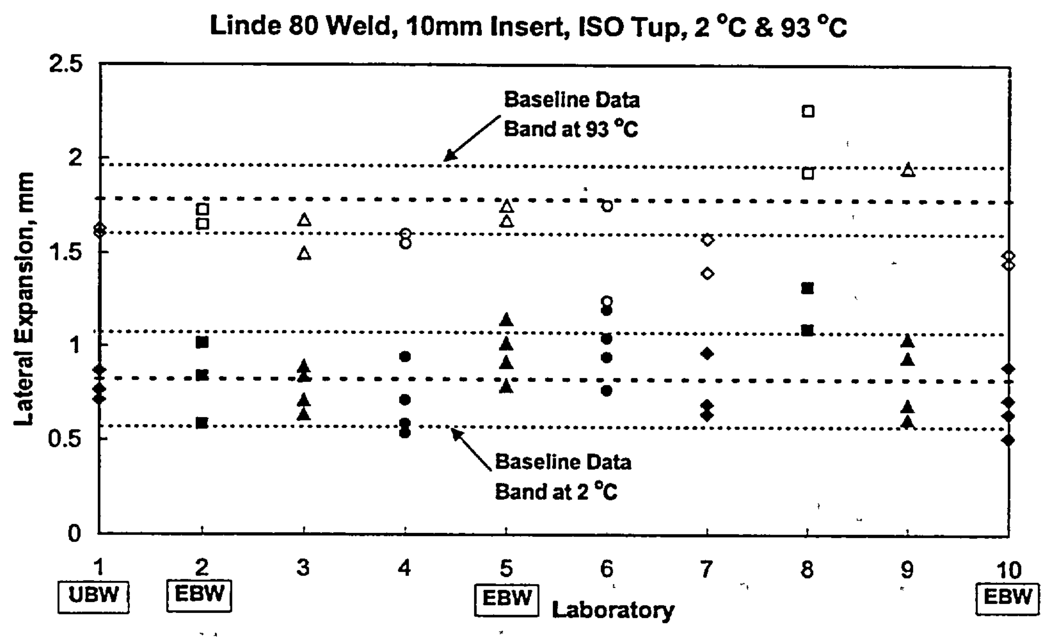
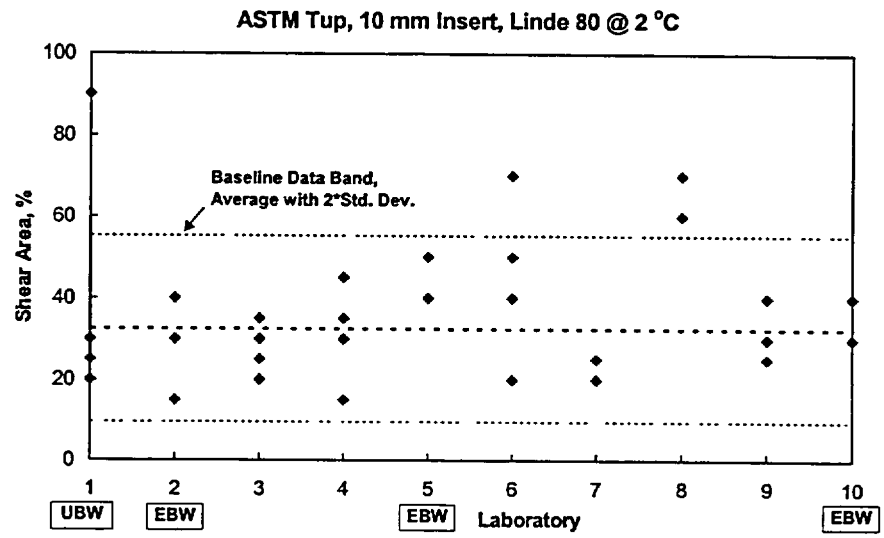


FIG. 5--Comparison of lateral expansion between original and reconstituted specimens having 10 mm insert of Linde 80 tested with (a) the ASTM tup and (b) the ISO tup.

Figure 6 shows the comparison of the percent shear fracture area (SFA) for the Linde 80 weld specimens with a 10 mm insert, tested at 2°C. In some cases, higher

SFA values are found, although there is a large scatter in the baseline condition. The HSST-03 specimens were tested at a lower transition temperature, -12°C, and the same value of 10 % was attributed to all the original specimens, as shown in Table 2. Therefore, the analysis of this condition was also excluded.

(a)



(b)

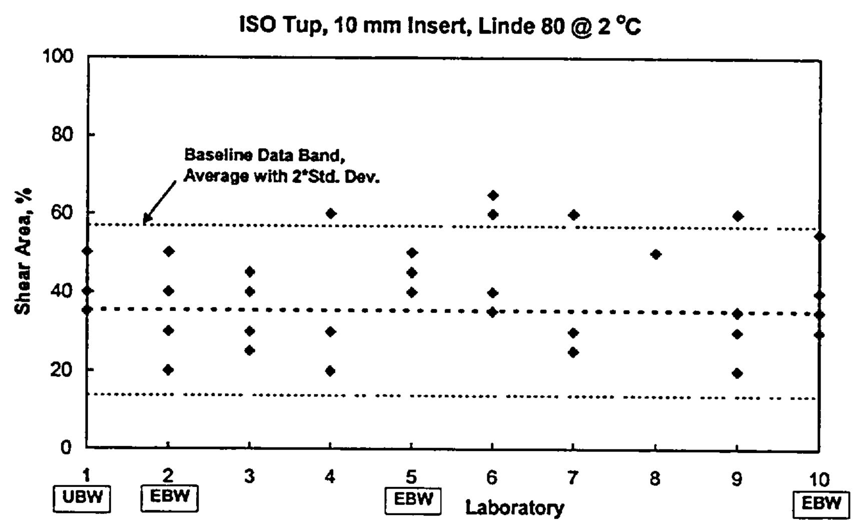
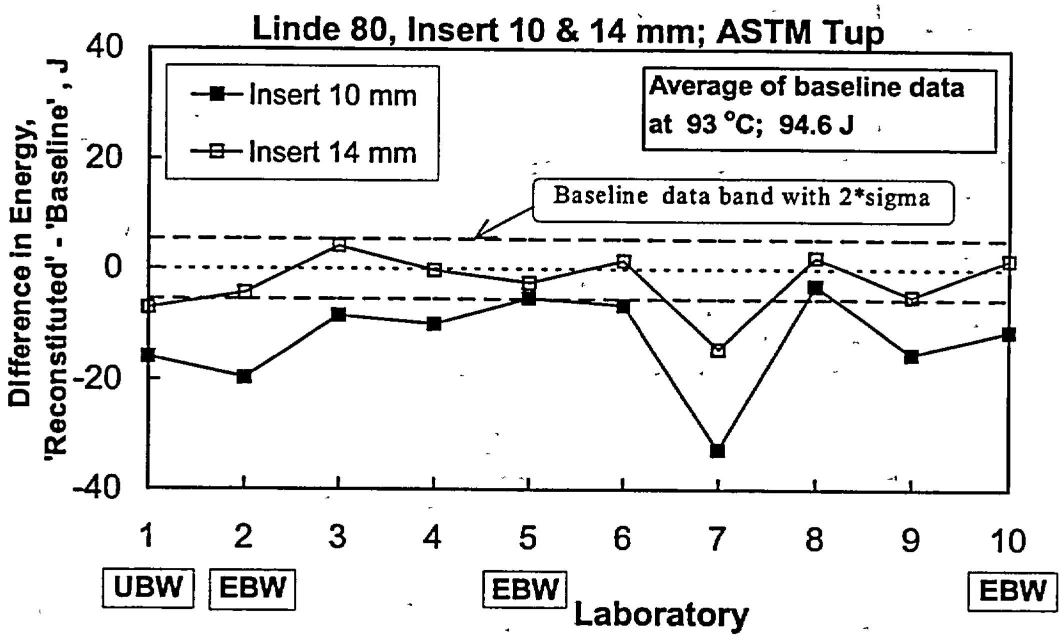


FIG. 6--Comparison of shear fracture area between virgin and reconstituted specimens having 10 mm insert of Linde 80 tested at 2°C with (a) the ASTM tup and (b) the ISO tup.

The energy differences before and after reconstitution for the specimens with 10 mm and 14 mm inserts, tested at 93°C are shown for Linde 80 and HSST-03 in Figures 7 and 8, respectively.

(a)



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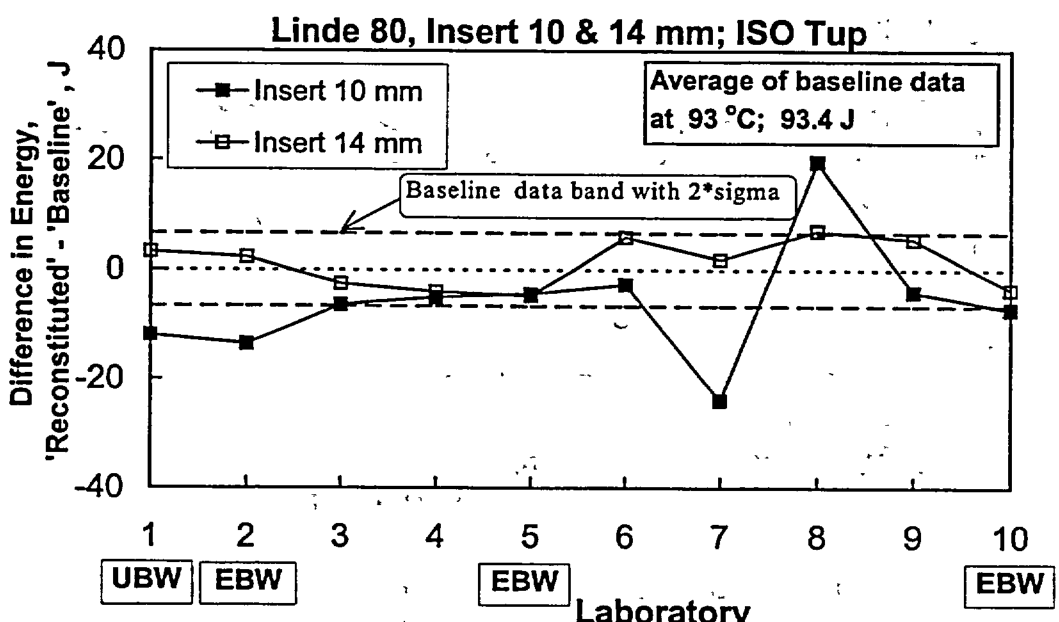
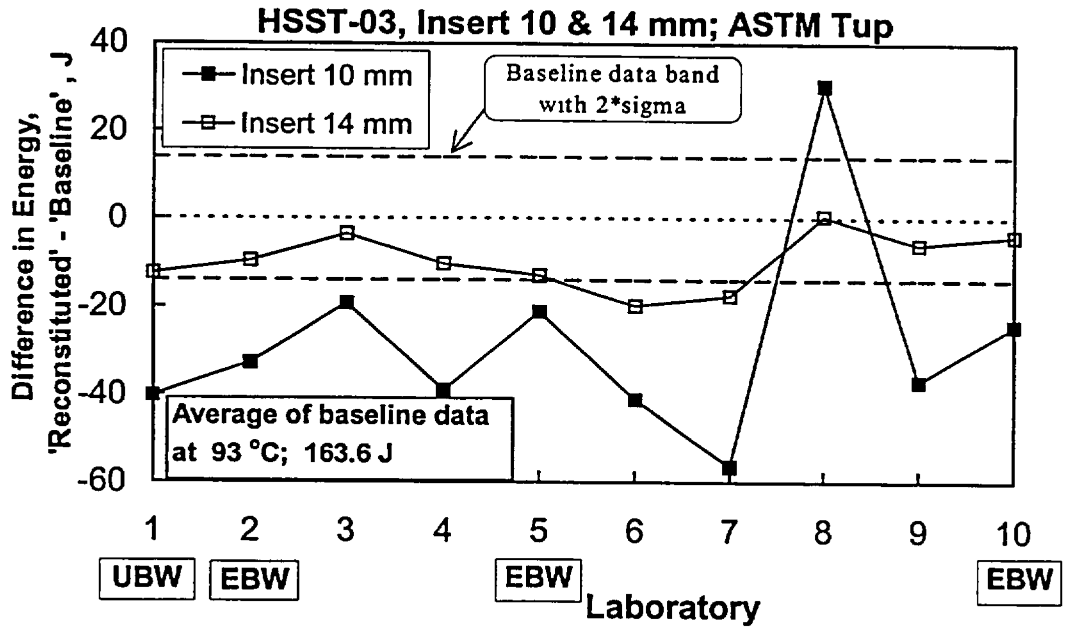


FIG. 7--Comparison of the differences in absorbed energy between original and reconstituted specimens having 10 mm and 14 mm inserts of Linde 80 tested at 93°C with (a) the ASTM tup and (b) the ISO tup.

(a)



(b)

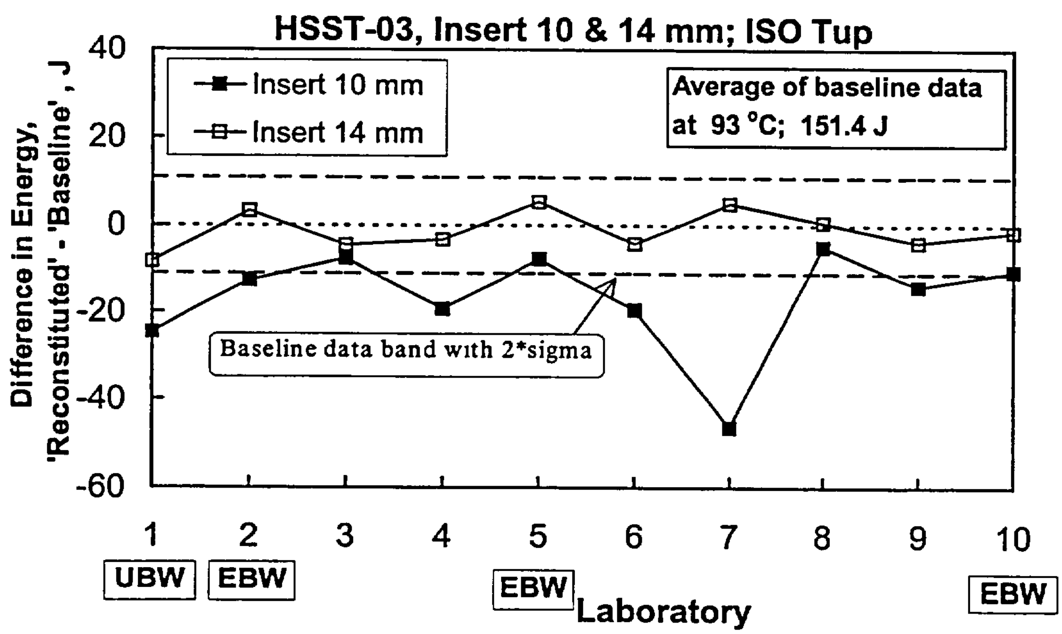


FIG. 8--Comparison of the differences in absorbed energy between original and reconstituted specimens having 10 mm and 14 mm inserts of HSST-03 tested at 93°C with (a) the ASTM tup and (b) the ISO tup.

The difference for each laboratory was obtained from the average values of specimens tested in the same condition. The data band that corresponds to two standard deviations of the virgin specimen data is shown in these figures. For the 10 mm inserts, many laboratories have larger deviations than the two standard deviations for both Linde 80 and HSST-03. The ASTM tup gives a larger difference than the ISO tup, especially for 10 mm inserts. For the 14 mm insert, some laboratories have larger differences than two standard deviations for HSST-03 specimens tested with the ASTM tup. However, for the 14 mm insert, all cases tested with the ISO tup show relatively small deviations and remain within the baseline data band.

4 DATA ANALYSIS

It is known that the hardened reconstitution weld and HAZ may affect the impact energy of Charpy specimens by constraining the plastic deformation [17, 18] during the Charpy test. As such, ASTM E1253 requires an insert of 14 mm to be free of plastic deformation from previous testing and of the HAZ from reconstitution. In fact, the insert size must be larger than 14 mm depending on the size of the HAZs in order to meet this requirement.

From a regulatory viewpoint, the absorbed energy value is the most important result from a Charpy impact test. In reactor application, the embrittlement of the material is evaluated from an index temperature characterizing the energy-temperature transition curve. The energy values may be influenced by reconstitution and may bias the 'degree of embrittlement' detected from a biased index temperature when a smaller insert from an irradiated specimen is used. Moreover, there are differences in reconstitution welding techniques, which may vary the size of the HAZ and affect the Charpy test results.

The instrumented Charpy impact test, cited in ASTM Standard Guide for Conducting Supplemental Surveillance Tests for Nuclear Power Reactor Vessels (E636), gives supplementary useful information. Figure 9 shows a schematic load-displacement curve that indicates the characteristic loads. The change in these loads with test temperature is shown in Figure 10 [19]. In principle, characteristic temperatures, T_I and T_0, corresponding respectively to the onset of ductile crack growth and the onset of the Charpy upper shelf, can be determined from the diagram. It was shown that T_I and T_0 are invariant before and after reconstitution [20].

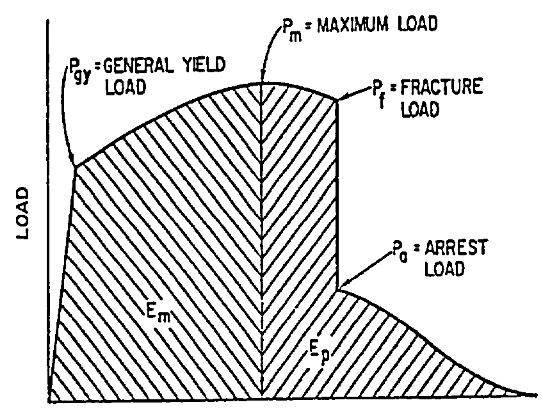


FIG. 9--Schematic load versus deflection curve from instrumented Charpy impact test (ASTM E636).

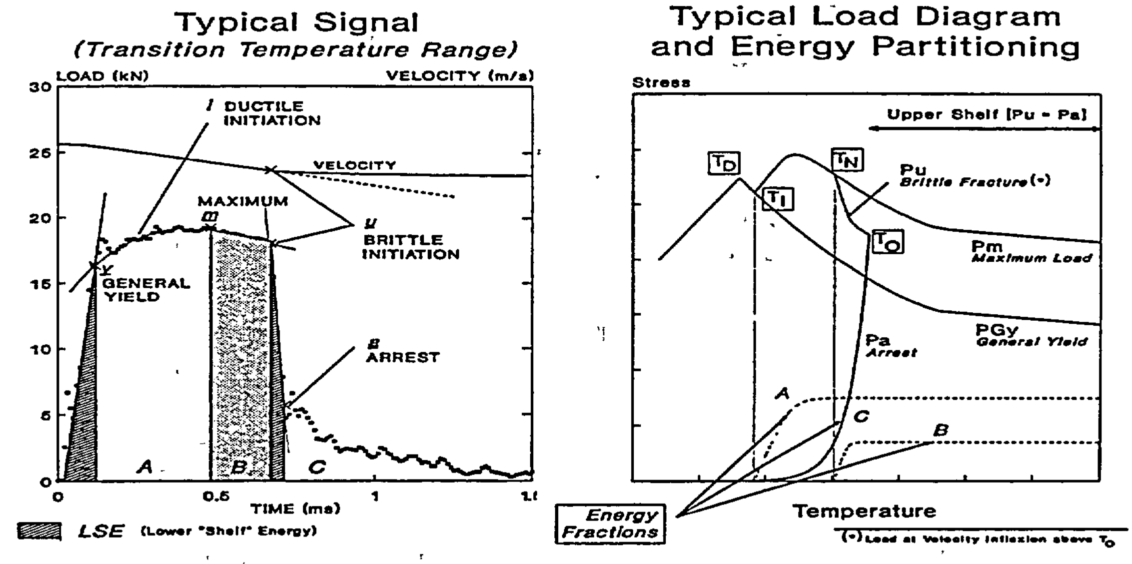


FIG. 10--Charpy load diagram approach to evaluate irradiation embrittlement [19].

Reconstituted specimens should have proper dimensions for testing. Machining after reconstitution welding makes the surface of the insert and over-sized end tabs flat and smooth. Consequently the insert can to some extent be reduced in cross section. The effect of the reduced cross section on test results and the specimen dimension requirements are discussed later in this report.

4.1 Variations in Welding Techniques and Laboratories

From Figures 4 through 8, it is seen that there are clear variations between different laboratories in absorbed energy after reconstitution. Lab. #7 gives very low values in all cases, while Lab. #8 gives much higher results than the mean baseline values. The average loss of upper shelf energy (USE) is calculated for each laboratory. Figures 11 and 12 show the loss of USE as a function of the baseline USE for 10 mm inserts and 14 mm inserts, respectively. As previously mentioned, the use of the ASTM tup clearly leads to higher absorbed energy losses than the ISO tup. These losses increase with increasing baseline USE values, and with decreasing insert length. From Figure 12, it can be seen that no loss is found for 14 mm inserts tested with the ISO tup. In summary, the ASTM tup, in the case of a high USE and a short insert can cause significant energy loss

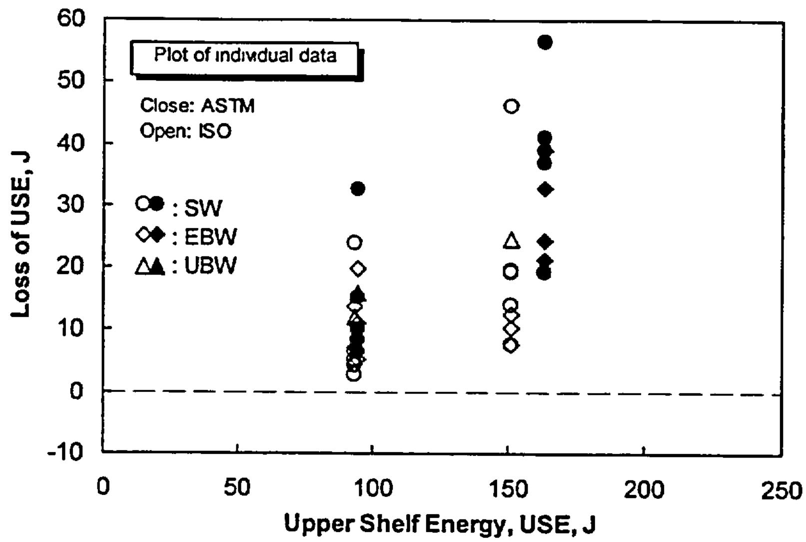


FIG. 11--The loss of upper shelf energy (USE) as a function of baseline USE for the 10 mm insert.

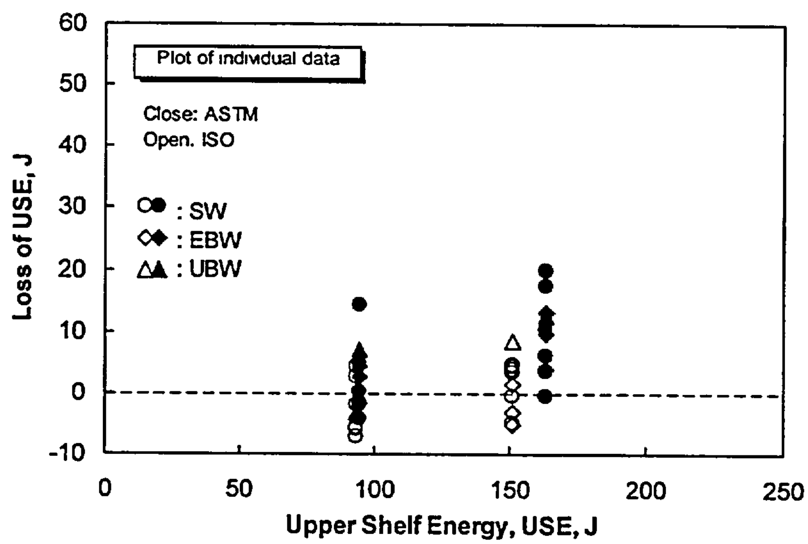


FIG. 12--The loss of upper shelf energy (USE) as a function of baseline USE for the 14 mm insert.

In terms of welding techniques applied in the RRR, the loss of USE is plotted in Figures 13 and 14 by averaging the values for each technique in the same manner as Figures 11 and 12. The data from Lab. #8 were excluded from the averaging in the case of the 10 mm insert tested with the ASTM tup. Data for the 10-mm insert from the literature [5] are also included in Figure 13. By adding these literature data, the loss due to reconstitution can be categorized by the welding technique and the impact tup geometry used. Three categories can be identified for the 10 mm inserts: 1) SW and UBW in combination with the ASTM tup, 2) SW and UBW together with the ISO tup and EBW with the ASTM tup, and 3) EBW with the ISO tup. Comparing the baseline data and the data after reconstitution , the first category shows the highest loss of USE whereas the third combination indicates the least. It appears that no category gives consistently satisfactory results for USE characterization. The 14-mm insert specimens can be divided into two groups as shown in Fig. 14: 1) SW, UBW and EBW with the ASTM tup and UBW with the ISO tup, and 2) SW and EBW with the ISO tup. The latter combination gives, as mentioned before, no loss after reconstitution.

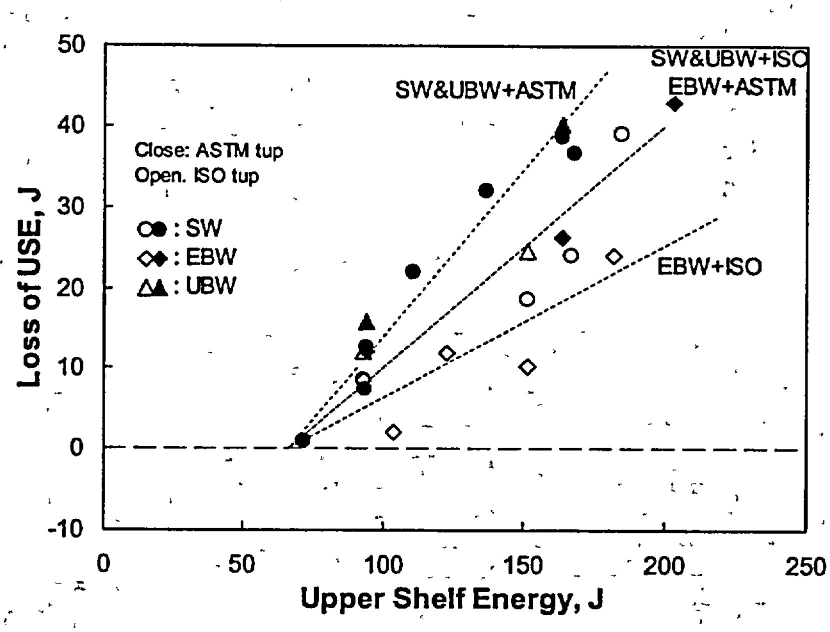


FIG. 13--Categorized average loss of upper shelf energy (USE) as a function of baseline USE for the 10 mm insert together with data from ref. [4].

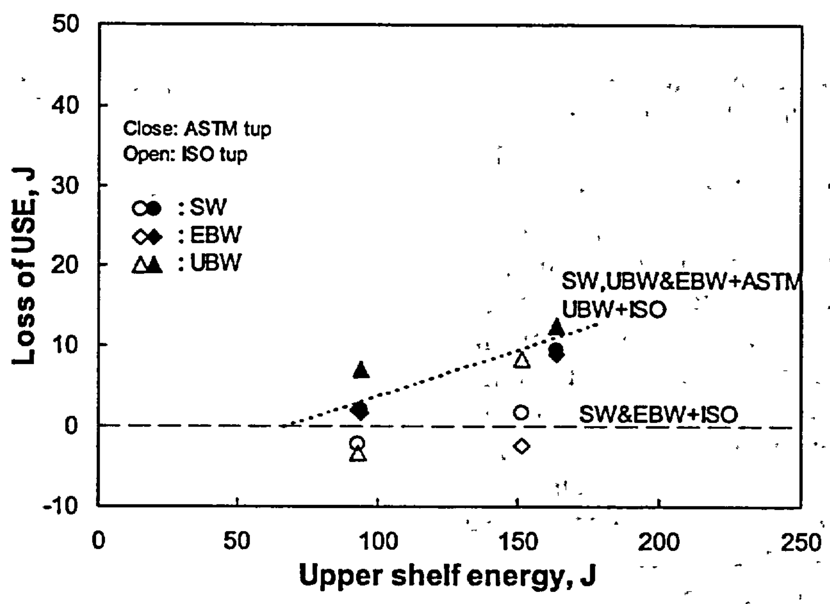


FIG. 14--Categorized average loss of upper shelf energy (USE) as a function of baseline USE for the 14 mm insert.

As shown in Figure 11, there exists a large variation in the loss of USE within the same welding technique. Moreover, the lowest loss with stud welding is almost the same as the lowest loss with electron beam welding. It should be noted that the categories mentioned above are based on average results from a particular welding technique that has different welding parameters.

Table 5 lists the heat input calculated from the welding parameters used by each laboratory. The information on welding parameters from Labs. #7 and #8 was not available. The table also includes the results of temperature and hardness measurements performed at each laboratory, as well as the loss of USE. The maximum temperature, which occurs at 2 and 4 mm from the welding interface, was measured with a calibrated thermocouple by each participant (see Table 3).

TABLE 5--Comparison of heat source, maximum temperature, hardened width and loss of upper shelf energy (USE).

Lab.#	Welding Method	Heat Input kJ	Tmax, °C Average @ 3mm	Hardened Width, mm Average	Linde 80 USE Loss*, J		HSST-03 USE Loss*, J		Quality of Weld Seam
					ASTM	ISO	ASTM	ISO	
1	UBW	15	488	4.2	15.9	12.0	40.2	24.6	Good
5	EBW	1.4	188	1.9	5.3	4.6	21.2	7.8	Good
2	EBW	1.6	214	2.2	19.7	13.7	32.9	12.6	Good
10	EBW	2.51	275	2.5	11.2	7.3	24.3	10.4	Good
8	SW	-	195	1.6	3.1	-19.7	-30.4	5.0	~50%
3	SW	1.26	287	1.9	8.5	6.6	19.2	7.7	Good
9	SW	6.3	298	2.9	15.3	4.2	37.0	13.9	~80%
4	SW	5.52	331	3.4	10.0	5.2	39.0	19.3	Good
6	SW	2.09	335	2.6	6.6	2.8	41.2	19.5	Good
7	SW	-	-	-	32.7	24.0	56.5	46.3	Good

*: Insert of 10mm

Figure 15 shows temperature profiles for every laboratory together with data from literature [20]. Clearly EBW results in the lowest temperatures during welding, while UBW results in the highest temperatures. This trend is also found in the distribution of the hardened region adjacent to the weld. Figure 16 indicates the hardened width and the mean maximum temperature at 3 mm from the interface in combination with the heat input. As expected, the laboratories with the highest temperatures during welding (Lab. #1, Lab. #4 and Lab. #6, see Figure 15) showed the widest hardened regions adjacent to the welds. Figure 17 shows the maximum temperature and the hardened width as a function of the heat input during welding. It indicates the increasing trend of those weld characteristics with increasing heat input. For SW, slightly higher temperatures were obtained with the same heat input as EBW. UBW had the highest heat input of approximately 15 kJ, resulting in the highest temperature and the widest hardened region.

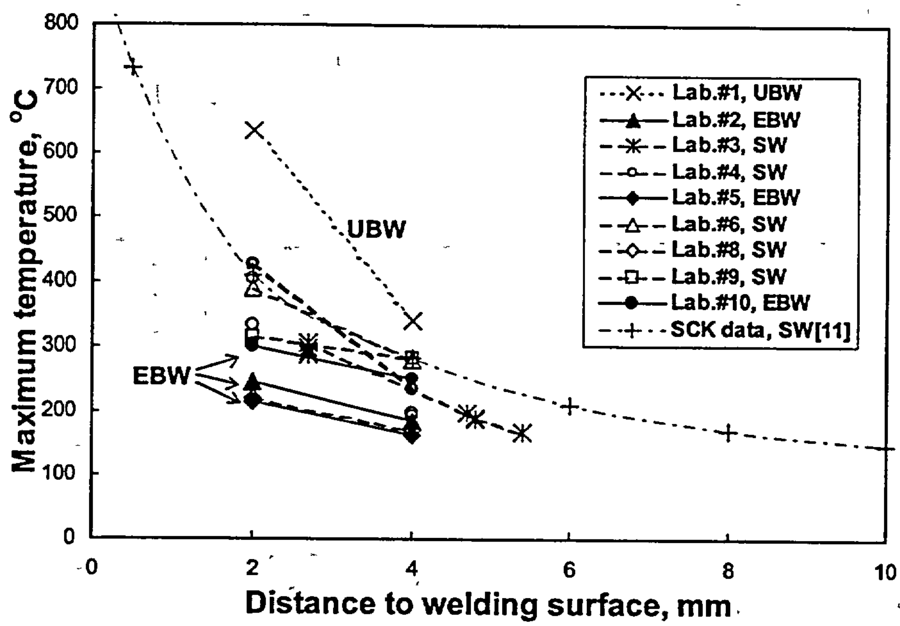


FIG. 15--Measured temperature during reconstitution welding with reference data [20].

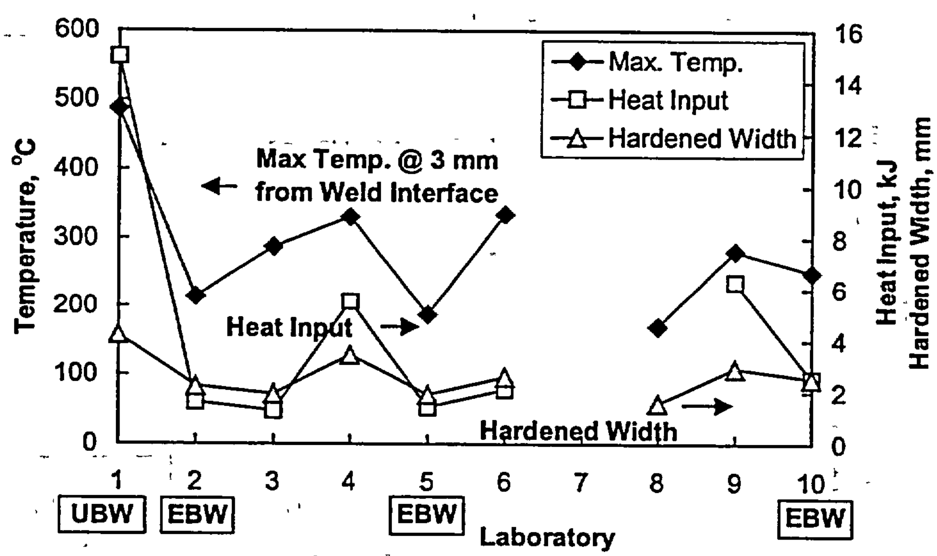


FIG 16--Variations between different laboratories: maximum temperature, hardened width and heat input.

Figure 18 shows the loss of USE for the 10 mm insert specimen of HSST-03 as a function of the heat input. Clearly the ASTM tup has a higher loss than the ISO tup. SW and UBW give higher USE losses in comparison with EBW with the latter technique resulting in the least loss of insert length. Additionally, the loss of USE tends to saturate to about 40 J for the ASTM tup and about 25 J for the ISO tup for more than 2 kJ of heat input. However, the lowest heat input for SW gave the smallest loss of USE, as was mentioned before. This means that arc stud welding can be optimized in order to give the best results for the absorbed energy.

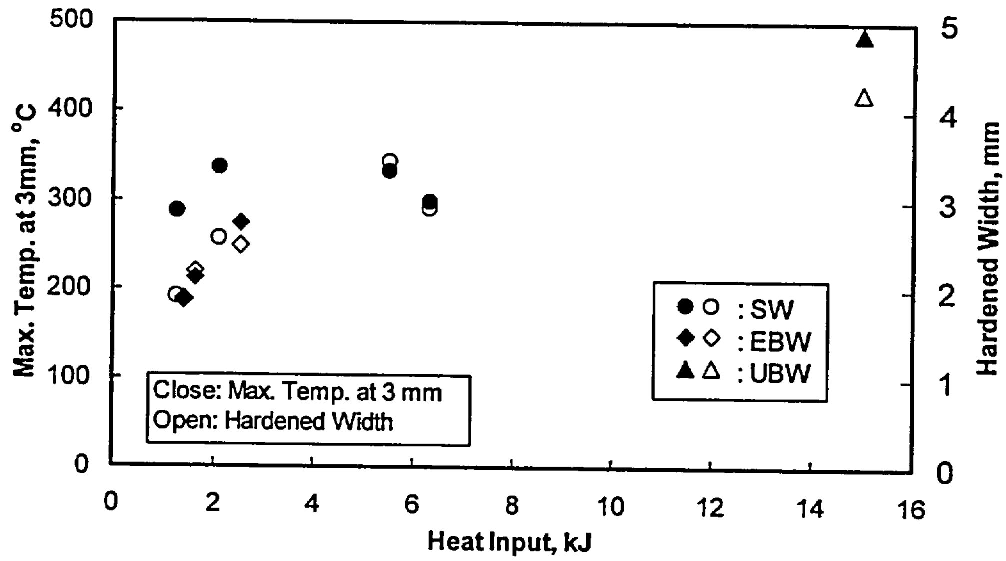


FIG. 17--Comparison of the maximum temperature and the hardened width as a function of the heat input for welding.

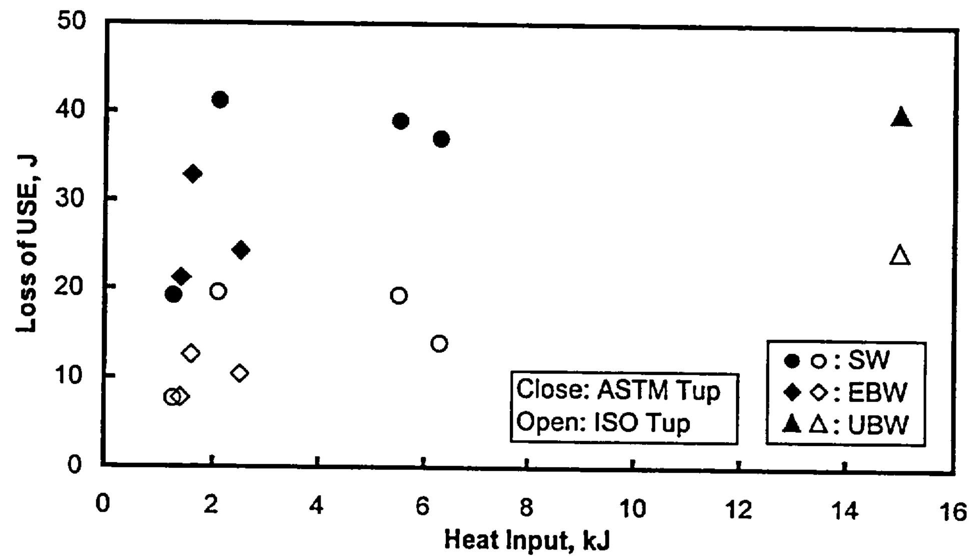
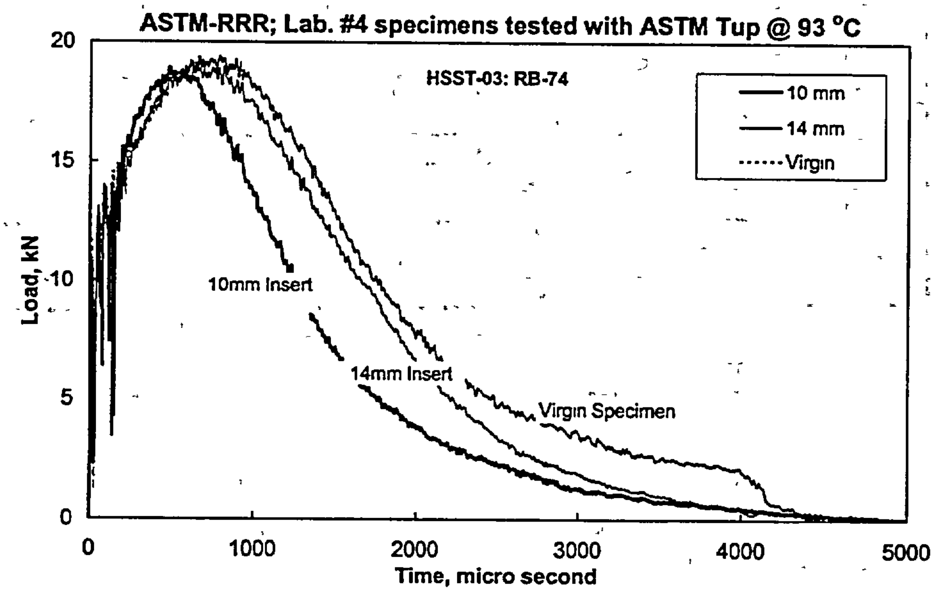


FIG. 18--Comparison of loss of upper shelf energy for HSST-03 specimen with a 10 mm insert as a function of the heat input for welding.

4.2 Effect of Reconstitution on Instrumented Charpy Signals

More than 600 instrumented Charpy signals were analyzed to obtain characteristic load values. Figure 19 compares typical instrumented signals obtained from stud welded specimens. Apparently, the general yield load, P_{gy}, is not affected by reconstitution in all cases. However, a consistent procedure for the determination of P_{gy} is not available; therefore, this evaluation concentrates on the maximum load, P_m.

(a)



(b)

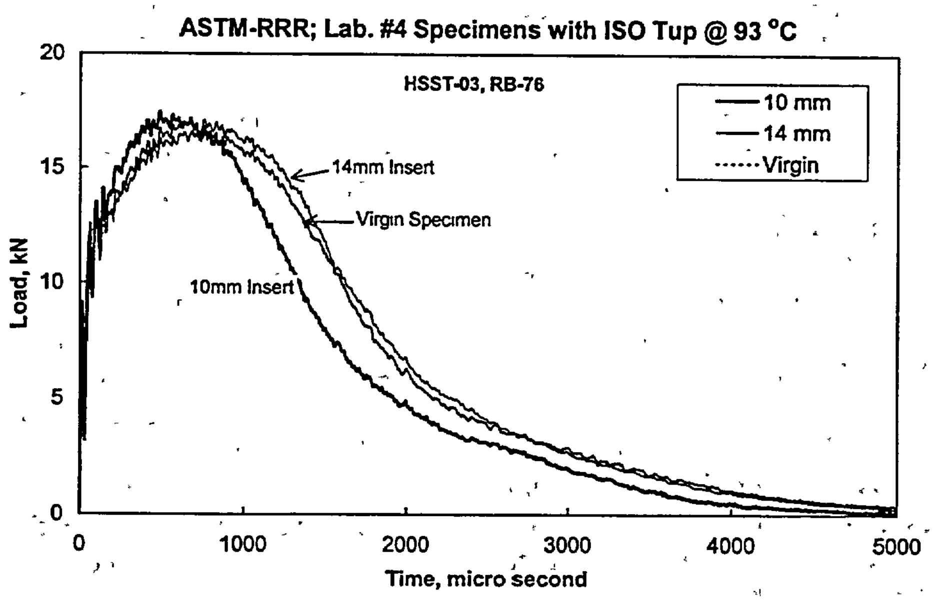


FIG. 19--Examples of instrumented Charpy signals before and after reconstitution at upper shelf temperature obtained from HSST-03 together with (a) the ASTM tup and (b) the ISO tup.

Table 6 summarizes the P_m values obtained from upper shelf data before and after reconstitution, while Figure 20 shows all data from the present analysis as a function of USE.

TABLE 6--Comparison of maximum load (Pm) and absorbed energy at upper shelf test temperature.

Material	Tup	Insert Length	Energy, J		Pm, kN		Number of Data
			Average	Std. Dev.	Average	Std. Dev.	
HSST-03	ASTM	10 mm	132.5	14 4	18.5	0.4	15
HSST-03	ASTM	14 mm	154.4	7.4	18.5	0.6	19
HSST-03	ASTM	Baseline	163.0	6.6	18.8	0.3	17
HSST-03	ISO	10mm	135.7	10.0	16.8	0.3	18
HSST-03	ISO	14 mm	150.2	5.6	16.4	0.5	20
HSST-03	ISO	Baseline	151.2	5.9	16.5	0.2	18
Linde 80	ASTM	10 mm	80.8	9.1	17.0	0.8	18
Linde 80	ASTM	14 mm	91.8	6.6	16.8	0.8	20
Linde 80	ASTM	Baseline	94.3	2.8	16.9	0.2	18
Linde 80	ISO	10 mm	87.3	11.0	15 4	0.4	20
Linde 80	ISO	14 mm	94.3	5.6	15.2	0 4	19
Linde 80	ISO	Baseline	93.3	3.4	15.2	0.1	17

The P_m point is slightly affected in the 10 mm insert case; it is reached at shorter times, but with little difference in the load value. As a result, the energy loss is significant for specimens with 10 mm inserts and causes the loss of absorbed energy and is caused by the constraint of plastic deformation at the hardened region (weldment and HAZ). However, there is no difference before and after reconstitution in the signals from specimens with 14mm inserts, except for HSST-03 specimens that were tested with the ASTM tup. The 'larger' ASTM tup induces plastic deformation in a larger length of the insert causing interaction with the HAZ and weld.

The average P_m values obtained for 10 mm insert specimens are approximately the same as the values from the virgin specimens. The difference in the average values is less than a standard deviation, although a small increase of P_m values can be seen for the ISO tup case.

Figure 21 is a graph of the average P_m values as a function of USE for baseline data, 14 mm insert and 10 mm insert specimens. The right symbol in three series of data corresponds to the baseline data, while the left symbol corresponds to the 10 mm insert data. In comparison with the loss of USE, the difference in P_m is clearly negligible.
In the transition temperature range, the specimens exhibit brittle fracture characterized by a sudden load drop eventually followed by crack arrest. Two to four Linde 80 weld specimens of each laboratory were tested at 2°C. A brittle crack initiation load, P_u, and a crack arrest load, Pa, were determined from the instrumented signal for each specimen

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(a)

(b)

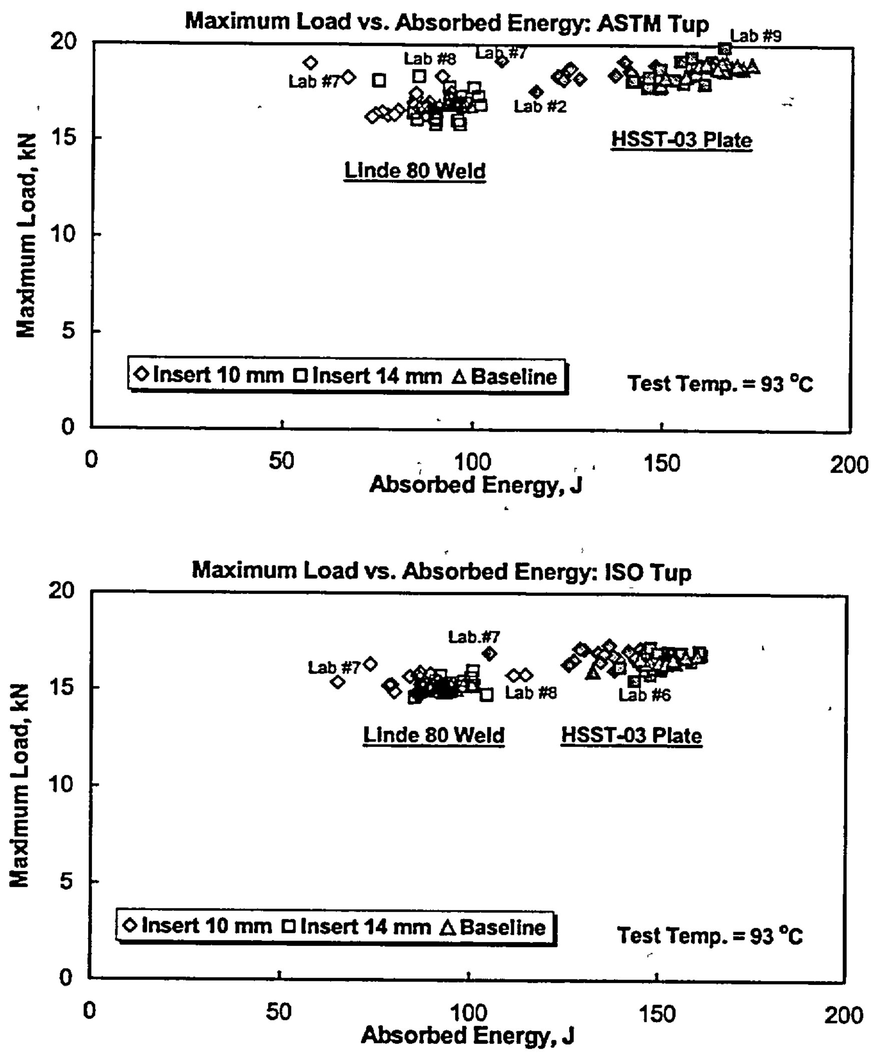


FIG 20--Relation between maximum load and upper shelf energy tested at 93°C with (a) the ASTM tup and (b) the ISO tup.

Figures 22 and 23 show the effect of insert length on the values of P_u and P_a, respectively. There is large scatter for each of these loads for both the virgin and reconstituted specimens, but the scatter band after reconstitution is slightly larger than the baseline data band. In particular, there are some Pa data from the ISO tup tests that deviate significantly from the average values. Table 7 and Figure 24 indicate the average values and standard deviations of P_u and P_a from all laboratories as well as those of shear fracture appearance. The P_u data after reconstitution are equivalent to the baseline data, while the P_a data and the shear appearance data increase after reconstitution. However, compared to the standard deviations, these increases are relatively small: about 1 kN for P_a and 5% for shear appearance.

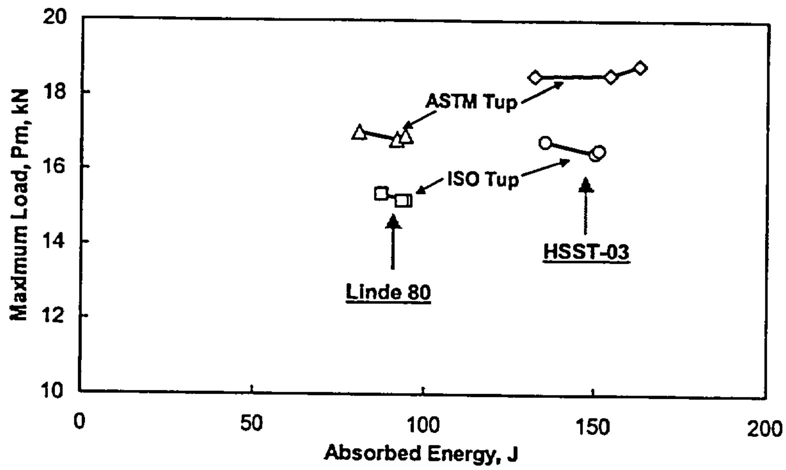
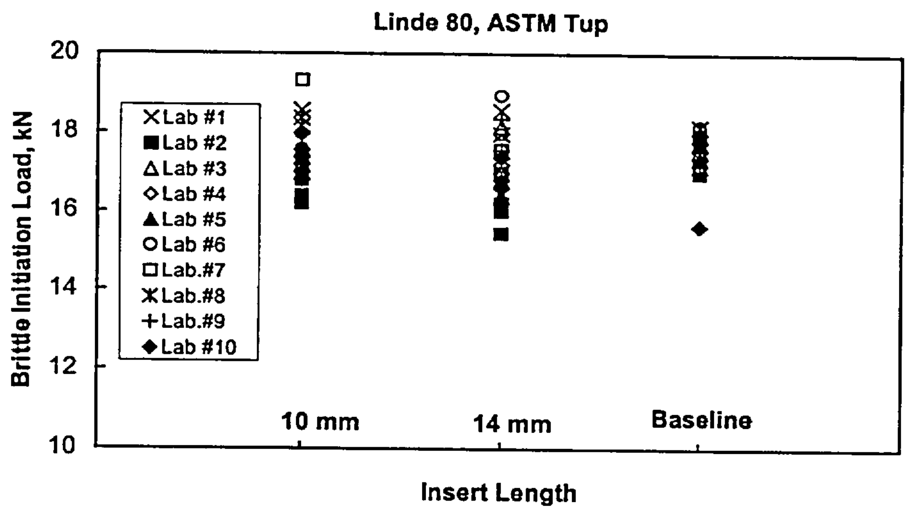
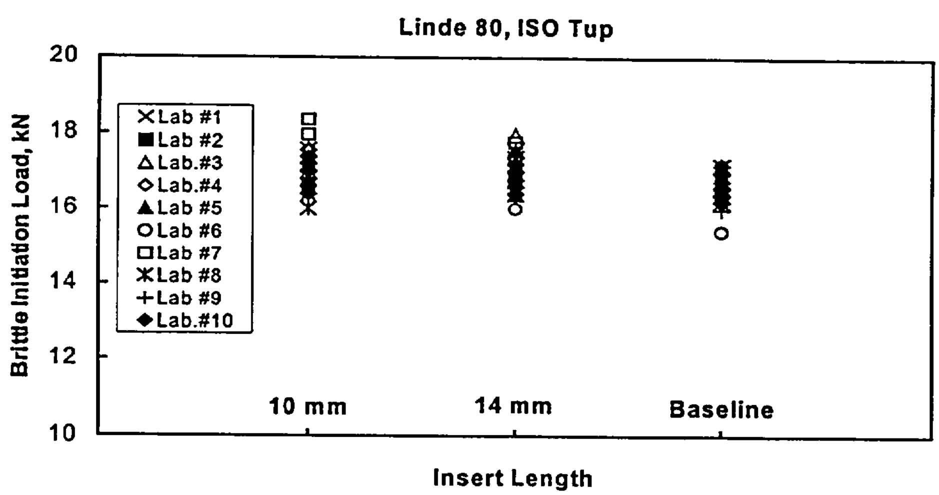


FIG. 21--The effect of reconstitution on the average maximum load (Pm) and the average absorbed energy at upper shelf temperature.

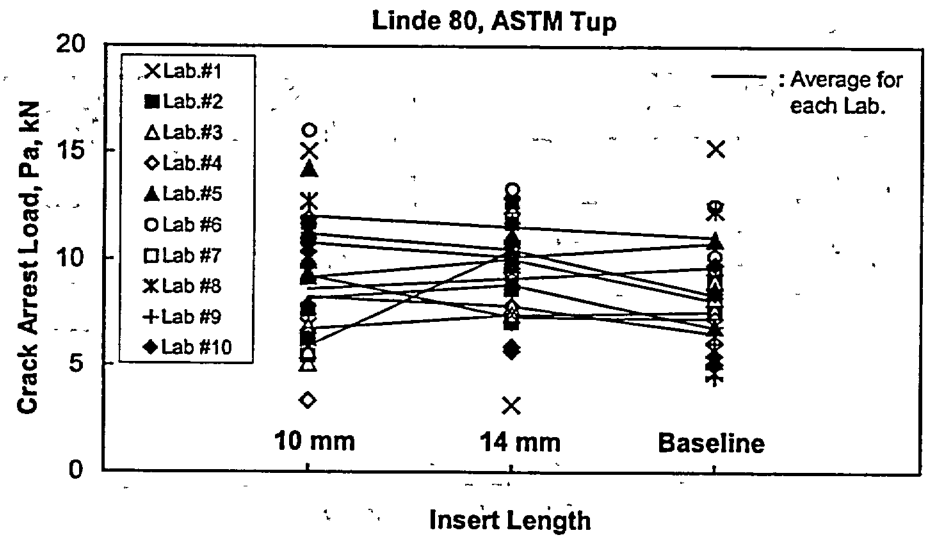


(a)



(b)

FIG. 22--Comparison of brittle crack initiation load before and after reconstitution for Linde 80 specimens tested at 2°C with (a) the ASTM tup and (b) the ISO tup.



(b)

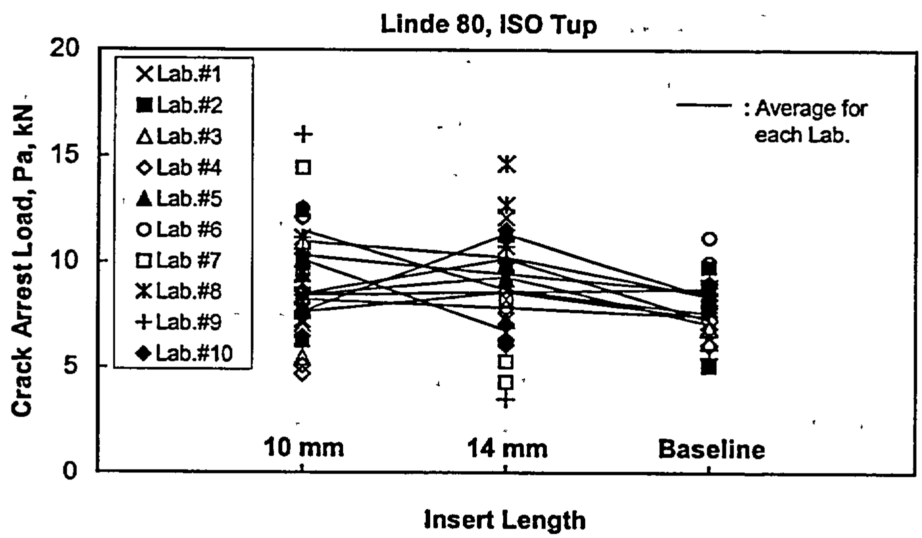


FIG. 23--Comparison of crack arrest load before and after reconstitution obtained from Linde 80 specimens tested at 2°C with (a) the ASTM tup and (b) the ISO tup. The average values for each laboratory (Lab.) are also indicated.

TABLE 7--Comparison of cleavage initiation load (Pu) and arrest load (Pa) of Linde 80.

(a) ASTM Tup at 2 °C

Average / Std.Dev.	Insert 10 mm	Insert 14 mm	Baseline
Cleavage Pu, kN	17.4	17.2	17.6
	0.6	0.8	0.5
Arrest Pa, kN	9.1	9.3	8.2
	3.1	2.2	2.4
Shear %	37.0	35.0	33.0
	16.9	11.4	11.9

(b) ISO Tup at 2 °C

Average / Std.Dev.	Insert 10 mm	Insert 14 mm	Baseline
Cleavage Pu, kN	17.1	16.9	16.6
	0.5	0.5	0.4
Arrest Pa, kN	9.2	9.2	7.9
	2.7	2.6	1.4
Shear %	39.5	39.8	33.2
	13.0	13.6	10.6

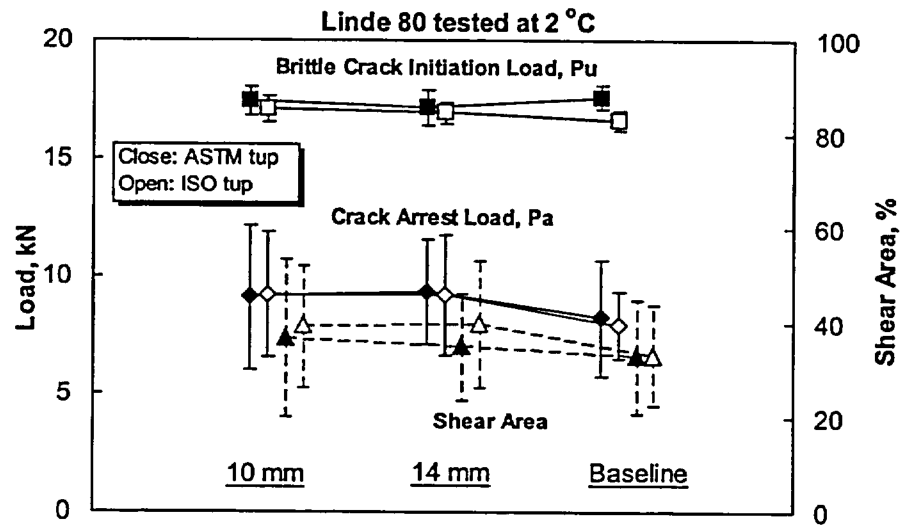


FIG. 24--The effect of reconstitution on brittle crack initiation load (Pu), crack arrest load (Pa), and percent shear fracture area.

Figure 25 shows a typical load diagram for the HSST-03 plate (data from ref. [5]) without the P_{gy} data. All data were from specimens of L-T and T-L orientations tested with the ASTM tup. The Charpy specimens were reconstituted by SW with a 10 mm insert. As can be seen in the figure, the P_u and P_a values in the transition temperature region are scattered even in the baseline condition. After reconstitution, the data points are also scattered but do not deviate from the baseline data range. The P_m data of HSST-03 from the RRR are also shown in Figure 25. There is negligible influence of reconstitution on the load diagram, since only 1 kN of difference in P_a was caused by reconstitution. Index temperatures T_I and T_0 from the load diagram are unaffected by the reconstitution process and provide reliable parameters for the characterization of Charpy shifts regardless of insert size or reconstitution process. In contrast, the absorbed energy and lateral expansion can be reduced by reconstitution when a small insert is used, leading to erroneous 41J temperature shift values. Therefore, the load diagram can be useful when the use of small inserts is necessary.

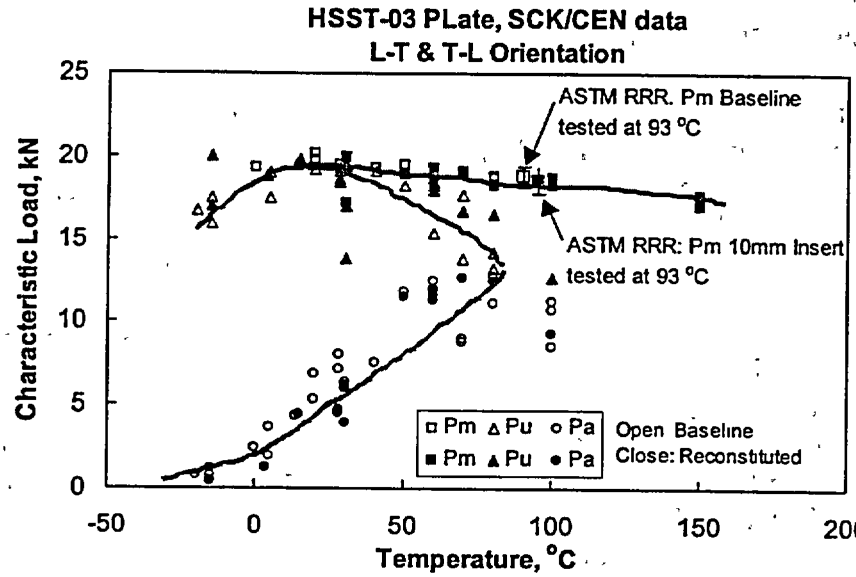


FIG. 25--Typical example of Charpy load diagram [4] together with the ASTM Round-Robin Reconstitution (RRR) data.

4.3 Effect of Specimen Dimension after Reconstitution

The important tolerance limits for the dimensions of Charpy specimen given in ASTM E23 are:

Thickness, B: 10.000 ± 0.075, mm
Width, W: 10.000 ± 0.075, mm
Notch depth, a: 2.000 ± 0.025, mm
Notch radius, R: 0.250 ± 0.025, mm

The thickness B and width W of the insert section are likely to violate these limits because the specimen machining after reconstitution may reduce the cross section of an original insert. The variation of specimen dimensions was checked for specimens that were reconstituted at each laboratory. Forty-eight specimens were reconstituted at each laboratory, as indicated in Table 1. For specimens reconstituted by Laboratories #2, #6 and #8, more than ten (13, 13 and 16, respectively) specimens were found to be outside of the tolerance limits. The other laboratories, except for Laboratory #7 which never measured the specimen dimension, had less than three specimens with dimensions outside the limits. The smallest W and B were 9.76 mm and 9.87 mm, respectively, and were found from different specimens. In many specimens with a W under the tolerance, the notch depth was also short, resulting in a ligament equivalent to a specimen meeting the dimensional requirements.

When the Charpy data were compared between specimens with and without satisfactory dimensions, no systematic deviations in results were found. For example, the specimen having the smallest W and the shortest ligament of 7.77 mm, showed the highest absorbed energy among four specimens reconstituted and tested at the same condition. This means that the variations in specimen dimensions after reconstitution are not significant as compared to the data scatter.

5 CONCLUSIONS

The analysis of results from the ASTM Round-Robin on Reconstitution was performed. The effects of reconstitution on the conventional Charpy results, instrumented Charpy signals as well as variations among participants, were discussed. The conclusions are:

1. It is found that there is generally little effect of reconstitution on Charpy properties when the 14 mm insert is used for all reconstitution techniques for all energy levels, particularly for the ISO-tup test. However, Figure 14 shows significant loss of upper shelf energy when upper shelf energy is high and an ASTM tup is used. E1253 requires an insert size larger than 14mm by the size of the HAZs caused by the reconstitution process. Therefore, it is concluded that the insert size requirement of E1253 cannot be universally reduced.

2. There is an effect of reconstitution on the absorbed energy and lateral expansion when the 10 mm insert is used. Therefore, 10 mm inserts should not be used to the upper shelf or the mid-transition regions of Charpy transition curves. The loss of upper shelf energy due to reconstitution can be separated into two or three categories based on the combination of welding technique and tup geometry. The highest loss occurs when thick welds are present and when the specimens are tested with the ASTM tup.

3. The measured temperature during welding and the hardened width across the weldment are correlated with the heat input.

4. There are large variations in welding parameters even with the same welding technique. The best temperature distribution in the specimen (leading to the smallest HAZs) was obtained from electron-beam welding. The results from stud welding were highly dependent upon the welding parameters.

5. There was no significant effect on characteristic loads in the instrumented Charpy signals. It is concluded that the load diagram can be used when small insert sizes are required.

6. In some cases there were violations of the dimensional requirements of ASTM E23 for the reconstituted specimens. However, these violations did not significantly affect the absorbed energy of the reconstituted specimens.

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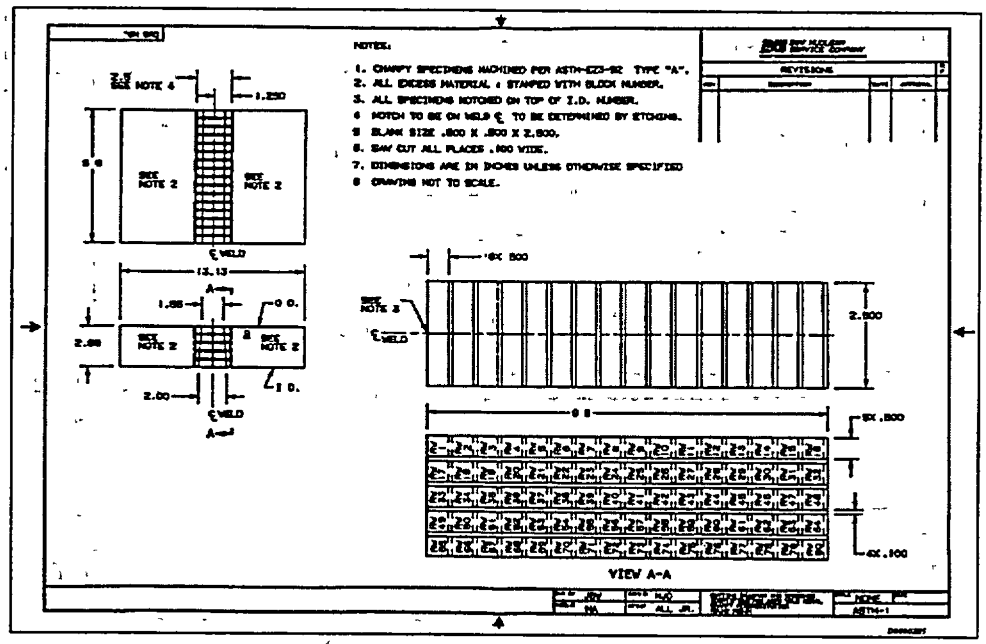
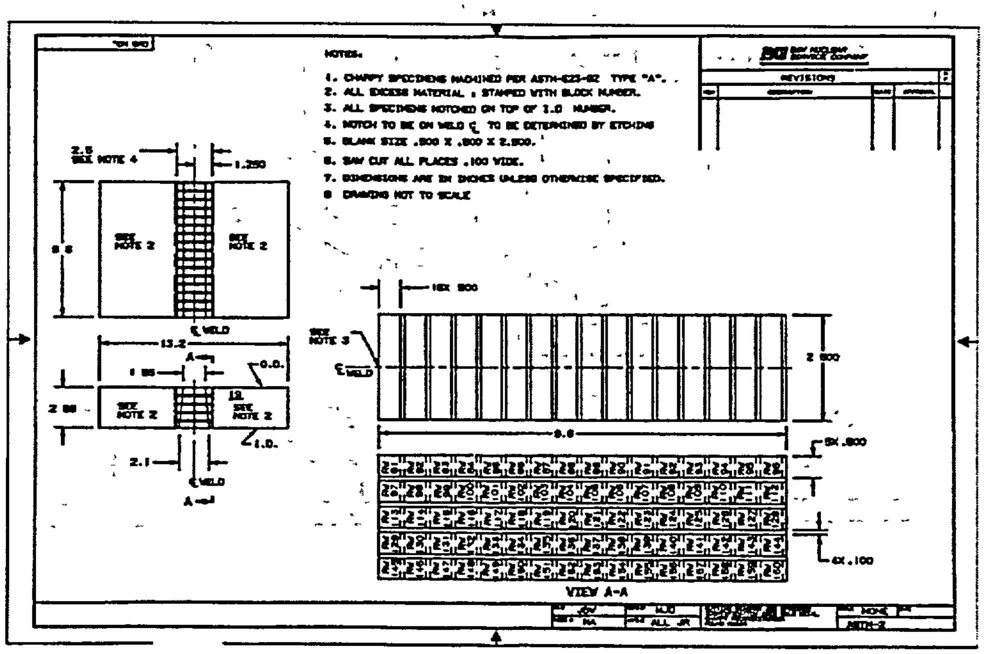
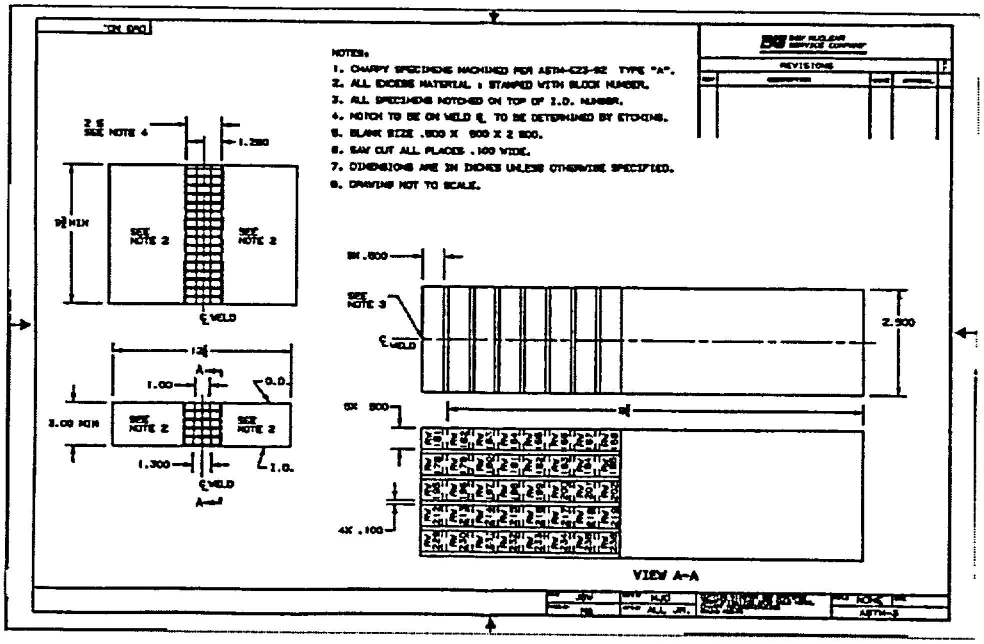
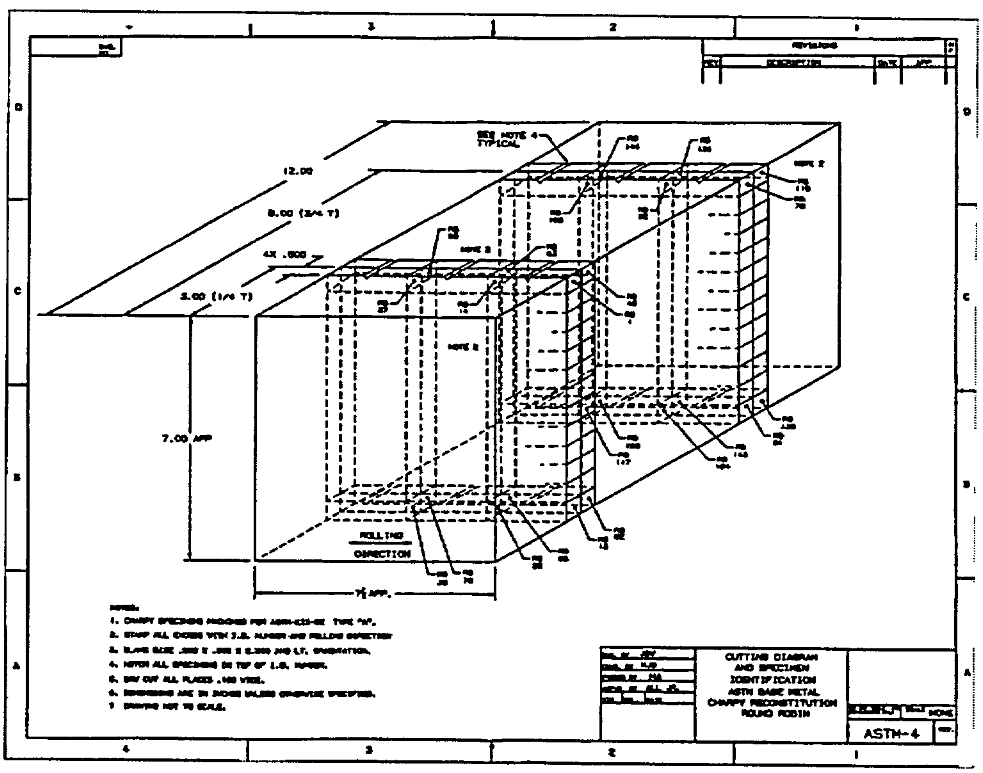
APPENDIX A

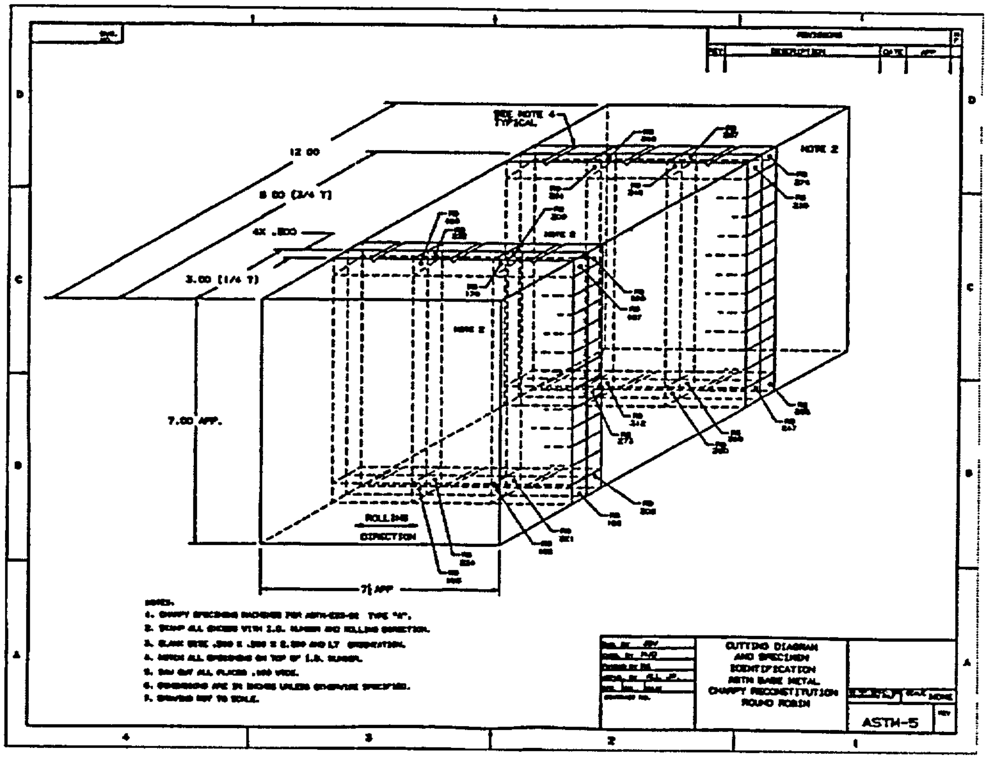
CUTTING DIAGRAM WITH THE LOCATION OF VIRGIN SPECIMENS WITHIN (A) HSST-03 AND (B) LINDE 80.






NOTES:
1. CHARPY SPECIMENS MACHINED PER ASTM-E23-92 TYPE "A".
2. ALL EXCESS MATERIAL : STAMPED WITH BLOCK NUMBER.
3. ALL SPECIMENS NOTCHED ON TOP OF I.D. NUMBER.
4. NOTCH TO BE ON WELD ℄ TO BE DETERMINED BY ETCHING.
5. BLANK SIZE .500 X .500 X 2.500.
6. SAW CUT ALL PLACES .100 WIDE.
7. DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
8. DRAWING NOT TO SCALE.
REVISIONS
SEE NOTE 4
1.280
SEE NOTE 2
SEE NOTE 2
℄ WELD
1.00
3.00 MIN
1.300
I.D.
O.D.
SEE NOTE 3
2.500
VIEW A-A
4X .100
ASTM-3


REVISIONS
DESCRIPTION
SEE NOTE 4 TYPICAL
12.00
9.00 (3/4 T)
4X .600
3.00 (1/4 T)
7.00 APP
ROLLING DIRECTION
NOTE 2
NOTES:
CUTTING DIAGRAM
AND SPECIMEN
IDENTIFICATION
ASTM BASE METAL
CHARPY RECONSTITUTION
ROUND ROBIN
ASTM-4
NONE


SEE NOTE 4
TYPICAL
NOTE 2
12.00
8.00 (3/4 T)
4X .500
3.00 (1/4 T)
7.00 APP.
ROLLING
DIRECTION
CUTTING DIAGRAM
AND SPECIMEN
IDENTIFICATION
ASTM BASE METAL
CHARPY RECONSTITUTION
ROUND ROBIN
ASTM-5

APPENDIX B

PROCEDURE FOR THE ASTM ROUND-ROBIN ON RECONSTITUTION.

E. van Walle, T. Van Ransbeeck, J. Van de Velde
SCK•CEN, Mol, Belgium

W. Pavinich
Invex Engineering, Knoxville, USA

1. Purpose

The purpose of this procedure is to define the different steps before, during and after reconstitution of broken Charpy-V specimens. These steps are to be followed by the participants of the RRR to provide adequate information to ASTM.

2. Related documents

2.1 ASTM Standard Guide E1253 on "Reconstitution of Irradiated Charpy Specimens".

2.2 Test matrix: defined in Memorandum on "ASTM Reconstituted Charpy Specimen Round Robin" from Wayne Pavinich to Round Robin Participants, dated July 10, 1992.

3. Necessary Equipment

3.1 Reconstitution Set Up

Participant's installation.

3.2 Hardness testing

All hardness tests should be performed with Vickers Hardness 49N (5kgf). The participants are asked to verify the calibration before testing. The verification shall be recorded on data sheet 1.

3.3 Dimensional control

The dimensions of finished reconstituted samples should be measured with a profile projector and/or with micrometers and should be in accordance with ASTM Standard Guide E1253. The data should be recorded on data sheet 2 (the ASTM specification is more stringent than the DIN specification).

4. Procedure

4.1 Hardness measurements

The hardness data shall be taken:

a) on insert material before reconstitution and on completed reconstituted Charpy-V samples. Hardness testing shall be performed on the face, as indicated in the drawing on data sheet 1; in the longitudinal direction along lines at 2, 5 and 8mm from the (future) notch surface. At 1mm intervals, a hardness measurement shall be taken in the longitudinal direction. These data shall be recorded on data sheet 1. Hardness measurements shall be taken, before re-constitution, on two inserts for both insert lengths for both materials (for a total of eight inserts), and

b) on the stud material before welding. Hardness tests shall be taken as close to the future finished (side) surface as possible. In this way, the comparison of hardness values before and after reconstitution will be as accurate as possible. This comparison will determine the effect of reconstitution on the mechanical properties of the studs. Hardness tests shall be taken on the sixteen studs that will be reconstituted with the eight inserts that are also hardness tested before reconstitution.

4.2 Stud material

Every participant will receive a 12x13x20cm block of nuclear grade material (18MND5) with chemical composition and tensile data, as specified in Tables B-1 and B-2. The rolling direction is along the 20cm direction and will be indicated on the top surface of the block. The participants are asked to cut their studs lengthwise in the rolling direction of this block. Only material between 1.5cm from the top surface and 1.5cm above the bottom surface should be used. The material should be enough for at least 120 studs (maximum dimensions per stud: 2x2x4cm).

The participants are free to determine additional tensile data from the remaining material.

The participants are requested to take hardness data on 16 marked (with the identification of the respective future inserts, see section 4.4.1) studs before reconstitution. The procedure for hardness testing is given in section 4.1.

4.3 Reception of the specimens

The participants will receive broken Charpy specimens: 24 halves of low upper shelf energy (USE) material (Linde 80 weld), 24 halves of high USE-material (HSST-03 plate). The specimens have an identification number on both halves. The left half of the specimen has a code like XY123, whereas the right side has the identical code supplemented with a dot (e.g. XY123.).

4.4 Insert preparation

4.4.1 Identification

The inserts shall be controlled with registration cards, that will accompany each insert, until the reconstitution is completed. An example is given in data sheet 3. The inserts shall retain the original identification of the Charpy half, supplemented with an additional code. An additional letter A indicates the insert was taken next to the 'old' notch of the broken Charpy half. When a second insert is taken from one Charpy half it will carry an additional letter B. Since it is difficult to mark the inserts, it is recommended to place each insert in a small can-nister, labelled with its identification.

4.4.2 Notch plane

Before cutting any material from the broken Charpy specimen, a mark should be made to define the future notch plane and notch orientation. For this RRR, the future notch shall be on the same face as in the original Charpy specimen and shall have the same orientation.

4.4.3 Insert preparation

For the low USE-material, chemical etching should be used to clearly identify the weld and the base material. The inserts shall be fully taken from the weld and a maximum of one insert per Charpy half can be extracted. One Charpy half of the high USE-material will in most cases allow for the extraction of two inserts.

For each material, twelve 10mm long inserts will be prepared from 12 halves, while twelve 14mm long inserts will be prepared from the remaining 12 halves. Any unused insert material shall be returned to ASTM unless ASTM has approved the use of this material for other purposes.

When preparing the inserts remove all plastic deformation first. Depending upon the test temperature of the original Charpy specimen the size of the plastic zone will vary. It is important to note that the exact insert length before reconstitution should be 10 and 14mm.

4.4.4 Hardness measurements

For each material, hardness measurements shall be taken on two 10mm and two 14mm inserts. The procedure is given in section 4.1. The data shall be recorded on data sheet 1.

5. Reconstitution

5.1 Recording information

Every participant is requested to fill out a data sheet for each reconstituted Charpy specimen. As previously mentioned, data sheet 3 gives an example. Information to be recorded includes: identification of the insert, position of the insert within the original Charpy half, insert length, temperature on dummy test samples before and after reconstitution (see below), reconstitution method, specific welding parameters and remarks.

5.2 Temperature measurement before and after reconstitution

Every participant must perform a temperature test before and after a series of reconstitution weldments (the number of reconstitution welds within a welding campaign is at the discretion of the participant; however this number should be maximised to avoid variation). The temperature should at all times remain below 300 . C.

For these measurements, thermocouples brazed within dummy insert pieces (length 10 and 14mm), shall be used by all participants. The temperature shall be measured at 3mm from the future notch position. The type of thermocouple to be used is a 1mm diameter Chromel Alumel K-type thermocouple with grounded hot junction (possible world wide supplier: Thermoelectric). The preparation method for instrumenting the dummy samples is given below.

5.2.1. Dummy insert preparation

Drawing 1 shows a typical 10x10xX mm insert (X=10, 14mm) that has been prepared for the inser-tion of a thermocouple with a 1mm diameter. The design might be different for different reconstitution set ups. The important dimensions are the 1.1mm diameter hole, the dummy insert length corresponding to the to-be-reconstituted insert length, and the distance of resp. 2 and 4mm between the to-be-welded surface(s) and the future position of the tip of the thermocouple for resp. 10 and 14mm. The hole shall be larger in diameter near the surface and shall taper to the smaller diameter of 1.1mm. This avoids fracture of the thermocouple after brazing.

5.2.2. Insertion and brazing of the thermocouple

A fixture shall be used to assure that the tip of the thermocouple is at the bottom of the hole after brazing. Then add 30 mg of Nicrobraz LM (composition see drawing 2). Follow the thermal cycle given in drawing 3 (maintain the temperature at 1070°C for one minute) for brazing the thermocouple into the dummy insert.

The participants shall provide ASTM with a schematic drawing showing the layout of their instrumented insert. The output voltage of the thermocouple as a function of time shall also be recorded. A voltage-temperature conversion table can be found in the Handbook of Chemistry and Physics.

5.3 Reconstitution

Every participant shall use his own method to reconstitute the 48 insert pieces. Since hardness measurements are to be performed after reconstitution, care should be taken to weld the sixteen marked studs to the corresponding eight insert pieces on which hardness measurements were made, as defined under 4.2 and 4.4.4.

5.4 Sample Machining

The participant shall machine the reconstituted Charpy specimen according to the ASTM standard. Care shall be taken to the notch position and the notch depth and profile. The dimensional data shall be recorded on data sheet 2. The notch preparation method shall also be recorded.

5.5 Hardness testing

After reconstituting and machining the samples, the participant is requested to make hardness measurements on the overall length of the eight reconstituted Charpy specimens (two materials with each two different insert lengths) where hardness data exist on the inserts and studs before reconstitution. The procedure to be followed is outlined in 4.1.

6. Shipping of the reconstituted specimens

Ship the 48 reconstituted specimens to Oak Ridge National Lab for testing, along with the dimensional data, the hardness data and the individual record sheets.

Shipping address:

Dr R.K. Nanstad
Oak Ridge National Laboratory
Building 45005, MS-151
P.O. Box 2008
Oak Ridge, TN 37831-6151
USA

Table B-1.Chemical analysis performed at 1/4 thickness for the 18MND5 stud material.

weight %	specification	actual top	actual bottom
C	≤0.22	0.180	0.170
Mn	1.15-1.60	1.560	1.540
Si	0.10-0.30	0.250	0.240
Ni	0.50-0.80	0.645	0.635
Cr	≤0.25	0.180	0.175
Mo	0.43-0.57	0.500	0.490
Cu	≤0.20	0.130	0.125
S	≤0.015	0.002	0.002
P	≤0.020	0.008	0.008
Al	≤0.04	0.020	0.021
V	≤0.03	<0.005	<0.005

Table B-2. Tensile properties of the 18MND5 stud material in transverse direction (1/4 thickness, room temperature).

18MND5 RRR	Yield 0.2% (MPa)	Ultimate (MPa)	Reduction of Area (%)	Elongation (%)
Top	506	651	71.9	24.0
bottom	522	660	70.8	23.0

APPENDIX C

CHARPY IMPACT TEST DATA FOR VIRGIN SPECIMENS

Table C-1 Charpy impact test data for virgin specimens: HSST-03 plate, ASTM tup, High temperature.

COUNT	IDENT	TEMP DEG C	TEMP DEG F	ENERGY J	ENERGY FT-LB	EXPAN MM	EXPAN IN	SHEAR PERCENT
1	RB_2	93.3	200	166.8	123.0	1.295	0.051	100
2	RB_6	93.3	200	172.5	127.2	1.295	0.051	100
3	RB_10	93.3	200	172.5	127.2	1.295	0.051	100
4	RB_14	93.3	200	149.3	110.1	1.143	0.045	100
5	RB_18	93.3	200	172.1	126.9	1.321	0.052	100
6	RB_22	93.3	200	163.6	120.7	1.295	0.051	100
7	RB_26	93.3	200	169.5	125.0	1.245	0.049	100
8	RB_30	93.3	200	164.2	121.1	1.321	0.052	100
9	RB_34	93.3	200	161.2	118.9	1.245	0.049	100
10	RB_38	93.3	200	161.2	118.9	1.321	0.052	100
11	RB_42	93.3	200	159.3	117.5	1.219	0.048	100
12	RB_46	93.3	200	162.7	120.0	1.245	0.049	100
13	RB_50	93.3	200	165.4	122.0	1.295	0.051	100
14	RB_54	93.3	200	173.5	128.0	1.270	0.050	100
15	RB_58	93.3	200	153.5	113.2	1.168	0.046	100
16	RB_62	93.3	200	163.1	120.3	1.219	0.048	100
17	RB_66	93.3	200	150.5	111.0	1.194	0.047	100
18	RB_70	93.3	200	171.1	126.2	1.321	0.052	100
19	RB_74	93.3	200	166.6	122.9	1.295	0.051	100
20	RB_78	93.3	200	168.1	124.0	1.270	0.050	100
21	RB_82	93.3	200	162.7	120.0	1.270	0.050	100
22	RB_86	93.3	200	155.9	115.0	1.219	0.048	100
23	RB_90	93.3	200	157.3	116.0	1.143	0.045	100
			Average	163.6	120.7	1.257	0.049	100
			Std. Dev.	7.0	5.1	0.056	0.002	0

Table C-2 Charpy impact test data for virgin specimens: HSST-03 plate, ISO tup, High temperature.

COUNT	IDENT	TEMP DEG C	TEMP DEG F	ENERGY J	ENERGY FT-LB	EXPAN MM	EXPAN IN	SHEAR PERCENT
1	RB_4	93.3	200	151.9	112.0	2.311	0.091	100
2	RB_8	93.3	200	150.5	111.0	2.159	0.085	100
3	RB_12	93.3	200	157.5	116.2	2.413	0.095	100
4	RB_16	93.3	200	147.8	109.0	2.286	0.09	100
5	RB_20	93.3	200	154.6	114.0	2.337	0.092	100
6	RB_24	93.3	200	153.9	113.5	2.362	0.093	100
7	RB_28	93.3	200	157.3	116.0	2.337	0.092	100
8	RB_32	93.3	200	154.6	114.0	2.311	0.091	100
9	RB_36	93.3	200	154.0	113.6	2.261	0.089	100
10	RB_40	93.3	200	147.8	109.0	2.311	0.091	100
11	RB_44	93.3	200	160.3	118.2	2.362	0.093	100
12	RB_48	93.3	200	153.3	113.1	2.337	0.092	100
13	RB_52	93.3	200	155.1	114.4	2.337	0.092	100
14	RB_56	93.3	200	149.1	110.0	2.134	0.084	100
15	RB_60	93.3	200	151.9	112.0	2.286	0.09	100
16	RB_64	93.3	200	152.9	112.8	2.261	0.089	100
17	RB_68	93.3	200	152.0	112.1	2.159	0.085	100
18	RB_72	93.3	200	150.0	110.6	2.159	0.085	100
19	RB_76	93.3	200	146.6	108.1	2.21	0.087	100
20	RB_80	93.3	200	152.8	112.7	2.261	0.089	100
21	RB_84	93.3	200	150.2	110.8	2.311	0.091	100
22	RB_88	93.3	200	145.1	107.0	2.235	0.088	100
23	RB_92	93.3	200	132.6	97.8	2.057	0.081	100
			Average	151.4	111.6	2.269	0.089	100
			Std. Dev.	5.5	4.0	0.088	0.003	0

Table C-3 Charpy impact test data for virgin specimens: HSST-03 plate, ASTM tup, Low temperature.

COUNT	IDENT	TEMP DEG C	TEMP DEG F	ENERGY J	ENERGY FT-LB	EXPAN MM	EXPAN IN	SHEAR PERCENT
1	RB_1	-12.2	10	38.0	28.0	0.610	0.024	10
2	RB_5	-12.2	10	35.9	26.5	0.559	0.022	10
3	RB_9	-12.2	10	34.6	25.5	0.559	0.022	10
4	RB_13	-12.2	10	24.4	18.0	0.406	0.016	10
5	RB_17	-12.2	10	43.4	32.0	0.660	0.026	10
6	RB_21	-12.2	10	37.4	27.6	0.533	0.021	10
7	RB_25	-12.2	10	47.7	35.2	0.711	0.028	10
8	RB_29	-12.2	10	56.9	42.0	0.864	0.034	10
9	RB_33	-12.2	10	52.9	39.0	1.346	0.053	10
10	RB_37	-12.2	10	43.4	32.0	0.660	0.026	10
11	RB_41	-12.2	10	55.6	41.0	0.889	0.035	10
12	RB_45	-12.2	10	38.0	28.0	0.584	0.023	10
13	RB_49	-12.2	10	43.4	32.0	0.660	0.026	10
14	RB_53	-12.2	10	42.0	31.0	0.660	0.026	10
15	RB_57	-12.2	10	32.5	24.0	0.483	0.019	10
16	RB_61	-12.2	10	31.9	23.5	0.508	0.020	10
17	RB_65	-12.2	10	32.4	23.9	0.584	0.023	10
18	RB_69	-12.2	10	19.0	14.0	0.356	0.014	10
19	RB_73	-12.2	10	36.3	26.8	0.584	0.023	10
20	RB_77	-12.2	10	52.9	39.0	0.737	0.029	10
21	RB_81	-12.2	10	28.3	20.9	0.533	0.021	10
22	RB_85	-12.2	10	43.4	32.0	0.737	0.029	10
23	RB_89	-12.2	10	47.3	34.9	0.711	0.028	10
24	RB_93	-12.2	10	28.3	20.9	0.483	0.019	10
25	RB_97	-12.2	10	42.3	31.2	0.610	0.024	10
26	RB_101	-12.2	10	33.1	24.4	0.508	0.020	10
27	RB_105	-12.2	10	31.2	23.0	0.483	0.019	10
28	RB_109	-12.2	10	35.9	26.5	0.559	0.022	10
29	RB_113	-12.2	10	40.5	29.9	0.610	0.024	10
30	RB_117	-12.2	10	29.7	21.9	0.483	0.019	10
31	RB_121	-12.2	10	39.3	29.0	0.635	0.025	10
32	RB_125	-12.2	10	58.6	43.2	0.864	0.034	10
33	RB_129	-12.2	10	35.5	26.2	0.559	0.022	10
34	RB_133	-12.2	10	48.3	35.6	0.737	0.029	10
35	RB_137	-12.2	10	47.5	35.0	0.711	0.028	10
36	RB_141	-12.2	10	32.8	24.2	0.483	0.019	10
37	RB_145	-12.2	10	50.2	37.0	0.762	0.030	10
38	RB_149	-12.2	10	48.1	35.5	0.787	0.031	10
39	RB_153	-12.2	10	45.8	33.8	0.660	0.026	10
40	RB_157	-12.2	10	48.3	35.6	0.483	0.019	10
41	RB_161	-12.2	10	36.6	27.0	0.559	0.022	10
42	RB_165	-12.2	10	43.9	32.4	0.635	0.025	10
43	RB_169	-12.2	10	61.0	45.0	0.889	0.035	10
44	RB_173	-12.2	10	54.1	39.9	0.813	0.032	10
45	RB_177	-12.2	10	48.3	35.6	0.711	0.028	10
46	RB_181	-12.2	10	25.8	19.0	0.914	0.036	10
			Average	40.9	30.2	0.649	0.026	10
			Std. Dev.	9.7	7.1	0.170	0.007	0

Table C-4 Charpy impact test data for virgin specimens: HSST-03 plate, ISO tup, Low temperature.

COUNT	IDENT	TEMP DEG C	TEMP DEG F	ENERGY J	ENERGY FT-LB	EXPAN MM	EXPAN IN	SHEAR PERCENT
1	RB_3	-12.2	10	44.1	32.5	0.762	0.030	10
2	RB_7	-12.2	10	46.8	34.5	0.711	0.028	10
3	RB_11	-12.2	10	37.3	27.5	0.610	0.024	10
4	RB_15	-12.2	10	48.3	35.6	0.787	0.031	10
5	RB_19	-12.2	10	33.9	25.0	0.584	0.023	10
6	RB_23	-12.2	10	44.9	33.1	0.737	0.029	10
7	RB_27	-12.2	10	23.9	17.6	0.457	0.018	10
8	RB_31	-12.2	10	41.2	30.4	0.686	0.027	10
9	RB_35	-12.2	10	38.0	28.0	0.610	0.024	10
10	RB_39	-12.2	10	27.1	20.0	0.508	0.020	10
11	RB_43	-12.2	10	27.9	20.6	0.457	0.018	10
12	RB_47	-12.2	10	29.0	21.4	0.533	0.021	10
13	RB_51	-12.2	10	28.7	21.2	0.508	0.020	10
14	RB_55	-12.2	10	42.0	31.0	0.737	0.029	10
15	RB_59	-12.2	10	42.0	31.0	0.711	0.028	10
16	RB_63	-12.2	10	23.2	17.1	0.406	0.016	10
17	RB_67	-12.2	10	31.7	23.4	0.559	0.022	10
18	RB_71	-12.2	10	40.7	30.0	0.610	0.024	10
19	RB_75	-12.2	10	28.5	21.0	0.508	0.020	10
20	RB_79	-12.2	10	30.6	22.6	0.508	0.020	10
21	RB_83	-12.2	10	39.6	29.2	0.610	0.024	10
22	RB_87	-12.2	10	35.0	25.8	0.610	0.024	10
23	RB_91	-12.2	10	40.7	30.0	0.762	0.030	10
24	RB_95	-12.2	10	38.9	28.7	0.660	0.026	10
25	RB_99	-12.2	10	45.7	33.7	0.711	0.028	10
26	RB_103	-12.2	10	38.5	28.4	0.584	0.023	10
27	RB_107	-12.2	10	42.7	31.5	0.711	0.028	10
28	RB_111	-12.2	10	20.5	15.1	0.381	0.015	10
29	RB_115	-12.2	10	42.3	31.2	0.686	0.027	10
30	RB_119	-12.2	10	25.9	19.1	0.457	0.018	10
31	RB_123	-12.2	10	52.6	38.8	0.660	0.026	10
32	RB_127	-12.2	10	20.5	15.1	0.381	0.015	10
33	RB_131	-12.2	10	46.0	33.9	0.787	0.031	10
34	RB_135	-12.2	10	36.6	27.0	0.610	0.024	10
35	RB_139	-12.2	10	41.2	30.4	0.686	0.027	10
36	RB_143	-12.2	10	36.6	27.0	0.610	0.024	10
37	RB_147	-12.2	10	52.2	38.5	0.889	0.035	10
38	RB_151	-12.2	10	46.1	34.0	0.737	0.029	10
39	RB_155	-12.2	10	46.1	34.0	0.711	0.028	10
40	RB_159	-12.2	10	56.9	42.0	0.864	0.034	10
41	RB_163	-12.2	10	42.7	31.5	0.711	0.028	10
42	RB_167	-12.2	10	44.9	33.1	0.737	0.029	10
43	RB_171	-12.2	10	37.6	27.7	0.660	0.026	10
44	RB_175	-12.2	10	40.7	30.0	0.660	0.026	10
45	RB_179	-12.2	10	47.2	34.8	0.711	0.028	10
46	RB_183	-12.2	10	22.9	16.9	0.406	0.016	10
			Average	38.1	28.1	0.630	0.025	10
			Std. Dev.	8.9	6.6	0.125	0.005	0

Table C-5 Charpy impact test data for virgin specimens: Linde 80 weld, ASTM tup, High temperature.

COUNT	IDENT	TEMP DEG C	TEMP DEG F	ENERGY J	ENERGY FT-LB	EXPAN MM	EXPAN IN	SHEAR PERCENT
1	RW_2	93.3	200	96.0	70.8	1.651	0.065	99
2	RW_6	93.3	200	94.8	69.9	1.626	0.064	99
3	RW_10	93.3	200	95.2	70.2	1.651	0.065	99
4	RW_14	93.3	200	95.6	70.5	1.753	0.069	99
5	RW_18	93.3	200	88.0	64.9	1.499	0.059	99
6	RW_22	93.3	200	92.3	68.1	1.626	0.064	99
7	RW_26	93.3	200	90.8	67.0	1.600	0.063	100
8	RW_30	93.3	200	89.5	66.0	1.575	0.062	99
9	RW_34	93.3	200	96.4	71.1	1.626	0.064	99
10	RW_38	93.3	200	93.4	68.9	1.626	0.064	99
11	RW_42	93.3	200	94.2	69.5	1.651	0.065	99
12	RW_46	93.3	200	93.3	68.8	1.676	0.066	99
13	RW_50	93.3	200	97.6	72.0	1.626	0.064	100
14	RW_54	93.3	200	95.9	70.7	1.702	0.067	99
15	RW_58	93.3	200	95.6	70.5	1.778	0.070	99
16	RW_62	93.3	200	95.7	70.6	1.702	0.067	100
17	RW_66	93.3	200	95.4	70.4	1.651	0.065	100
18	RW_70	93.3	200	94.9	70.0	1.727	0.068	100
19	RW_74	93.3	200	91.9	67.8	1.676	0.066	97
20	RW_78	93.3	200	93.4	68.9	1.651	0.065	97
21	RW_82	93.3	200	97.3	71.8	1.676	0.066	99
22	RW_86	93.3	200	98.3	72.5	1.702	0.067	97
23	RW_90	93.3	200	99.1	73.1	1.753	0.069	99
			Average	94.5	69.7	1.661	0.065	99
			Std. Dev.	2.7	2.0	0.062	0.002	1

Table C-6 Charpy impact test data for virgin specimens: Linde 80 weld, ISO tup, High temperature.

COUNT	IDENT	TEMP DEG C	TEMP DEG F	ENERGY J	ENERGY FT-LB	EXPAN MM	EXPAN IN	SHEAR PERCENT
1	RW_4	93.3	200	91.5	67.5	1.702	0.067	99
2	RW_8	93.3	200	92.7	68.4	1.854	0.073	99
3	RW_12	93.3	200	89.5	66.0	1.651	0.065	99
4	RW_16	93.3	200	99.2	73.2	1.930	0.076	100
5	RW_20	93.3	200	88.1	65.0	1.778	0.070	99
6	RW_24	93.3	200	89.5	66.0	1.803	0.071	99
7	RW_28	93.3	200	86.8	64.0	1.651	0.065	100
8	RW_32	93.3	200	94.9	70.0	1.753	0.069	100
9	RW_36	93.3	200	93.4	68.9	1.829	0.072	99
10	RW_40	93.3	200	91.0	67.1	1.829	0.072	100
11	RW_44	93.3	200	91.9	67.8	1.753	0.069	99
12	RW_48	93.3	200	93.3	68.8	1.727	0.068	99
13	RW_52	93.3	200	95.4	70.4	1.727	0.068	100
14	RW_56	93.3	200	92.5	68.2	1.651	0.065	100
15	RW_60	93.3	200	95.0	70.1	1.778	0.070	100
16	RW_64	93.3	200	95.0	70.1	1.854	0.073	99
17	RW_68	93.3	200	93.8	69.2	1.727	0.068	100
18	RW_72	93.3	200	95.0	70.1	1.880	0.074	99
19	RW_76	93.3	200	91.5	67.5	1.676	0.066	99
20	RW_80	93.3	200	92.6	68.3	1.854	0.073	99
21	RW_84	93.3	200	96.3	71.0	1.753	0.069	99
22	RW_88	93.3	200	98.3	72.5	1.854	0.073	99
23	RW_92	93.3	200	100.5	74.1	1.981	0.078	99
			Average	93.4	68.9	1.782	0.070	99
			Std. Dev.	3.4	2.5	0.090	0.004	0

Table C-7 Charpy impact test data for virgin specimens: Linde 80 weld, ASTM tup, Low temperature.

COUNT	IDENT	TEMP DEG C	TEMP DEG F	ENERGY J	ENERGY FT-LB	EXPAN MM	EXPAN IN	SHEAR PERCENT
1	RW_1	1.7	35	39.6	29.2	0.686	0.027	20
2	RW_5	1.7	35	45.6	33.6	0.838	0.033	25
3	RW_9	1.7	35	40.7	30.0	0.762	0.030	30
4	RW_13	1.7	35	44.7	33.0	0.737	0.029	20
5	RW_17	1.7	35	32.7	24.1	0.584	0.023	20
6	RW_21	1.7	35	35.5	26.2	0.635	0.025	30
7	RW_25	1.7	35	44.7	33.0	0.737	0.029	30
8	RW_29	1.7	35	43.3	31.9	0.737	0.029	25
9	RW_33	1.7	35	44.9	33.1	0.737	0.029	35
10	RW_37	1.7	35	47.3	34.9	0.787	0.031	40
11	RW_41	1.7	35	46.0	33.9	0.838	0.033	45
12	RW_45	1.7	35	47.6	35.1	0.838	0.033	45
13	RW_49	1.7	35	42.0	31.0	0.660	0.026	15
14	RW_53	1.7	35	42.2	31.1	0.787	0.031	35
15	RW_57	1.7	35	49.5	36.5	0.787	0.031	40
16	RW_61	1.7	35	42.8	31.6	0.711	0.028	30
17	RW_65	1.7	35	42.6	31.4	0.762	0.030	35
18	RW_69	1.7	35	45.0	33.2	0.914	0.036	30
19	RW_73	1.7	35	40.5	29.9	0.660	0.026	30
20	RW_77	1.7	35	28.6	21.1	0.559	0.022	25
21	RW_81	1.7	35	46.9	34.6	0.762	0.030	25
22	RW_85	1.7	35	46.6	34.4	0.762	0.030	30
23	RW_89	1.7	35	45.1	33.3	0.787	0.031	35
24	RW_93	1.7	35	30.1	22.2	0.559	0.022	15
25	RW_97	1.7	35	38.8	28.6	0.610	0.024	25
26	RW_101	1.7	35	42.0	31.0	0.635	0.025	20
27	RW_105	1.7	35	40.5	29.9	0.660	0.026	25
28	RW_109	1.7	35	44.2	32.6	0.737	0.029	30
29	RW_113	1.7	35	38.0	28.0	0.660	0.026	30
30	RW_117	1.7	35	46.1	34.0	0.762	0.030	40
31	RW_121	1.7	35	40.8	30.1	0.686	0.027	30
32	RW_125	1.7	35	47.2	34.8	0.762	0.030	35
33	RW_129	1.7	35	42.2	31.1	0.737	0.029	30
34	RW_133	1.7	35	43.4	32.0	0.711	0.028	25
35	RW_137	1.7	35	57.6	42.5	0.864	0.034	35
36	RW_141	1.7	35	41.4	30.5	0.737	0.029	35
37	RW_145	1.7	35	39.0	28.8	0.660	0.026	20
38	RW_149	1.7	35	45.4	33.5	0.686	0.027	35
39	RW_153	1.7	35	34.6	25.5	0.559	0.022	25
40	RW_157	1.7	35	27.1	20.0	0.584	0.023	20
41	RW_161	1.7	35	66.4	49.0	1.067	0.042	60
42	RW_165	1.7	35	67.8	50.0	1.118	0.044	65
43	RW_181	1.7	35	47.7	35.2	0.838	0.033	45
44	RW_185	1.7	35	41.2	30.4	0.737	0.029	40
45	RW_197	1.7	35	56.5	41.7	0.940	0.037	50
46	RW_201	1.7	35	58.4	43.1	1.041	0.041	65
			Average	43.9	32.4	0.748	0.029	33
			Std. Dev.	8.1	5.9	0.125	0.005	12

Table C-8 Charpy impact test data for virgin specimens: Linde 80 weld, ISO tup, Low temperature.

COUNT	IDENT	TEMP DEG C	TEMP DEG F	ENERGY J	ENERGY FT-LB	EXPAN MM	EXPAN IN	SHEAR PERCENT
1	RW_3	1.7	35	37.1	27.4	0.711	0.028	35
2	RW_7	1.7	35	35.9	26.5	0.737	0.029	35
3	RW_11	1.7	35	43.4	32.0	0.762	0.030	30
4	RW_15	1.7	35	43.9	32.4	0.914	0.036	40
5	RW_19	1.7	35	38.8	28.6	0.813	0.032	35
6	RW_23	1.7	35	39.2	28.9	0.711	0.028	40
7	RW_27	1.7	35	35.9	26.5	0.762	0.030	35
8	RW_31	1.7	35	35.3	26.0	0.737	0.029	30
9	RW_35	1.7	35	40.7	30.0	0.914	0.036	40
10	RW_39	1.7	35	42.0	31.0	0.813	0.032	45
11	RW_43	1.7	35	40.7	30.0	0.838	0.033	40
12	RW_47	1.7	35	46.1	34.0	0.864	0.034	30
13	RW_51	1.7	35	48.7	35.9	0.940	0.037	50
14	RW_55	1.7	35	48.8	36.0	0.940	0.037	40
15	RW_59	1.7	35	46.1	34.0	0.889	0.035	40
16	RW_63	1.7	35	38.5	28.4	0.711	0.028	40
17	RW_67	1.7	35	44.7	33.0	0.914	0.036	35
18	RW_71	1.7	35	48.9	36.1	0.991	0.039	40
19	RW_75	1.7	35	40.9	30.2	0.762	0.030	30
20	RW_79	1.7	35	35.3	26.0	0.686	0.027	25
21	RW_83	1.7	35	39.3	29.0	0.787	0.031	30
22	RW_87	1.7	35	44.7	33.0	0.965	0.038	30
23	RW_91	1.7	35	45.3	33.4	0.889	0.035	35
24	RW_95	1.7	35	41.4	30.5	0.787	0.031	25
25	RW_99	1.7	35	40.5	29.9	0.762	0.030	30
26	RW_103	1.7	35	35.1	25.9	0.737	0.029	30
27	RW_107	1.7	35	37.1	27.4	0.711	0.028	30
28	RW_111	1.7	35	33.9	25.0	0.635	0.025	20
29	RW_115	1.7	35	42.0	31.0	0.787	0.031	25
30	RW_119	1.7	35	51.1	37.7	0.940	0.037	45
31	RW_123	1.7	35	35.8	26.4	0.686	0.027	20
32	RW_127	1.7	35	43.3	31.9	0.838	0.033	40
33	RW_131	1.7	35	48.0	35.4	0.838	0.033	30
34	RW_135	1.7	35	41.5	30.6	0.762	0.030	40
35	RW_139	1.7	35	38.2	28.2	0.737	0.029	25
36	RW_143	1.7	35	42.0	31.0	0.787	0.031	30
37	RW_147	1.7	35	35.5	26.2	0.711	0.028	20
38	RW_151	1.7	35	33.9	25.0	0.635	0.025	20
39	RW_155	1.7	35	37.1	27.4	0.787	0.031	25
40	RW_159	1.7	35	32.5	24.0	0.711	0.028	20
41	RW_163	1.7	35	67.8	50.0	1.245	0.049	70
42	RW_167	1.7	35	57.2	42.2	1.143	0.045	65
43	RW_179	1.7	35	44.9	33.1	0.914	0.036	55
44	RW_183	1.7	35	33.9	25.0	0.635	0.025	40
45	RW_195	1.7	35	50.4	37.2	0.889	0.035	40
46	RW_199	1.7	35	51.5	38.0	0.965	0.038	50
			Average	42.1	31.0	0.819	0.032	35
			Std. Dev.	6.8	5.0	0.126	0.005	11

APPENDIX D

CHARPY IMPACT TEST DATA FOR RECONSTITUTED SPECIMENS

Table D-1 Charpy impact test data for reconstituted specimens:
10 mm insert, HSST-03, ASTM tup, High temperature.

#1, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB78	93.3	200	122.0	90.0	1.905	0.075	100
RB86	93.3	200	124.7	92.0	1.981	0.078	100
AVERAGE			**123.4**	**91.0**	**1.943**	**0.077**	**100**
STANDARD DEVIATION			**1.9**	**1.4**	**0.054**	**0.002**	**0**
#2, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB72	93.3	200	145.1	107.0	2.235	0.088	100
RB72.X	93.3	200	116.3	85.8	2.108	0.083	100
AVERAGE			**130.7**	**96.4**	**2.172**	**0.086**	**100**
STANDARD DEVIATION			**20.4**	**15.0**	**0.090**	**0.004**	**0**
#3, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB61A	93.3	200	147.8	109.0	2.032	0.080	100
RB61.A	93.3	200	141.0	104.0	1.854	0.073	100
AVERAGE			**144.4**	**106.5**	**1.943**	**0.077**	**100**
STANDARD DEVIATION			**4.8**	**3.5**	**0.126**	**0.005**	**0**
#4, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB74	93.3	200	124.4	91.8	1.778	0.070	100
RB70	93.3	200	124.7	92.0	1.905	0.075	100
AVERAGE			**124.6**	**91.9**	**1.842**	**0.073**	**100**
STANDARD DEVIATION			**0.2**	**0.1**	**0.090**	**0.004**	**0**
#5, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB14.X	93.3	200	139.6	103.0	2.210	0.087	100
RB10.A	93.3	200	145.1	107.0	2.032	0.080	100
AVERAGE			**142.4**	**105.0**	**2.121**	**0.084**	**100**
STANDARD DEVIATION			**3.9**	**2.8**	**0.126**	**0.005**	**0**

Table D-1 (continued)

#6, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
B62B.X	93.3	200	123.5	91.1	1.829	0.072	100
B66B.X	93.3	200	121.3	89.5	2.057	0.081	100
AVERAGE			**122.4**	**90.3**	**1.943**	**0.077**	**100**
STANDARD DEVIATION			**1.6**	**1.1**	**0.161**	**0.006**	**0**
#7, 10mm ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB146	93.3	200	107.1	79.0	1.753	0.069	100
AVERAGE			**107.1**	**79.0**	**1.753**	**0.069**	**100**
STANDARD DEVIATION			**0.0**	**0.0**	**0.000**	**0.000**	**0**
#8, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB34L	93.3	200	164.2	121.1	2.210	0.087	100
RB38	93.3	200	223.7	165.0	1.854	0.073	100
AVERAGE			**194.0**	**143.1**	**2.032**	**0.080**	**100**
STANDARD DEVIATION			**42.1**	**31.0**	**0.252**	**0.010**	**0**
#9, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB50.X	93.3	200	127.7	94.2	2.184	0.086	100
RB54.X	93.3	200	125.4	92.5	1.905	0.075	100
AVERAGE			**126.6**	**93.4**	**2.045**	**0.081**	**100**
STANDARD DEVIATION			**1.6**	**1.2**	**0.197**	**0.008**	**0**
#10, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB26.X	93.3	200	137.2	101.2	2.057	0.081	100
RB30.X	93.3	200	141.4	104.3	1.905	0.075	100
AVERAGE			**139.3**	**102.8**	**1.981**	**0.078**	**100**
STANDARD DEVIATION			**3.0**	**2.2**	**0.107**	**0.004**	**0**
TOTAL AVERAGE			**137.0**	**101.0**	**1.989**	**0.078**	**100**
TOTAL STD DEV.			**25.0**	**18.4**	**0.152**	**0.006**	**0**

Table D-2 Charpy impact test data for reconstituted specimens:
10 mm insert, HSST-03, ISO tup, High temperature.

#1, 10mm, PLATE 03, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB44	93.3	200	127.4	94.0	2.108	0.083	100
RB92	93.3	200	126.1	93.0	1.930	0.076	100
AVERAGE			**126.8**	**93.5**	**2.019**	**0.080**	**100**
STANDARD DEVIATION			**0.9**	**0.7**	**0.126**	**0.005**	**0**
#2, 10mm, ISO, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB68	93.3	200	138.3	102.0	2.083	0.082	100
RB68.X	93.3	200	139.3	102.8	2.007	0.079	100
AVERAGE			**138.8**	**102.4**	**2.045**	**0.081**	**100**
STANDARD DEVIATION			**0.7**	**0.6**	**0.054**	**0.002**	**0**
#3, PLATE 03, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB1B	93.3	200	143.7	106.0	2.210	0.087	100
RB1.B	93.3	200	143.7	106.0	2.134	0.084	100
AVERAGE			**143.7**	**106.0**	**2.172**	**0.086**	**100**
STANDARD DEVIATION			**0.0**	**0.0**	**0.054**	**0.002**	**0**
#4, PLATE 03, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB80	93.3	200	133.9	98.8	1.803	0.071	100
RB76	93.3	200	130.2	96.0	1.651	0.065	100
AVERAGE			**132.1**	**97.4**	**1.727**	**0.068**	**100**
STANDARD DEVIATION			**2.6**	**2.0**	**0.107**	**0.004**	**0**
#5, 10mm, PLATE 03, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB28.A	93.3	200	142.1	104.8	1.981	0.078	100
RB32.A	93.3	200	145.1	107.0	2.083	0.082	100
AVERAGE			**143.6**	**105.9**	**2.032**	**0.080**	**100**
STANDARD DEVIATION			**2.1**	**1.6**	**0.072**	**0.003**	**0**

Table D-2 (continued)

#6, 10mm, ISO-TUP, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
B64B.X	93.3	200	134.6	99.3	1.829	0.072	100
B60B.X	93.3	200	129.1	95.3	1.829	0.072	100
AVERAGE			**131.9**	**97.3**	**1.829**	**0.072**	**100**
STANDARD DEVIATION			**3.9**	**2.8**	**0.000**	**0.000**	**0**
#7, 10mm, ISO, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB172	93.3	200	105.1	77.5	1.397	0.055	100
AVERAGE			**105.1**	**77.5**	**1.397**	**0.055**	**100**
STANDARD DEVIATION			**0.0**	**0.0**	**0.000**	**0.000**	**0**
#8, PLATE 03, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB84L	93.3	200	146.4	108.0	2.032	0.080	100
RB88L	93.3	200	**SPECIMEN BROKE ON WELD**				
AVERAGE			**146.4**	**108.0**	**2.032**	**0.080**	**100**
STANDARD DEVIATION			**0.0**	**0.0**	**0.000**	**0.000**	**0**
#9, 10mm, ISO, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB8	93.3	200	138.0	101.8	2.108	0.083	100
RB4	93.3	200	136.9	101.0	1.981	0.078	100
AVERAGE			**137.5**	**101.4**	**2.045**	**0.081**	**100**
STANDARD DEVIATION			**0.8**	**0.6**	**0.090**	**0.004**	**0**
#10, PLATE 03, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB20.	93.3	200	146.4	108.0	1.880	0.074	100
RB24.	93.3	200	135.6	100.0	1.880	0.074	100
AVERAGE			**141.0**	**104.0**	**1.880**	**0.074**	**100**
STANDARD DEVIATION			**7.6**	**5.7**	**0.000**	**0.000**	**0**
TOTAL AVERAGE			**135.7**	**100.1**	**1.940**	**0.076**	**100**
TOTAL STD DEV.			**10.0**	**7.4**	**0.196**	**0.008**	**0**

Table D-3 Charpy impact test data for reconstituted specimens:
10 mm insert, HSST-03, ASTM tup, Low temperature.

#1, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB21	-12.2	10	38.9	28.7	0.762	0.030	5
RB25	-12.2	10	32.9	24.3	0.635	0.025	5
RB29	-12.2	10	35.5	26.2	0.660	0.026	5
RB33	-12.2	10	31.3	23.1	0.559	0.022	5
AVERAGE			**34.7**	**25.6**	**0.654**	**0.026**	**5**
STANDARD DEVIATION			**3.3**	**2.4**	**0.084**	**0.003**	**0**
#2, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB37.X	-12.2	10	21.6	15.9	0.483	0.019	10
RB49	-12.2	10	21.2	15.6	0.381	0.015	10
RB49.X	-12.2	10	12.7	9.4	0.305	0.012	10
AVERAGE			**18.5**	**13.6**	**0.390**	**0.015**	**10**
STANDARD DEVIATION			**5.0**	**3.7**	**0.089**	**0.004**	**0**
#3, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB1A	-12.2	10	30.5	22.5	0.533	0.021	10
RB1.A	-12.2	10	47.8	35.3	0.686	0.027	30
RB61B	-12.2	10	34.9	25.8	0.635	0.025	10
RB61.B	-12.2	10	29.2	21.5	0.483	0.019	10
AVERAGE			**35.6**	**26.3**	**0.584**	**0.023**	**15**
STANDARD DEVIATION			**8.5**	**6.3**	**0.093**	**0.004**	**10**
#4, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB141	-12.2	10	31.9	23.5	0.559	0.022	15
RB145	-12.2	10	29.2	21.5	0.457	0.018	15
RB149	-12.2	10	25.8	19.0	0.406	0.016	10
RB153	-12.2	10	30.5	22.5	0.483	0.019	10
AVERAGE			**29.4**	**21.6**	**0.476**	**0.019**	**13**
STANDARD DEVIATION			**2.6**	**1.9**	**0.064**	**0.002**	**3**
#5, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB65.A	-12.2	10	25.1	18.5	0.457	0.018	15
RB69.A	-12.2	10	31.2	23.0	0.584	0.023	10
RB117.A	-12.2	10	27.1	20.0	0.457	0.018	10
RB121.A	-12.2	10	32.9	24.3	0.610	0.024	15
AVERAGE			**29.1**	**21.5**	**0.527**	**0.021**	**13**
STANDARD DEVIATION			**3.6**	**2.7**	**0.082**	**0.003**	**3**

Table D-3 (continued)

#6, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
B133A.X	-12.2	10	19.9	14.7	0.381	0.015	10
B137A.X	-12.2	10	22.2	16.4	0.432	0.017	10
B125A.X	-12.2	10	32.3	23.8	0.508	0.020	10
B129A.X	-12.2	10	34.4	25.4	0.559	0.022	10
AVERAGE			**27.2**	**20.1**	**0.470**	**0.019**	**10**
STANDARD DEVIATION			**7.2**	**5.3**	**0.079**	**0.003**	**0**
#7, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB185	-12.2	10	20.5	15.1	0.330	0.013	5
RB189	-12.2	10	18.6	13.7	0.305	0.012	5
RB193	-12.2	10	27.5	20.3	0.432	0.017	5
RB197	-12.2	10	22.2	16.4	0.457	0.018	5
AVERAGE			**22.2**	**16.4**	**0.381**	**0.015**	**5**
STANDARD DEVIATION			**3.8**	**2.8**	**0.075**	**0.003**	**0**
#8, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB89L	-12.2	10	**SPECIMEN BROKE ON WELD**				
RB93	-12.2	10	57.6	42.5	1.219	0.048	20
RB97L	-12.2	10	**SPECIMEN BROKE ON WELD**				
RB101	-12.2	10	**SPECIMEN BROKE ON WELD**				
AVERAGE			**57.6**	**42.5**	**1.219**	**0.048**	**20**
STANDARD DEVIATION			**0.0**	**0.0**	**0.000**	**0.000**	**0**
#9, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB5A	-12.2	10	41.8	30.8	0.737	0.029	10
RB9.A	-12.2	10	28.9	21.3	0.457	0.018	10
RB13A	-12.2	10	36.2	26.7	0.584	0.023	10
RB17A	-12.2	10	38.0	28.0	0.584	0.023	10
RB5B	-12.2	10	28.2	20.8	0.483	0.019	10
RB9.B	-12.2	10	28.3	20.9	0.533	0.021	10
RB13B	-12.2	10	29.4	21.7	0.432	0.017	10
RB17B	-12.2	10	**SPECIMEN BROKE ON WELD**				
AVERAGE			**33.0**	**24.3**	**0.544**	**0.021**	**10**
STANDARD DEVIATION			**5.6**	**4.1**	**0.104**	**0.004**	**0**
#10, 10mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB73.X	-12.2	10	29.7	21.9	0.432	0.017	10
RB77.X	-12.2	10	33.5	24.7	0.406	0.016	10
RB81.X	-12.2	10	32.9	24.3	0.483	0.019	10
RB85.X	-12.2	10	20.1	14.8	0.279	0.011	10
AVERAGE			**29.1**	**21.4**	**0.400**	**0.016**	**10**
STANDARD DEVIATION			**6.2**	**4.6**	**0.087**	**0.003**	**0**
TOTAL AVERAGE			**30.1**	**22.2**	**0.517**	**0.020**	**10**
TOTAL STD DEV.			**8.2**	**6.1**	**0.162**	**0.006**	**5**

Table D-4 Charpy impact test data for reconstituted specimens: 10 mm insert, HSST-03, ISO tup, Low temperature.

#1, 10mm, PLATE 03, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB39	-12.2	10	28.8	21.3	0.559	0.022	10
RB43	-12.2	10	28.8	21.3	0.584	0.023	10
RB47	-12.2	10	29.5	21.8	0.533	0.021	10
RB51	-12.2	10	23.7	17.5	0.483	0.019	10
AVERAGE			**27.7**	**20.5**	**0.540**	**0.021**	**10**
STANDARD DEVIATION			**2.7**	**2.0**	**0.043**	**0.002**	**0**
#2, 10mm, ISO, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB82	-12.2	10	23.7	17.5	0.483	0.019	5
RB82.X	-12.2	10	15.3	11.3	0.406	0.016	5
RB90	-12.2	10	14.4	10.6	0.330	0.013	5
RB90.X	-12.2	10	18.0	13.3	0.432	0.017	10
AVERAGE			**17.9**	**13.2**	**0.413**	**0.016**	**6**
STANDARD DEVIATION			**4.2**	**3.1**	**0.064**	**0.002**	**3**
#3, PLATE 03, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB119.	-12.2	10	45.4	33.5	0.737	0.029	15
RB53A	-12.2	10	29.5	21.8	0.533	0.021	10
RB57A	-12.2	10	40.7	30.0	0.686	0.027	10
RB57B	-12.2	10	26.4	19.5	0.483	0.019	10
AVERAGE			**35.5**	**26.2**	**0.610**	**0.024**	**11**
STANDARD DEVIATION			**9.0**	**6.6**	**0.121**	**0.005**	**3**
#4, PLATE 03, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB7	-12.2	10	34.6	25.5	0.533	0.021	10
RB15	-12.2	10	29.5	21.8	0.432	0.017	10
RB19	-12.2	10	30.5	22.5	0.457	0.018	10
AVERAGE			**31.5**	**23.3**	**0.474**	**0.019**	**10**
STANDARD DEVIATION			**2.7**	**2.0**	**0.053**	**0.002**	**0**
#5, 10mm, PLATE 03, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB67.A	-12.2	10	30.5	22.5	0.610	0.024	10
RB71.A	-12.2	10	29.8	22.0	0.559	0.022	15
RB75.A	-12.2	10	16.9	12.5	0.381	0.015	10
RB79.A	-12.2	10	34.3	25.3	0.610	0.024	20
AVERAGE			**27.9**	**20.6**	**0.540**	**0.021**	**14**
STANDARD DEVIATION			**7.6**	**5.6**	**0.109**	**0.004**	**5**

Table D-4 (continued)

#6, 10mm, ISO-TUP, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
B151A.X	-12.2	10	37.6	27.8	0.711	0.028	10
B155A.X	-12.2	10	32.5	24.0	0.584	0.023	10
B179A.X	-12.2	10	25.4	18.8	0.432	0.017	10
B183A.X	-12.2	10	39.3	29.0	0.660	0.026	10
AVERAGE			**33.7**	**24.9**	**0.597**	**0.024**	**10**
STANDARD DEVIATION			**6.2**	**4.6**	**0.122**	**0.005**	**0**
#7, 10mm, ISO, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB187	-12.2	10	34.2	25.3	0.610	0.024	10
RB191	-12.2	10	24.4	18.0	0.457	0.018	5
RB195	-12.2	10	20.7	15.3	0.432	0.017	10
RB199	-12.2	10	23.0	17.0	0.457	0.018	10
AVERAGE			**25.6**	**18.9**	**0.489**	**0.019**	**9**
STANDARD DEVIATION			**5.9**	**4.4**	**0.082**	**0.003**	**3**
#8, PLATE 03, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB27L	-12.2	10	40.3	29.8	0.838	0.033	10
RB23L	-12.2	10	198.9	146.8	2.489	0.098	100
AVERAGE			**40.3**	**29.8**	**0.838**	**0.033**	**10**
STANDARD DEVIATION			**0.0**	**0.0**	**0.000**	**0.000**	**0**
#9, 10mm, ISO, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB163A	-12.2	10	35.3	26.0	0.584	0.023	10
RB167A	-12.2	10	**SPECIMEN BROKE ON WELD**				
RB171A	-12.2	10	33.9	25.0	0.610	0.024	10
RB175A	-12.2	10	35.3	26.0	0.635	0.025	25
AVERAGE			**34.8**	**25.7**	**0.610**	**0.024**	**15**
STANDARD DEVIATION			**0.8**	**0.6**	**0.026**	**0.001**	**9**
#10, PLATE 03, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB59.	-12.2	10	33.9	25.0	0.508	0.020	20
RB63.	-12.2	10	26.8	19.8	0.432	0.017	15
RB55.	-12.2	10	31.2	23.0	0.432	0.017	20
AVERAGE			**30.6**	**22.6**	**0.457**	**0.018**	**18**
STANDARD DEVIATION			**3.6**	**2.6**	**0.044**	**0.002**	**3**
TOTAL AVERAGE			**29.5**	**21.8**	**0.536**	**0.021**	**11**
TOTAL STD DEV.			**7.4**	**5.5**	**0.112**	**0.004**	**4**

Specimen RB23L - Appears to have 14mm insert. Had stamp JPG37 on the side of the insert. None of the data from this specimen were included in the averages or the standard deviation determinations.

Table D-5 Charpy impact test data for reconstituted specimens:
14 mm insert, HSST-03, ASTM tup, High temperature.

#1, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB78.X	93.3	200	157.0	115.8	2.210	0.087	100
RB86.X	93.3	200	145.2	107.1	2.083	0.082	100
AVERAGE			**151.1**	**111.5**	**2.147**	**0.085**	**100**
STANDARD DEVIATION			**8.3**	**6.2**	**0.090**	**0.004**	**0**
#2, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB147	93.3	200	155.2	114.5	2.235	0.088	100
RB147.X	93.3	200	152.7	112.6	2.159	0.085	100
AVERAGE			**154.0**	**113.6**	**2.197**	**0.087**	**100**
STANDARD DEVIATION			**1.8**	**1.3**	**0.054**	**0.002**	**0**
#3, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB42.X	93.3	200	161.3	119.0	2.057	0.081	100
RB46.X	93.3	200	158.6	117.0	2.134	0.084	100
AVERAGE			**160.0**	**118.0**	**2.096**	**0.083**	**100**
STANDARD DEVIATION			**1.9**	**1.4**	**0.054**	**0.002**	**0**
#4, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB70.X	93.3	200	157.3	116.0	2.159	0.085	100
RB74.X	93.3	200	149.1	110.0	1.956	0.077	100
AVERAGE			**153.2**	**113.0**	**2.058**	**0.081**	**100**
STANDARD DEVIATION			**5.8**	**4.2**	**0.144**	**0.006**	**0**
#5, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB10A	93.3	200	154.6	114.0	2.134	0.084	100
RB14	93.3	200	146.4	108.0	2.134	0.084	100
AVERAGE			**150.5**	**111.0**	**2.134**	**0.084**	**100**
STANDARD DEVIATION			**5.8**	**4.2**	**0.000**	**0.000**	**0**

Table D-5 (continued)

#6, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
B62A	93.3	200	141.8	104.6	2.159	0.085	100
B66A	93.3	200	145.8	107.5	2.057	0.081	100
AVERAGE			**143.8**	**106.1**	**2.108**	**0.083**	**100**
STANDARD DEVIATION			**2.8**	**2.1**	**0.072**	**0.003**	**0**
#7, 14 mm, ASTM TUP, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB150A	93.3	200	146.1	107.8	2.032	0.080	100
AVERAGE			**146.1**	**107.8**	**2.032**	**0.080**	**100**
STANDARD DEVIATION			**0.0**	**0.0**	**0.000**	**0.000**	**0**
#8, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB34.R	93.3	200	165.4	122.0	2.057	0.081	100
RB38.R	93.3	200	162.7	120.0	2.210	0.087	100
AVERAGE			**164.1**	**121.0**	**2.134**	**0.084**	**100**
STANDARD DEVIATION			**1.9**	**1.4**	**0.108**	**0.004**	**0**
#9, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB50	93.3	200	166.1	122.5	2.388	0.094	100
RB54	93.3	200	149.1	110.0	2.210	0.087	100
AVERAGE			**157.6**	**116.3**	**2.299**	**0.091**	**100**
STANDARD DEVIATION			**12.0**	**8.8**	**0.126**	**0.005**	**0**
#10, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB26	93.3	200	158.5	116.9	2.108	0.083	100
RB30	93.3	200	160.8	118.6	2.057	0.081	100
AVERAGE			**159.7**	**117.8**	**2.083**	**0.082**	**100**
STANDARD DEVIATION			**1.6**	**1.2**	**0.036**	**0.001**	**0**
TOTAL AVERAGE			**154.4**	**113.9**	**2.134**	**0.084**	**100**
TOTAL STD DEV.			**7.4**	**5.4**	**0.095**	**0.004**	**0**

Table D-6 Charpy impact test data for reconstituted specimens: 14 mm insert, HSST-03, ISO tup, High temperature.

#1, 14mm, PLATE 03, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB44.	93.3	200	146.4	108.0	1.981	0.078	100
RB92.	93.3	200	139.6	103.0	2.083	0.082	100
AVERAGE			**143.0**	**105.5**	**2.032**	**0.080**	**100**
STANDARD DEVIATION			**4.8**	**3.5**	**0.072**	**0.003**	**0**
#2, 14mm, ISO, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB143	93.3	200	147.8	109.0	2.337	0.092	100
RB143.X	93.3	200	161.3	119.0	2.388	0.094	100
AVERAGE			**154.6**	**114.0**	**2.363**	**0.093**	**100**
STANDARD DEVIATION			**9.5**	**7.1**	**0.036**	**0.001**	**0**
#3, PLATE 03, ISO TUP, 14mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB36.	93.3	200	145.8	107.5	1.930	0.076	100
RB40.	93.3	200	147.8	109.0	1.778	0.070	100
AVERAGE			**146.8**	**108.3**	**1.854**	**0.073**	**100**
STANDARD DEVIATION			**1.4**	**1.1**	**0.107**	**0.004**	**0**
#4, PLATE 03, ISO TUP, 14mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB80.	93.3	200	146.4	108.0	2.159	0.085	100
RB76.	93.3	200	149.8	110.5	2.184	0.086	100
AVERAGE			**148.1**	**109.3**	**2.172**	**0.086**	**100**
STANDARD DEVIATION			**2.4**	**1.8**	**0.018**	**0.001**	**0**
#5, 14mm, PLATE 03, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB28A	93.3	200	152.5	112.5	2.159	0.085	100
RB32A	93.3	200	160.7	118.5	2.286	0.090	100
AVERAGE			**156.6**	**115.5**	**2.223**	**0.088**	**100**
STANDARD DEVIATION			**5.8**	**4.2**	**0.090**	**0.004**	**0**

Table D-6 (continued)

#6, 14mm, ISO TUP, PLATE 03							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT*LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
B60A	93.3	200	143.7	106.0	2.311	0.091	100
B64A	93.3	200	150.5	111.0	2.362	0.093	100
AVERAGE			**147.1**	**108.5**	**2.337**	**0.092**	**100**
STANDARD DEVIATION			**4.8**	**3.5**	**0.036**	**0.001**	**0**
#7, 14mm, ISO, PLATE 03							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT*LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RB172A	93.3	200	153.9	113.5	2.032	0.080	100
RB168A	93.3	200	158.6	117.0	2.108	0.083	100
AVERAGE			**156.3**	**115.3**	**2.070**	**0.082**	**100**
STANDARD DEVIATION			**3.3**	**2.5**	**0.054**	**0.002**	**0**
#8, PLATE 03, ISO TUP, 14mm							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT-LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RB84.R	93.3	200	148.1	109.3	2.083	0.082	100
RB88.R	93.3	200	155.9	115.0	2.311	0.091	100
AVERAGE			**152.0**	**112.2**	**2.197**	**0.087**	**100**
STANDARD DEVIATION			**5.5**	**4.0**	**0.161**	**0.006**	**0**
#9, 14mm, ISO, PLATE 03							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT*LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RB4.X	93.3	200	146.4	108.0	2.057	0.081	100
RB8.X	93.3	200	148.5	109.5	2.108	0.083	100
AVERAGE			**147.5**	**108.8**	**2.083**	**0.082**	**100**
STANDARD DEVIATION			**1.5**	**1.1**	**0.036**	**0.001**	**0**
#10, PLATE 03, ISO TUP, 14mm							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT-LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RB24	93.3	200	149.1	110.0	1.981	0.078	100
RB20	93.3	200	150.8	111.3	2.108	0.083	100
AVERAGE			**150.0**	**110.7**	**2.045**	**0.081**	**100**
STANDARD DEVIATION			**1.2**	**0.9**	**0.090**	**0.004**	**0**
TOTAL AVERAGE			**150.2**	**110.8**	**2.137**	**0.084**	**100**
TOTAL STD DEV.			**5.6**	**4.1**	**0.160**	**0.006**	**0**

Table D-7 Charpy impact test data for reconstituted specimens:
14 mm insert, HSST-03, ASTM tup, Low temperature.

#1, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB21.X	-12.2	10	47.2	34.8	0.787	0.031	10
RB25.X	-12.2	10	49.6	36.6	0.813	0.032	10
RB29.X	-12.2	10	45.7	33.7	0.787	0.031	10
RB33.X	-12.2	10	62.0	45.7	0.965	0.038	15
AVERAGE			**51.1**	**37.7**	**0.838**	**0.033**	**11**
STANDARD DEVIATION			**7.4**	**5.5**	**0.086**	**0.003**	**3**
#2, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB41	-12.2	10	14.5	10.7	0.330	0.013	15
RB41.X	-12.2	10	19.9	14.7	0.483	0.019	15
RB45	-12.2	10	14.2	10.5	0.279	0.011	10
RB45.X	-12.2	10	19.1	14.1	0.406	0.016	15
AVERAGE			**16.9**	**12.5**	**0.375**	**0.015**	**14**
STANDARD DEVIATION			**3.0**	**2.2**	**0.089**	**0.004**	**3**
#3, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB53B	-12.2	10	58.3	43.0	0.787	0.031	45
RB36	-12.2	10	25.8	19.0	0.356	0.014	10
RB40	-12.2	10	43.0	31.8	0.610	0.024	10
RB131.X	-12.2	10	39.3	29.0	0.686	0.027	20
AVERAGE			**41.6**	**30.7**	**0.610**	**0.024**	**21**
STANDARD DEVIATION			**13.4**	**9.9**	**0.184**	**0.007**	**17**
#4, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB141.X	-12.2	10	27.1	20.0	0.381	0.015	5
RB145.X	-12.2	10	36.9	27.3	0.533	0.021	5
RB149.X	-12.2	10	28.5	21.0	0.457	0.018	5
RB153.X	-12.2	10	31.5	23.3	0.457	0.018	20
AVERAGE			**31.0**	**22.9**	**0.457**	**0.018**	**9**
STANDARD DEVIATION			**4.3**	**3.2**	**0.062**	**0.002**	**8**
#5, 14mm, ASTM, Plate 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB65	-12.2	10	29.2	21.5	0.508	0.020	15
RB69	-12.2	10	30.2	22.3	0.533	0.021	10
RB117	-12.2	10	32.5	24.0	0.584	0.023	20
RB121	-12.2	10	35.3	26.0	0.584	0.023	15
AVERAGE			**31.8**	**23.5**	**0.552**	**0.022**	**15**
STANDARD DEVIATION			**2.7**	**2.0**	**0.038**	**0.002**	**4**

Table D-7 (continued)

#6, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
B133A	-12.2	10	31.0	22.9	0.584	0.023	10
B137A	-12.2	10	43.1	31.8	0.660	0.026	10
B125A	-12.2	10	42.3	31.2	0.635	0.025	10
B129A	-12.2	10	39.9	29.4	0.635	0.025	10
AVERAGE			**39.1**	**28.8**	**0.629**	**0.025**	**10**
STANDARD DEVIATION			**5.6**	**4.1**	**0.032**	**0.001**	**0**
#7, 14 mm, ASTM TUP, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB185A	-12.2	10	36.6	27.0	0.533	0.021	10
RB189A	-12.2	10	46.1	34.0	0.711	0.028	10
RB193A	-12.2	10	32.5	24.0	0.508	0.020	10
RB197A	-12.2	10	29.2	21.5	0.483	0.019	10
AVERAGE			**36.1**	**26.6**	**0.559**	**0.022**	**10**
STANDARD DEVIATION			**7.3**	**5.4**	**0.104**	**0.004**	**0**
#8, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB89.R	-12.2	10	48.4	35.7	0.686	0.027	10
RB93.R	-12.2	10	44.2	32.6	0.660	0.026	10
RB97.R	-12.2	10	44.5	32.8	0.635	0.025	10
RB101.R	-12.2	10	32.0	23.6	0.457	0.018	5
AVERAGE			**42.3**	**31.2**	**0.610**	**0.024**	**9**
STANDARD DEVIATION			**7.1**	**5.2**	**0.104**	**0.004**	**3**
#9, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB5.X	-12.2	10	40.7	30.0	0.559	0.022	10
RB9	-12.2	10	35.3	26.0	0.610	0.024	15
RB13.X	-12.2	10	36.6	27.0	0.610	0.024	10
RB17.X	-12.2	10	42.7	31.5	0.635	0.025	10
AVERAGE			**38.8**	**28.6**	**0.604**	**0.024**	**11**
STANDARD DEVIATION			**3.5**	**2.6**	**0.032**	**0.001**	**3**
#10, 14mm, ASTM, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB73	-12.2	10	37.0	27.3	0.508	0.020	10
RB77	-12.2	10	41.2	30.4	0.584	0.023	10
RB81	-12.2	10	35.1	25.9	0.508	0.020	10
RB85	-12.2	10	43.7	32.2	0.610	0.024	10
AVERAGE			**39.3**	**29.0**	**0.553**	**0.022**	**10**
STANDARD DEVIATION			**3.9**	**2.9**	**0.052**	**0.002**	**0**
TOTAL AVERAGE			**36.8**	**27.1**	**0.578**	**0.023**	**12**
TOTAL STD DEV.			**10.4**	**7.7**	**0.140**	**0.006**	**6**

Table D-8 Charpy impact test data for reconstituted specimens:
14 mm insert, HSST-03, ISO tup, Low temperature.

#1, 14mm, PLATE 03, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB39.	-12.2	10	44.4	32.8	0.762	0.030	20
RB43.	-12.2	10	37.3	27.5	0.711	0.028	15
RB47.	-12.2	10	33.2	24.5	0.533	0.021	10
RB51.	-12.2	10	50.2	37.0	0.711	0.028	15
AVERAGE			**41.3**	**30.5**	**0.679**	**0.027**	**15**
STANDARD DEVIATION			**7.5**	**5.6**	**0.100**	**0.004**	**4**
#2, 14mm, ISO, PLATE 03							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RB135	-12.2	10	19.0	14.0	0.406	0.016	10
RB135.X	-12.2	10	23.0	17.0	0.559	0.022	10
RB139	-12.2	10	33.6	24.8	0.610	0.024	5
RB139.X	-12.2	10	35.3	26.0	0.711	0.028	10
AVERAGE			**27.7**	**20.5**	**0.572**	**0.023**	**9**
STANDARD DEVIATION			**8.0**	**5.9**	**0.127**	**0.005**	**3**
#3, PLATE 03, ISO TUP, 14mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB119	-12.2	10	43.7	32.3	0.737	0.029	15
RB123	-12.2	10	46.1	34.0	0.762	0.030	15
RB127	-12.2	10	48.8	36.0	0.838	0.033	15
RB131	-12.2	10	44.4	32.8	0.711	0.028	20
AVERAGE			**45.8**	**33.8**	**0.762**	**0.030**	**16**
STANDARD DEVIATION			**2.3**	**1.6**	**0.055**	**0.002**	**3**
#4, PLATE 03, ISO TUP, 14mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB7.	-12.2	10	26.1	19.3	0.483	0.019	10
RB11.	-12.2	10	32.5	24.0	0.508	0.020	10
RB15.	-12.2	10	34.9	25.8	0.559	0.022	10
RB19.	-12.2	10	43.4	32.0	0.660	0.026	10
AVERAGE			**34.2**	**25.3**	**0.553**	**0.022**	**10**
STANDARD DEVIATION			**7.2**	**5.3**	**0.078**	**0.003**	**0**
#5, 14mm, PLATE 03, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RB67A	-12.2	10	32.5	24.0	0.635	0.025	10
RB71A	-12.2	10	39.0	28.8	0.711	0.028	15
RB75A	-12.2	10	29.2	21.5	0.559	0.022	10
RB79A	-12.2	10	32.2	23.8	0.635	0.025	20
AVERAGE			**33.2**	**24.5**	**0.635**	**0.025**	**14**
STANDARD DEVIATION			**4.1**	**3.1**	**0.062**	**0.002**	**5**

Table D-8 (continued)

#6, ISO TUP, PLATE 03							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT*LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
B151A	-12.2	10	38.6	28.5	0.711	0.028	10
B155A	-12.2	10	41.0	30.3	0.711	0.028	10
B179A	-12.2	10	46.8	34.5	0.787	0.031	10
B183A	-12.2	10	42.7	31.5	0.737	0.029	10
AVERAGE			**42.3**	**31.2**	**0.737**	**0.029**	**10**
STANDARD DEVIATION			**3.5**	**2.5**	**0.036**	**0.001**	**0**
#7, 14mm, ISO, PLATE 03							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT*LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RB187A	-12.2	10	30.5	22.5	0.559	0.022	5
RB191A	-12.2	10	46.1	34.0	0.787	0.031	10
RB195A	-12.2	10	39.7	29.3	0.686	0.027	10
RB199A	-12.2	10	19.7	14.5	0.381	0.015	10
AVERAGE			**34.0**	**25.1**	**0.603**	**0.024**	**9**
STANDARD DEVIATION			**11.5**	**8.5**	**0.175**	**0.007**	**3**
#8, PLATE 03, ISO TUP, 14mm							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT-LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RB23.R	-12.2	10	38.0	28.0	0.584	0.023	10
RB27.R	-12.2	10	42.0	31.0	0.559	0.022	20
RB31.R	-12.2	10	42.7	31.5	0.635	0.025	10
RB35.R	-12.2	10	47.5	35.0	0.660	0.026	10
AVERAGE			**42.6**	**31.4**	**0.610**	**0.024**	**13**
STANDARD DEVIATION			**3.9**	**2.9**	**0.046**	**0.002**	**5**
#9, 14mm, ISO, PLATE 03							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT*LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RB163	-12.2	10	45.1	33.3	0.711	0.028	10
RB167	-12.2	10	50.2	37.0	0.737	0.029	15
RB171	-12.2	10	52.9	39.0	0.914	0.036	10
RB175	-12.2	10	48.8	36.0	0.762	0.030	10
AVERAGE			**49.3**	**36.3**	**0.781**	**0.031**	**11**
STANDARD DEVIATION			**3.2**	**2.4**	**0.091**	**0.004**	**3**
#10, PLATE 03, ISO TUP, 14mm							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT-LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RB3	-12.2	10	56.9	42.0	0.864	0.034	25
RB59	-12.2	10	44.7	33.0	0.660	0.026	20
RB63	-12.2	10	52.9	39.0	0.787	0.031	20
RB155	-12.2	10	46.8	34.5	0.711	0.028	20
AVERAGE			**50.3**	**37.1**	**0.756**	**0.030**	**21**
STANDARD DEVIATION			**5.6**	**4.1**	**0.089**	**0.004**	**3**
TOTAL AVERAGE			**40.1**	**29.6**	**0.669**	**0.026**	**13**
TOTAL STD DEV.			**9.1**	**6.7**	**0.117**	**0.005**	**5**

Table D-9 Charpy impact test data for reconstituted specimens:
10 mm insert, Linde 80 weld, ASTM tup, High temperature.

#1, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW10	93.3	200	80.0	59.0	1.727	0.068	100
RW14	93.3	200	77.3	57.0	1.600	0.063	100
AVERAGE			**78.7**	**58.0**	**1.664**	**0.066**	**100**
STANDARD DEVIATION			**1.9**	**1.4**	**0.090**	**0.004**	**0**
#2, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW179	93.3	200	75.7	55.8	1.651	0.065	100
RW179.X	93.3	200	74.0	54.6	1.448	0.057	100
AVERAGE			**74.9**	**55.2**	**1.550**	**0.061**	**100**
STANDARD DEVIATION			**1.2**	**0.8**	**0.144**	**0.006**	**0**
#3, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW50.X	93.3	200	84.1	62.0	1.549	0.061	100
RW46.X	93.3	200	88.1	65.0	1.702	0.067	100
AVERAGE			**86.1**	**63.5**	**1.626**	**0.064**	**100**
STANDARD DEVIATION			**2.8**	**2.1**	**0.108**	**0.004**	**0**
#4, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW78	93.3	200	84.7	62.5	1.575	0.062	100
RW90	93.3	200	84.4	62.3	1.600	0.063	100
AVERAGE			**84.6**	**62.4**	**1.588**	**0.063**	**100**
STANDARD DEVIATION			**0.2**	**0.1**	**0.018**	**0.001**	**0**
#5, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW6A	93.3	200	84.7	62.5	1.702	0.067	100
RW42.A	93.3	200	93.9	69.3	1.803	0.071	100
AVERAGE			**89.3**	**65.9**	**1.753**	**0.069**	**100**
STANDARD DEVIATION			**6.5**	**4.8**	**0.071**	**0.003**	**0**

Table D-9 (continued)

#6, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
W34B.X	93.3	200	87.2	64.3	1.346	0.053	100
W38B.X	93.3	200	88.8	65.5	1.549	0.061	100
AVERAGE			**88.0**	**64.9**	**1.448**	**0.057**	**100**
STANDARD DEVIATION			**1.1**	**0.8**	**0.144**	**0.006**	**0**
#7, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW178	93.3	200	66.8	49.3	1.422	0.056	100
RW182	93.3	200	56.9	42.0	1.194	0.047	95
AVERAGE			**61.9**	**45.7**	**1.308**	**0.052**	**98**
STANDARD DEVIATION			**7.0**	**5.2**	**0.161**	**0.006**	**4**
#8, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW22L	93.3	200	91.5	67.5	1.753	0.069	100
RW26	93.3	200	**SPECIMEN BROKE ON WELD**				
AVERAGE			**91.5**	**67.5**	**1.753**	**0.069**	**100**
STANDARD DEVIATION			**0.0**	**0.0**	**0.000**	**0.000**	**0**
#9, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW66	93.3	200	85.4	63.0	1.803	0.071	100
RW82	93.3	200	73.1	53.9	1.448	0.057	100
AVERAGE			**79.3**	**58.5**	**1.626**	**0.064**	**100**
STANDARD DEVIATION			**8.7**	**6.4**	**0.251**	**0.010**	**0**
#10, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW18.X	93.3	200	79.0	58.3	1.372	0.054	100
RW62.X	93.3	200	87.8	64.8	1.549	0.061	100
AVERAGE			**83.4**	**61.6**	**1.461**	**0.058**	**100**
STANDARD DEVIATION			**6.2**	**4.6**	**0.125**	**0.005**	**0**
TOTAL AVERAGE			**81.0**	**59.7**	**1.581**	**0.062**	**100**
TOTAL STD DEV.			**9.5**	**7.0**	**0.168**	**0.007**	**1**

Table D-10 Charpy impact test data for reconstituted specimens:
10 mm insert, Linde 80 weld, ISO tup, High temperature.

#1, 10mm, LUSW, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW80	93.3	200	84.1	62.0	1.600	0.063	100
RW84	93.3	200	78.6	58.0	1.626	0.064	100
AVERAGE			**81.4**	**60.0**	**1.613**	**0.064**	**100**
STANDARD DEVIATION			**3.9**	**2.8**	**0.018**	**0.001**	**0**
#2, 10mm, LUSW, ISO-TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW167	93.3	200	80.0	59.0	1.727	0.068	100
RW167.X	93.3	200	79.3	58.5	1.651	0.065	100
AVERAGE			**79.7**	**58.8**	**1.689**	**0.067**	**100**
STANDARD DEVIATION			**0.5**	**0.4**	**0.054**	**0.002**	**0**
#3, WELD, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW28.	93.3	200	86.8	64.0	1.676	0.066	100
RW32.	93.3	200	86.8	64.0	1.499	0.059	100
AVERAGE			**86.8**	**64.0**	**1.588**	**0.063**	**100**
STANDARD DEVIATION			**0.0**	**0.0**	**0.125**	**0.005**	**0**
#4, WELD, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW44	93.3	200	86.8	64.0	1.549	0.061	100
RW48	93.3	200	89.5	66.0	1.600	0.063	100
AVERAGE			**88.2**	**65.0**	**1.575**	**0.062**	**100**
STANDARD DEVIATION			**1.9**	**1.4**	**0.036**	**0.001**	**0**
#5, 10mm, LUSW, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW20.A	93.3	200	86.1	63.5	1.676	0.066	100
RW24.A	93.3	200	91.5	67.5	1.753	0.069	100
AVERAGE			**88.8**	**65.5**	**1.715**	**0.068**	**100**
STANDARD DEVIATION			**3.8**	**2.8**	**0.054**	**0.002**	**0**

Table D-10 (continued)

#6, 10mm, ISO-TUP, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
W40B.X	93.3	200	93.6	69.0	1.753	0.069	100
W36B.X	93.3	200	87.5	64.5	1.245	0.049	100
AVERAGE			**90.6**	**66.8**	**1.499**	**0.059**	**100**
STANDARD DEVIATION			**4.3**	**3.2**	**0.359**	**0.014**	**0**
#7, 10mm, ISO, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW128	93.3	200	73.6	54.3	1.575	0.062	100
RW124	93.3	200	65.1	48.0	1.397	0.055	99
AVERAGE			**69.4**	**51.2**	**1.486**	**0.059**	**100**
STANDARD DEVIATION			**6.0**	**4.5**	**0.126**	**0.005**	**1**
#8, WELD, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW76	93.3	200	114.6	84.5	2.261	0.089	100
RW72	93.3	200	111.5	82.3	1.930	0.076	100
AVERAGE			**113.1**	**83.4**	**2.096**	**0.083**	**100**
STANDARD DEVIATION			**2.2**	**1.6**	**0.234**	**0.009**	**0**
#9, 10mm, ISO, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW68	93.3	200	87.1	64.3	1.956	0.077	100
RW64	93.3	200	91.2	67.3	1.956	0.077	100
AVERAGE			**89.2**	**65.8**	**1.956**	**0.077**	**100**
STANDARD DEVIATION			**2.9**	**2.1**	**0.000**	**0.000**	**0**
#10, WELD, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW88.	93.3	200	86.1	63.5	1.499	0.059	100
RW92.	93.3	200	86.1	63.5	1.448	0.057	100
AVERAGE			**86.1**	**63.5**	**1.474**	**0.058**	**100**
STANDARD DEVIATION			**0.0**	**0.0**	**0.036**	**0.001**	**0**
TOTAL AVERAGE			**87.3**	**64.4**	**1.669**	**0.066**	**100**
TOTAL STD DEV.			**11.0**	**8.1**	**0.229**	**0.009**	**0**

Table D-11 Charpy impact test data for reconstituted specimens: 10 mm insert, Linde 80 weld, ASTM tup, Low temperature.

#1, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW1	1.7	35	31.5	23.2	0.635	0.025	25
RW153	1.7	35	24.9	18.4	0.559	0.022	20
RW201	1.7	35	59.9	44.2	1.194	0.047	90
RW3	1.7	35	32.5	24.0	0.686	0.027	30
AVERAGE			**37.2**	**27.5**	**0.769**	**0.030**	**41**
STANDARD DEVIATION			**15.5**	**11.4**	**0.288**	**0.011**	**33**
#2, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW97	1.7	35	41.5	30.6	0.991	0.039	40
RW97.X	1.7	35	30.0	22.1	0.711	0.028	30
RW125	1.7	35	23.6	17.4	0.432	0.017	15
RW125.X	1.7	35	41.2	30.4	0.889	0.035	30
AVERAGE			**34.1**	**25.1**	**0.756**	**0.030**	**29**
STANDARD DEVIATION			**8.8**	**6.5**	**0.245**	**0.010**	**10**
#3, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW13	1.7	35	40.0	29.5	0.432	0.017	35
RW13.X	1.7	35	38.0	28.0	0.457	0.018	30
RW117	1.7	35	31.2	23.0	0.584	0.023	20
RW46	1.7	35	39.3	29.0	0.635	0.025	25
AVERAGE			**37.1**	**27.4**	**0.527**	**0.021**	**28**
STANDARD DEVIATION			**4.0**	**3.0**	**0.098**	**0.004**	**6**
#4, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW81	1.7	35	44.1	32.5	0.838	0.033	45
RW85	1.7	35	42.7	31.5	0.864	0.034	30
RW101	1.7	35	24.7	18.3	0.432	0.017	15
RW47	1.7	35	43.4	32.0	0.838	0.033	35
AVERAGE			**38.7**	**28.6**	**0.743**	**0.029**	**31**
STANDARD DEVIATION			**9.4**	**6.9**	**0.208**	**0.008**	**13**
#5, 10mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW33.A	1.7	35	52.2	38.5	1.067	0.042	50
RW109.A	1.7	35	39.7	29.3	0.889	0.035	40
RW113A	1.7	35	49.8	36.8	1.143	0.045	50
RW149.A	1.7	35	43.4	32.0	0.838	0.033	40
AVERAGE			**46.3**	**34.2**	**0.984**	**0.039**	**45**
STANDARD DEVIATION			**5.7**	**4.2**	**0.144**	**0.006**	**6**

Table D-11 (continued)

#6, 10mm, ASTM, LUSW							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT*LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
W197A	1.7	35	39.9	29.4	0.813	0.032	40
W181A.X	1.7	35	62.4	46.0	1.168	0.046	70
W45B.X	1.7	35	46.9	34.6	0.965	0.038	50
W41A.X	1.7	35	42.7	31.5	0.889	0.035	20
AVERAGE			**48.0**	**35.4**	**0.959**	**0.038**	**45**
STANDARD DEVIATION			**10.0**	**7.4**	**0.153**	**0.006**	**21**
#7, 10mm, ASTM, LUSW							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT*LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RW217	1.7	35	29.2	21.5	0.457	0.018	20
RW229	1.7	35	36.9	27.2	0.584	0.023	25
AVERAGE			**33.1**	**24.4**	**0.521**	**0.021**	**23**
STANDARD DEVIATION			**5.4**	**4.0**	**0.090**	**0.004**	**4**
#8, 10mm, ASTM, LUSW							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT-LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RW165L	1.7	35	68.9	50.8	1.067	0.042	60
RW165.X	1.7	35	73.2	54.0	1.143	0.045	70
RW185	1.7	35	SPECIMEN BROKE ON WELD				
RW185.X	1.7	35	SPECIMEN BROKE ON WELD				
AVERAGE			**71.1**	**52.4**	**1.105**	**0.044**	**65**
STANDARD DEVIATION			**3.0**	**2.3**	**0.054**	**0.002**	**7**
#9, 10mm, ASTM, LUSW							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT*LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RW17	1.7	35	SPECIMEN BROKE ON WELD				
RW25	1.7	35	45.7	33.7	0.610	0.024	30
RW129	1.7	35	42.6	31.4	0.965	0.038	40
RW133	1.7	35	36.9	27.2	0.711	0.028	25
AVERAGE			**41.7**	**30.8**	**0.762**	**0.030**	**32**
STANDARD DEVIATION			**4.5**	**3.3**	**0.183**	**0.007**	**8**
#10, 10mm, ASTM, LUSW							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT-LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RW49.X	1.7	35	36.1	26.6	0.559	0.022	30
RW157.X	1.7	35	46.8	34.5	0.813	0.032	40
RW37.X	1.7	35	39.2	28.9	0.635	0.025	30
AVERAGE			**40.7**	**30.0**	**0.669**	**0.026**	**33**
STANDARD DEVIATION			**5.5**	**4.1**	**0.130**	**0.005**	**6**
TOTAL AVERAGE			**41.8**	**30.8**	**0.779**	**0.031**	**37**
TOTAL STD DEV.			**11.5**	**8.5**	**0.232**	**0.009**	**17**

Specimen RW157.X - Energy was determined using the area under the curve as compared to the areas from similar curves. During the test the tup struck another object after impacting the specimen. The scope trace from the specimen impact was collected, but the energy from the dial readout was unreliable.

Table D-12 Charpy impact test data for reconstituted specimens: 10 mm insert, Linde 80 weld, ISO tup, Low temperature.

#1, 10mm, LUSW, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW7	1.7	35	32.5	24.0	0.711	0.028	40
RW9	1.7	35	33.6	24.8	0.711	0.028	40
RW135	1.7	35	32.5	24.0	0.762	0.030	35
RW139	1.7	35	44.1	32.5	0.864	0.034	50
AVERAGE			**35.7**	**26.3**	**0.762**	**0.030**	**41**
STANDARD DEVIATION			**5.6**	**4.1**	**0.072**	**0.003**	**6**
#2, 10mm, LUSW, ISO-TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW119.X	1.7	35	45.8	33.8	1.016	0.040	50
RW119	1.7	35	26.8	19.8	0.584	0.023	20
RW123	1.7	35	36.6	27.0	0.838	0.033	30
RW123.X	1.7	35	46.8	34.5	1.016	0.040	40
AVERAGE			**39.0**	**28.8**	**0.864**	**0.034**	**35**
STANDARD DEVIATION			**9.3**	**6.9**	**0.204**	**0.008**	**13**
#3, WELD, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW63	1.7	35	33.6	24.8	0.635	0.025	25
RW63.	1.7	35	47.5	35.0	0.838	0.033	40
RW28	1.7	35	45.8	33.8	0.889	0.035	45
RW32	1.7	35	38.0	28.0	0.711	0.028	30
AVERAGE			**41.2**	**30.4**	**0.768**	**0.030**	**35**
STANDARD DEVIATION			**6.6**	**4.8**	**0.116**	**0.005**	**9**
#4, WELD, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW95	1.7	35	46.8	34.5	0.940	0.037	60
RW103	1.7	35	30.5	22.5	0.533	0.021	20
RW107	1.7	35	32.5	24.0	0.584	0.023	20
RW143	1.7	35	37.6	27.8	0.711	0.028	30
AVERAGE			**36.9**	**27.2**	**0.692**	**0.027**	**33**
STANDARD DEVIATION			**7.3**	**5.4**	**0.181**	**0.007**	**19**
#5, 10mm, LUSW, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW79.A	1.7	35	43.4	32.0	0.914	0.036	45
RW83.A	1.7	35	35.3	26.0	0.787	0.031	40
RW99.A	1.7	35	45.8	33.8	1.016	0.040	50
RW147A	1.7	35	50.8	37.5	1.143	0.045	45
AVERAGE			**43.8**	**32.3**	**0.965**	**0.038**	**45**
STANDARD DEVIATION			**6.5**	**4.8**	**0.151**	**0.006**	**4**

Table D-12 (continued)

#6, 10mm, ISO-TUP, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
W19A.X	1.7	35	47.1	34.8	0.940	0.037	40
W59A	1.7	35	54.2	40.0	1.041	0.041	60
W159A.X	1.7	35	49.5	36.5	1.194	0.047	65
W163A.X	1.7	35	38.6	28.5	0.762	0.030	35
AVERAGE			**47.4**	**35.0**	**0.984**	**0.039**	**50**
STANDARD DEVIATION			**6.5**	**4.8**	**0.181**	**0.007**	**15**
#7, 10mm, ISO, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW215	1.7	35	30.5	22.5	0.965	0.038	30
RW231	1.7	35	42.0	31.0	0.686	0.027	60
RW235	1.7	35	32.2	23.8	0.635	0.025	25
AVERAGE			**34.9**	**25.8**	**0.762**	**0.030**	**38**
STANDARD DEVIATION			**6.2**	**4.6**	**0.178**	**0.007**	**19**
#8, WELD, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW15	1.7	35	62.4	46.0	1.321	0.052	50
RW30	1.7	35	45.4	33.5	1.092	0.043	50
RW23L	1.7	35	**SPECIMEN BROKE ON WELD**				
RW27L	1.7	35	**SPECIMEN BROKE ON WELD**				
AVERAGE			**53.9**	**39.8**	**1.207**	**0.048**	**50**
STANDARD DEVIATION			**12.0**	**8.8**	**0.162**	**0.006**	**0**
#9, 10mm, ISO, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW31	1.7	35	35.3	26.0	0.610	0.024	20
RW35	1.7	35	60.3	44.5	1.041	0.041	60
RW183.X	1.7	35	36.9	27.3	0.686	0.027	30
RW60	1.7	35	46.4	34.3	0.940	0.037	35
AVERAGE			**44.7**	**33.0**	**0.819**	**0.032**	**36**
STANDARD DEVIATION			**11.5**	**8.5**	**0.204**	**0.008**	**17**
#10, WELD, ISO TUP, 10mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW51.	1.7	35	55.6	41.0	0.889	0.035	55
RW55.	1.7	35	42.0	31.0	0.711	0.028	40
RW87.	1.7	35	35.3	26.0	0.635	0.025	35
RW91.	1.7	35	35.6	26.3	0.508	0.020	30
AVERAGE			**42.1**	**31.1**	**0.686**	**0.027**	**40**
STANDARD DEVIATION			**9.5**	**7.0**	**0.159**	**0.006**	**11**
TOTAL AVERAGE			**41.5**	**30.6**	**0.834**	**0.033**	**40**
TOTAL STD DEV.			**8.6**	**6.4**	**0.197**	**0.008**	**13**

Table D-13 Charpy impact test data for reconstituted specimens: 14 mm insert, Linde 80 weld, ASTM tup, High temperature.

#1, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW10.X	93.3	200	85.0	62.7	1.626	0.064	100
RW14.X	93.3	200	89.9	66.3	1.727	0.068	100
AVERAGE			**87.5**	**64.5**	**1.677**	**0.066**	**100**
STANDARD DEVIATION			**3.5**	**2.5**	**0.071**	**0.003**	**0**
#2, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW69	93.3	200	90.0	66.4	1.727	0.068	100
RW69.X	93.3	200	90.3	66.6	1.829	0.072	100
AVERAGE			**90.2**	**66.5**	**1.778**	**0.070**	**100**
STANDARD DEVIATION			**0.2**	**0.1**	**0.072**	**0.003**	**0**
#3, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW137.X	93.3	200	101.0	74.5	1.829	0.072	100
RW50	93.3	200	96.3	71.0	1.778	0.070	100
AVERAGE			**98.7**	**72.8**	**1.804**	**0.071**	**100**
STANDARD DEVIATION			**3.3**	**2.5**	**0.036**	**0.001**	**0**
#4, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW90.X	93.3	200	94.9	70.0	1.702	0.067	100
RW78.X	93.3	200	93.6	69.0	1.676	0.066	100
AVERAGE			**94.3**	**69.5**	**1.689**	**0.067**	**100**
STANDARD DEVIATION			**0.9**	**0.7**	**0.018**	**0.001**	**0**
#5, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW42A	93.3	200	97.6	72.0	1.803	0.071	100
RW6.A	93.3	200	86.4	63.8	1.702	0.067	99
AVERAGE			**92.0**	**67.9**	**1.753**	**0.069**	**100**
STANDARD DEVIATION			**7.9**	**5.8**	**0.071**	**0.003**	**1**

Table D-13 (continued)

#6, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
W34A	93.3	200	95.7	70.6	0.686	0.027	100
W38A	93.3	200	96.3	71.0	1.880	0.074	100
AVERAGE			**96.0**	**70.8**	**1.283**	**0.051**	**100**
STANDARD DEVIATION			**0.4**	**0.3**	**0.844**	**0.033**	**0**
#7, 14mm, ASTM TUP, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW178A	93.3	200	85.4	63.0	1.448	0.057	100
RW182A	93.3	200	74.9	55.3	1.422	0.056	100
AVERAGE			**80.2**	**59.2**	**1.435**	**0.057**	**100**
STANDARD DEVIATION			**7.4**	**5.4**	**0.018**	**0.001**	**0**
#8, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW30.X	93.3	200	93.4	68.9	1.549	0.061	99
RW26.X	93.3	200	99.9	73.7	1.676	0.066	100
AVERAGE			**96.7**	**71.3**	**1.613**	**0.064**	**100**
STANDARD DEVIATION			**4.6**	**3.4**	**0.090**	**0.004**	**1**
#9, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW66.X	93.3	200	89.5	66.0	1.575	0.062	100
RW82.X	93.3	200	89.8	66.2	1.626	0.064	100
AVERAGE			**89.7**	**66.1**	**1.601**	**0.063**	**100**
STANDARD DEVIATION			**0.2**	**0.1**	**0.036**	**0.001**	**0**
#10, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW18	93.3	200	90.8	67.0	1.422	0.056	100
RW62	93.3	200	101.7	75.0	1.702	0.067	100
AVERAGE			**96.3**	**71.0**	**1.562**	**0.062**	**100**
STANDARD DEVIATION			**7.7**	**5.7**	**0.198**	**0.008**	**0**
TOTAL AVERAGE			**92.1**	**68.0**	**1.619**	**0.064**	**100**
TOTAL STD DEV.			**6.4**	**4.7**	**0.257**	**0.010**	**0**

Table D-14 Charpy impact test data for reconstituted specimens:
14 mm insert, Linde 80 weld, ISO tup, High temperature.

#1, 14mm, LUSW, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW84.	93.3	200	100.3	74.0	1.880	0.074	100
RW80.	93.3	200	92.9	68.5	1.727	0.068	100
AVERAGE			**96.6**	**71.3**	**1.804**	**0.071**	**100**
STANDARD DEVIATION			**5.2**	**3.9**	**0.108**	**0.004**	**0**
#2, 14mm, ISO, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW12.X	93.3	200	94.9	70.0	1.880	0.074	100
RW12	93.3	200	96.3	71.0	1.854	0.073	100
AVERAGE			**95.6**	**70.5**	**1.867**	**0.074**	**100**
STANDARD DEVIATION			**1.0**	**0.7**	**0.018**	**0.001**	**0**
#3, WELD, ISO TUP, 14mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW155.	93.3	200	86.8	64.0	1.600	0.063	100
RW151.	93.3	200	94.6	69.8	1.753	0.069	100
AVERAGE			**90.7**	**66.9**	**1.677**	**0.066**	**100**
STANDARD DEVIATION			**5.5**	**4.1**	**0.108**	**0.004**	**0**
#4, WELD, ISO TUP, 14mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW44.	93.3	200	87.5	64.5	1.575	0.062	100
RW48.	93.3	200	90.8	67.0	1.321	0.052	100
AVERAGE			**89.2**	**65.8**	**1.448**	**0.057**	**100**
STANDARD DEVIATION			**2.3**	**1.8**	**0.180**	**0.007**	**0**
#5, 14mm, LUSW, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW20A	93.3	200	90.2	66.5	1.651	0.065	100
RW24A	93.3	200	86.8	64.0	1.753	0.069	100
AVERAGE			**88.5**	**65.3**	**1.702**	**0.067**	**100**
STANDARD DEVIATION			**2.4**	**1.8**	**0.072**	**0.003**	**0**

Table D-14 (continued)

#6, ISO-TUP, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
W40A	93.3	200	97.6	72.0	1.829	0.072	100
W36A	93.3	200	101.0	74.5	2.007	0.079	100
AVERAGE			**99.3**	**73.3**	**1.918**	**0.076**	**100**
STANDARD DEVIATION			**2.4**	**1.8**	**0.126**	**0.005**	**0**
#7, 14mm, ISO, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW124A	93.3	200	98.3	72.5	1.854	0.073	100
RW128A	93.3	200	92.2	68.0	1.829	0.072	100
AVERAGE			**95.3**	**70.3**	**1.842**	**0.073**	**100**
STANDARD DEVIATION			**4.3**	**3.2**	**0.018**	**0.001**	**0**
#8, WELD, ISO TUP, 14mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW72.R	93.3	200	100.3	74.0	1.854	0.073	100
RW76.R	93.3	200	100.7	74.3	1.702	0.067	100
AVERAGE			**100.5**	**74.2**	**1.778**	**0.070**	**100**
STANDARD DEVIATION			**0.3**	**0.2**	**0.107**	**0.004**	**0**
#9, 14mm, ISO, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW64.X	93.3	200	93.6	69.0	1.702	0.067	100
RW68.X	93.3	200	104.4	77.0	1.905	0.075	100
AVERAGE			**99.0**	**73.0**	**1.804**	**0.071**	**100**
STANDARD DEVIATION			**7.6**	**5.7**	**0.144**	**0.006**	**0**
#10, WELD, ISO TUP, 14mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW92	93.3	200	85.4	63.0	1.575	0.062	90
RW88	93.3	200	93.9	69.3	1.600	0.063	95
AVERAGE			**89.7**	**66.2**	**1.588**	**0.063**	**93**
STANDARD DEVIATION			**6.0**	**4.5**	**0.018**	**0.001**	**4**
TOTAL AVERAGE			**94.4**	**69.6**	**1.743**	**0.069**	**99**
TOTAL STD DEV.			**5.5**	**4.0**	**0.158**	**0.006**	**2**

Table D-15 Charpy impact test data for reconstituted specimens:
14 mm insert, Linde 80 weld, ASTM tup, Low temperature.

#1, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW1.X	1.7	35	56.4	41.6	1.118	0.044	60
RW153.X	1.7	35	41.6	30.7	0.889	0.035	50
RW201.X	1.7	35	58.8	43.4	1.016	0.040	20
RW3.X	1.7	35	52.6	38.8	0.965	0.038	55
AVERAGE			**52.4**	**38.6**	**0.997**	**0.039**	**46**
STANDARD DEVIATION			**7.6**	**5.6**	**0.096**	**0.004**	**18**
#2, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW65	1.7	35	54.2	40.0	1.016	0.040	30
RW65.X	1.7	35	37.7	27.8	0.813	0.032	30
RW21	1.7	35	48.4	35.7	0.914	0.036	25
RW21.X	1.7	35	33.8	24.9	0.737	0.029	15
AVERAGE			**43.5**	**32.1**	**0.870**	**0.034**	**25**
STANDARD DEVIATION			**9.4**	**7.0**	**0.121**	**0.005**	**7**
#3, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW53	1.7	35	50.2	37.0	0.787	0.031	35
RW53.X	1.7	35	38.0	28.0	0.686	0.027	25
RW117.X	1.7	35	37.3	27.5	0.584	0.023	20
RW137	1.7	35	40.7	30.0	0.737	0.029	30
AVERAGE			**41.6**	**30.6**	**0.699**	**0.028**	**28**
STANDARD DEVIATION			**6.0**	**4.4**	**0.087**	**0.003**	**6**
#4, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW81.X	1.7	35	42.0	31.0	0.635	0.025	20
RW85.X	1.7	35	33.2	24.5	0.610	0.024	20
RW101.X	1.7	35	40.7	30.0	0.660	0.026	20
RW47.X	1.7	35	40.0	29.5	0.660	0.026	30
AVERAGE			**39.0**	**28.8**	**0.641**	**0.025**	**23**
STANDARD DEVIATION			**3.9**	**2.9**	**0.024**	**0.001**	**5**
#5, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW33A	1.7	35	43.4	32.0	0.940	0.037	35
RW109A	1.7	35	44.1	32.5	1.016	0.040	45
RW113.A	1.7	35	45.4	33.5	0.889	0.035	45
RW149A	1.7	35	47.5	35.0	0.965	0.038	40
AVERAGE			**45.1**	**33.3**	**0.953**	**0.038**	**41**
STANDARD DEVIATION			**1.8**	**1.3**	**0.053**	**0.002**	**5**

Table D-15 (continued)

#6, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
W41A	1.7	35	56.8	41.9	1.041	0.041	30
W45A	1.7	35	50.2	37.0	0.889	0.035	25
W181A	1.7	35	56.0	41.3	1.041	0.041	40
W197A.X	1.7	35	55.5	40.9	0.991	0.039	35
AVERAGE			**54.6**	**40.3**	**0.991**	**0.039**	**33**
STANDARD DEVIATION			**3.0**	**2.2**	**0.072**	**0.003**	**6**
#7, 14mm, ASTM TUP, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW213A	1.7	35	40.7	30.0	0.737	0.029	40
RW217A	1.7	35	38.6	28.5	0.635	0.025	45
RW229A	1.7	35	50.2	37.0	0.889	0.035	50
RW233A	1.7	35	43.4	32.0	0.686	0.027	45
AVERAGE			**43.2**	**31.9**	**0.737**	**0.029**	**45**
STANDARD DEVIATION			**5.0**	**3.7**	**0.110**	**0.004**	**4**
#8, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW2L	-12.2	10	42.3	31.2	0.813	0.032	40
RW2R.X	1.7	35	48.5	35.8	0.762	0.030	50
RW22.X	1.7	35	53.0	39.1	0.889	0.035	50
RW11L	1.7	35	51.0	37.6	0.838	0.033	50
AVERAGE			**48.7**	**35.9**	**0.826**	**0.033**	**48**
STANDARD DEVIATION			**4.6**	**3.4**	**0.053**	**0.002**	**5**
#9, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW17.X	1.7	35	47.2	34.8	0.838	0.033	35
RW25.X	1.7	35	**SPECIMEN BROKE ON WELD**				
RW129.X	1.7	35	54.8	40.4	0.889	0.035	30
RW133.X	1.7	35	64.8	47.8	1.118	0.044	40
AVERAGE			**55.6**	**41.0**	**0.948**	**0.037**	**35**
STANDARD DEVIATION			**8.8**	**6.5**	**0.149**	**0.006**	**5**
#10, 14mm, ASTM, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW37	1.7	35	55.2	40.8	0.813	0.032	30
RW49	1.7	35	63.0	46.5	0.889	0.035	45
RW157	1.7	35	51.5	38.0	0.864	0.034	50
AVERAGE			**56.6**	**41.8**	**0.855**	**0.034**	**42**
STANDARD DEVIATION			**5.9**	**4.3**	**0.039**	**0.002**	**10**
TOTAL AVERAGE			**47.6**	**36.3**	**0.886**	**0.035**	**34**
TOTAL STD DEV.			**8.6**	**6.3**	**0.143**	**0.006**	**9**

Table D-16 Charpy impact test data for reconstituted specimens:
14 mm insert, Linde 80 weld, ISO tup, Low temperature.

#1, 14mm, LUSW, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW7.	1.7	35	56.3	41.5	1.016	0.040	45
RW9.	1.7	35	59.0	43.5	1.143	0.045	60
RW135.	1.7	35	36.6	27.0	0.737	0.029	30
RW139.	1.7	35	42.0	31.0	0.940	0.037	40
AVERAGE			**48.5**	**35.8**	**0.959**	**0.038**	**44**
STANDARD DEVIATION			**10.9**	**8.0**	**0.170**	**0.007**	**13**
#2, 14mm, ISO, LUSW							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT*LB)	(MM)	(IN)	(PERCENT)
RW89	1.7	35	46.1	34.0	0.762	0.030	50
RW89.X	1.7	35	34.9	25.8	0.813	0.032	25
RW93	1.7	35	32.5	24.0	0.533	0.021	25
RW93.X	1.7	35	42.0	31.0	0.737	0.029	30
AVERAGE			**38.9**	**28.7**	**0.711**	**0.028**	**33**
STANDARD DEVIATION			**6.3**	**4.6**	**0.123**	**0.005**	**12**
#3, WELD, ISO TUP, 14mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW67	1.7	35	46.8	34.5	0.864	0.034	30
RW67.	1.7	35	46.8	34.5	0.787	0.031	30
RW151	1.7	35	42.0	31.0	0.711	0.028	20
RW155	1.7	35	47.5	35.0	0.838	0.033	30
AVERAGE			**45.8**	**33.8**	**0.800**	**0.032**	**28**
STANDARD DEVIATION			**2.5**	**1.8**	**0.067**	**0.003**	**5**
#4, WELD, ISO TUP, 14mm							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW95.	1.7	35	41.4	30.5	0.838	0.033	35
RW103.	1.7	35	35.6	26.3	0.686	0.027	25
RW107.	1.7	35	48.1	35.5	0.838	0.033	40
RW143.	1.7	35	43.0	31.8	0.838	0.033	35
AVERAGE			**42.0**	**31.0**	**0.800**	**0.032**	**34**
STANDARD DEVIATION			**5.1**	**3.8**	**0.076**	**0.003**	**6**
#5, 14mm, LUSW, ISO TUP							
IDENT	TEMP	TEMP	ENERGY	ENERGY	EXPAN	EXPAN	SHEAR
	(DEG C)	(DEG F)	(J)	(FT-LB)	(MM)	(IN)	(PERCENT)
RW79A	1.7	35	54.2	40.0	1.092	0.043	50
RW83.A	1.7	35	46.1	34.0	1.092	0.043	60
RW99A	1.7	35	50.2	37.0	1.092	0.043	50
RW147.A	1.7	35	42.0	31.0	0.864	0.034	45
AVERAGE			**48.1**	**35.5**	**1.035**	**0.041**	**51**
STANDARD DEVIATION			**5.3**	**3.9**	**0.114**	**0.004**	**6**

Table D-16 (continued)

#6, ISO-TUP, LUSW							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT*LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
W19A	1.7	35	51.5	38.0	0.965	0.038	40
W59A.X	1.7	35	54.2	40.0	0.991	0.039	35
W159A	1.7	35	59.7	44.0	1.168	0.046	50
W163A	1.7	35	46.1	34.0	0.914	0.036	50
AVERAGE			**52.9**	**39.0**	**1.010**	**0.040**	**44**
STANDARD DEVIATION			**5.7**	**4.2**	**0.110**	**0.004**	**8**
#7, 14mm, ISO, LUSW							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT*LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RW215A	1.7	35	23.0	17.0	0.457	0.018	15
RW219A	1.7	35	38.0	28.0	0.787	0.031	30
RW231A	1.7	35	36.9	27.3	0.559	0.022	30
RW235A	1.7	35	36.6	27.0	0.686	0.027	20
AVERAGE			**33.6**	**24.8**	**0.622**	**0.025**	**24**
STANDARD DEVIATION			**7.1**	**5.2**	**0.144**	**0.006**	**8**
#8, WELD, ISO TUP, 14mm							
IDENT	TEMP (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT-LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RW15.R	1.7	35	48.8	36.0	0.762	0.030	45
RW23.R	1.7	35	59.0	43.5	0.991	0.039	65
RW27.R	1.7	35	62.4	46.0	0.889	0.035	60
RW11.R	1.7	35	33.9	25.0	0.533	0.021	25
AVERAGE			**51.0**	**37.6**	**0.794**	**0.031**	**49**
STANDARD DEVIATION			**12.8**	**9.4**	**0.197**	**0.008**	**18**
#9, 14mm, ISO, LUSW							
IDENT	TEMP. (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT*LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RW31.X	1.7	35	56.8	41.9	1.118	0.044	60
RW35.X	1.7	35	47.5	35.0	0.838	0.033	20
RW183	1.7	35	42.4	31.3	0.787	0.031	45
RW60.X	1.7	35	43.7	32.3	0.813	0.032	45
AVERAGE			**47.6**	**35.1**	**0.889**	**0.035**	**43**
STANDARD DEVIATION			**6.5**	**4.8**	**0.154**	**0.006**	**17**
#10, WELD, ISO TUP, 14mm							
IDENT	TEMP. (DEG C)	TEMP (DEG F)	ENERGY (J)	ENERGY (FT-LB)	EXPAN (MM)	EXPAN (IN)	SHEAR (PERCENT)
RW51	1.7	35	63.7	47.0	1.143	0.045	50
RW55	1.7	35	59.7	44.0	0.965	0.038	55
RW87	1.7	35	41.4	30.5	0.711	0.028	30
RW91	1.7	35	39.0	28.8	0.635	0.025	30
AVERAGE			**51.0**	**37.6**	**0.864**	**0.034**	**41**
STANDARD DEVIATION			**12.6**	**9.3**	**0.234**	**0.009**	**13**
TOTAL AVERAGE			**45.9**	**33.9**	**0.848**	**0.033**	**39**
TOTAL STD DEV.			**9.2**	**6.8**	**0.180**	**0.007**	**13**

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11. ABSTRACT *(200 words or less)*

In 1992, the American Society for Testing and Materials (ASTM) initiated a Round Robin on Reconstitution (RRR) to assist the review of ASTM E1253 Guide on Charpy specimen reconstitution. The purpose is to study the influence of parameters, such as the reconstitution technique, the insert length, the hammer tup geometry and the material on test results. Ten laboratories participated in the RRR Charpy specimen reconstitution on unirradiated material according to a pre-defined test matrix with both 10-and 14-mm inserts. All Charpy impact tests were conducted by the U.S. NRC-sponsored Heavy-Section Steel Irradiation Program. Comparison of the absorbed energy and lateral expansion before and after reconstitution demonstrates that the loss due to reconstitution can be characterized by the combination of the insert length, the welding method, and the tup geometry used. In general, stud and upset-butt welding combined with the ASTM tup show the highest energy difference whereas electron-beam welding with the ISO tup exhibit the least. Variations among welding techniques and laboratories are also described. It is concluded that reconstitution does not affect characteristic loads in the instrumented load-time traces, and that the 10-mm insert length should not be used in the upper shelf or mid-transition temperature region.

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