Qualification of the Reclamation Welding Parameters for 316 CRES Stems

by

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MASTER

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MTS
STRATEGIC MATERIALS DEPARTMENT

Reclamation
Life Storage
Tritium
SRTC Task Job # 22610

**QUALIFICATION OF THE RECLAMATION WELDING
PARAMETERS FOR 316 CRES STEMS (U)**

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September 1997

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T. H. Kopolat
Authorized Derivative Classifier & RO

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Westinghouse Savannah River Company
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TABLE 1 Results of Reclamation Welding Demonstration

TABLE 2 Test Base Dimensions and Usage

TABLE 3 Fill Stem Dimensions and Usage

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1.0 SUMMARY

1.1 A demonstration was performed to prove the acceptability of using existing reclamation weld parameters for joining a new fill stem made of 316 Corrosion Resistant Stainless Steel (CRES) to a 304L stainless steel vessel. Previously qualified weld parameters are for welding the old 0.275" diameter stem of 304L stainless steel to a 304L vessel. The weld quality acceptance criteria included leak rate, proof test, burst strength and evaluation by metallography. All tests and examinations indicated that welds made within the demonstrated parameters met all requirements. The results from this work demonstrate that the welding of 316 CRES 0.275" diameter stems can be successfully performed using the same weld parameters as those for 304L stems.

2.0 BACKGROUND

2.1 Introduction - The Weld Engineering Group of the Materials Technology Section of Savannah River Technology Center (SRTC) was requested by Tritium Operations to provide a demonstration to prove the acceptability of using existing weld parameters for future production with 316L stem material. To provide a valid demonstration, the reclamation welder in building 723-A was outfitted with current measuring devices and a data acquisition system comparable to those used in the north welder of the production facility. Reclamation welding development, troubleshooting, demonstrations, and comparative tests can now be done conveniently and cost effectively in SRTC.

2.2 Demonstration Variables - All reclamation welding in 723-A was done by joining fill stems to test bases, as essential variables can be cost effectively addressed using test bases. Essential variables such as the fit between the fill stem and counterbore, the welding current, and the initial force applied were varied in this demonstration. These values were varied to produce welds near the parametric limits. Other values easily controlled in production were also controlled in the demonstration. Fill stem foot diameters (see Table 3), the weld cycle time, and the "percent heat" (weld voltage wave form) were held constant.

2.3 Acceptance Criteria - The acceptance criteria include the following:

Leak Rate < 5.0 E-9 std. cc. He/ sec* (at 1 atm. differential)

Proof / Burst Strength > = strength of stem

Metallography

-Bond Quality Good (class 2 bond or better, as determined in pinch welding)

- Bond Line Length Greater than 70% of maximum possible throat.

2.4 Tooling Design- The test base dimensions conform to the specifications identified in Figure 1. The test stems meet the dimension requirements for 304L stems, though they are made of 316 CRES.

3.0 ELEMENTS OF DEMONSTRATION

3.1 Procurement of Test Bases and Stems - The 316 CRES test stems were supplied by Sandia National Laboratory/California (SNL/CA) and were produced by hot working, rather than by High Energy Rate Forging (HERF). No certified materials test report was supplied with the stems. The test bases were supplied by Tritium from the routine production test supply. The chemistry of the test bases met commercial specifications for Type 304L stainless steel. The hardness was approximately 91 R_B, which is within the expected R_B 90-100 R_B hardness value. Some test bases were intentionally remachined to provide weld samples with mating surfaces near the bounds of acceptable counterbore dimensions (see Figure 1).

3.2 Equipment Upgrades - The reclamation welder in 723-A was modified by Engineered Equipment & Systems (EES) to allow simultaneous recording of data collected from each of several current indicating devices. Graphic printout of data capability was also added (see Figure 2). These modifications made the 723-A welder system comparable to the production systems. The previously used Duffers Scientific current indicating device remained in place for independent, but not time dependent recording of the weld current. The use of Holt Shunt and Robotron current indicating devices make the 723-A and the production systems comparable for developmental, trouble-shooting, and comparative testing activities.

* Std. cc. He/sec : Standard cubic centimeters per second at standard pressure of 14.7 psia and standard temperature of 25 Deg. C.

3.3 Preparation and Evaluation of Welded Coupons - The demonstration samples were prepared, welded, and examined using the procedures identified in references 7.1 through 7.7. The sample weld quality was evaluated by leak, proof, and burst testing and by metallurgical examination as described below.

3.3.1 Leak / Proof / Burst Tests - Procedure L9.4-8303 was used by the High Pressure Laboratory of Savannah River Technology Center (SRTC) for the three load integrity tests. The leak rate test was performed using helium gas as the test fluid. The pressure, range, and maximum acceptable leakage rate were the same as specified in reference 7.12. The hydraulic burst test was performed by increasing the pressure until stem rupture occurred. The proof test acceptance criteria was met before rupture.

3.3.2 Metallography - The quality of the weld was rated from metallographic examination as discussed below.

3.3.2.1 Minimum Weld Throat - One measure of weld quality was made by evaluation of minimum weld throat length. The acceptance criteria as identified in SOP MTF-4.15, reference 7.8, requires the weld fusion heights at opposite sides of a weld joint cross section to be greater than 70% of the height from the top of the base to the bottom of the counterbore.

3.3.2.2 Bond Quality - The appearances of the polished and etched weld cross sections were characterized and assigned bond class ratings identified in references 7.7 and 7.8. A bond rating of Class I or II was required for acceptance. The extent of weld interface area recrystallization was not estimated due to the variations in deformation between the stems and the test bases.

3.4 Equipment Calibration - Calibration of the reclamation welder system in 723-A was performed and documented (Ref. 7.10 and 7.11).

4.0 RESULTS

4.1 Welding - Of the 23 stems/bases welded during this demonstration, 18 were within the specified target parameters (Ref. 7.9). The data produced are given in Tables 1 and 2. The data acquisition system for the welder recorded the test variables of current and initial loading force (see Figure 2). Other weld parameters were also recorded, but were either not allowed to vary or otherwise remained essentially constant during this demonstration. The percent heat was maintained at 97% for each weld and the voltage was set to achieve the targeted value of current. Hold current values were used as the primary target for all tests except test numbers 3 and 4 in Table 1, which used the higher amperage Duffers current as the targeted value.

4.2 Leak / Proof / Burst Tests - Ten of the welds were evaluated by leak rate, proof, and burst testing. The results of all ten leak rate, proof, and burst tests were within the specifications and are given in Table 1. The leak rates were near the limit of detection and the burst strengths all exceeded 50,000 psig.

4.3 Metallography - Eight of the welds were evaluated by metallography. Table 1 identifies all eight weld coupons which met the stated acceptance criteria concerning bond quality (see Figures 3, 4 and 5) and the required 70% of the maximum possible throat length of the welded stem/test base combination (Ref. 7.8).

5.0 DISCUSSION

5.1 Calibration of 723-A Welder Measuring Equipment -

The 723-A Reclamation Welder contains calibrated measuring devices coordinated with the Data Acquisition System (DAS). The DAS contains modules which convert the signal outputs for plotting and archiving purposes. Electrode initial force, root mean squared (rms) amperage, weld voltage, wave form, weld cycle time and stem displacement were recorded by the DAS (see Figure 2). Three current measuring devices, the Holt AC Shunt, the Robotron WS-20, and the Duffers Scientific Current Time Analyzer were used for comparative purposes. As on the production facility north welder, the Holt Shunt is used as the primary current measuring device. Calibrations and evaluations of these current measuring devices are documented in References 7.10 and 7.11.

5.2 Metallography - Weld microstructure was acceptable for all welds made for qualification. The minimum weld throat lengths exceeded the required 70% of maximum possible throat in all instances. Figures 3 through 5 illustrate the cross section and bond line at different magnifications. All were judged to be acceptable bonds.

6.0 CONCLUSIONS

6.1 The previously established welding parameters for the 0.275 in. stem foot diameter 304L stems can be successfully used with 316 CRES stems of the same size.

6.2 Slight adjustments in the actual parameters used in production may be necessary due to system variations from the 723-A welder. Demonstration welds performed during transition work should be evaluated by methods similar to those performed at SRTC before actual production welds are produced.

7.0 REFERENCES

- 7.1 L9.3-4700 Materials Consultation Work Procedure
- 7.2 L9.3-4701 Metallurgical Technical Assistance Basis Training and Qualification Procedure
- 7.3 L9.3-6527 Vibromet Polishing Operations
- 7.4 L9.3-6533 Olympus Measuring Microscope Operation
- 7.5 L9.3-8504 Operating Procedure for Reclamation Welder System
- 7.6 L9.4-8303 Proof/Leak Test Procedure
- 7.7 SOP MTF-4.14 Rev. 3, Metallurgical Evaluation of Pinch Weld Bonds, Manual L11.1.
- 7.8 SOP MTF-4.15 Rev. 1, Metallurgical Evaluation of Reclamation Welds, Manual L11.1.
- 7.9 Letter G. J. McKinney, S. R. Howard, & C. E. Sessions, to E. G. Caveness, Task Scope, SRT -MTS-5070, June 6, 1997.
- 7.10 Calibration Report - 723-A Reclamation Welder, Holt Shunt, SRT IES 97037, James Tarpley to Charles Sessions, et al., September 4, 1997.
- 7.11 Evaluation of Four Robotron Model WS-20 Resistance Welding Current Monitors, Report Number 96-01003, High Current Technologies, Inc., December 10, 1996.
- 7.12 SOP RF-H-505 Rev. 2

8.0 ACKNOWLEDGMENTS

8.1 This activity was funded by Tritium Operations as a three part effort as discussed in the memo SRT-MTS-5070, reference 7.9 given as Attachment A of this report. The north welder in the production facility has been upgraded to measure welding current with a Holt Shunt. A similar modification to use the Holt Shunt is planned for the production facility south welder.

8.2 Personnel -

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Facility Manager - G. A. Donham
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9.0 FIGURES AND TABLES

FIGURE 1 Specially Machined and Standard Test Base Dimensions
FIGURE 2 Typical DAS Test Archive Report
FIGURE 3 Typical Metallographic Cross Section of Reclamation Weld (1.5X)
FIGURE 4 Typical Metallographic Cross Section of Reclamation Weld (100X)
FIGURE 5 Typical Metallographic Cross Section of Reclamation Weld (400X)

TABLE 1 Results of Reclamation Welding Demonstration
TABLE 2 Test Base Dimensions and Usage
TABLE 3 Fill Stem Dimensions and Usage

10.0 ATTACHMENTS

Attachment A Table 1, Task Plan

FIGURE 1

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**Specially Machined and Standard Test Base Dimensions
for Reclamation Welds**

Specially Machined Dimensions

A = Leave as is
B=0.285" +/- 0.010"
C=0.250" + 0.003", -0.001"
(for #'s 1B -8B);
C=0.256" + 0.001", -0.003"
(for #'s 9B-12B & #21-24)
D=0.091" +/- 0.003"
E=0.075" +/- 0.001
Hole F, Drill thru piece with same
diameter, +/- 0.0015"
C'sink angle= 43-47 degrees

Standard Dimensions

A=0.967"- 0.966"
B=0.275"-0.295"
C=0.249"-0.257"

D=0.088"-0.094"
E=0.074"-0.076"

FIGURE 2
Typical DAS Archive Test Report

FIGURE 3
Typical Metallographic Cross Section
of Reclamation Weld (1.5X), (below)

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FIGURE 4
Typical Metallographic Cross Section
of Reclamation Weld (100X), (below)

FIGURE 5
Typical Metallographic Cross Section
of Reclamation Weld (400X), (below)

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Fill Stem Foot Base Metal

Solid State Bond Interface

Test Base Metal

TABLE 1
Results of Reclamation Welding Demonstration
for Reclamation Welds

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Test #	Weld	Voltage	Duffer Current (AMPS)	Holt Current (AMPS)	Force (lbs.)	Counter Bore Dia. (in)	Interference (in.)	Pass Leak Test	Pass Proof Test	Pass Burst Test	Pass Bond Quality	Pass Dimension Criteria
1	Nom.	330	12,380	11,314	2,244	0.251	0.0246	YES	YES	YES		
2	Nom.	327	12,330	11,315	2,239	0.252	0.0235	YES	YES	YES		
3	Hot	352	13,390	12,202	2,235	0.253	0.0226	YES	YES	YES		
4	*Hot	360	13,980	12,823	2,254	0.251	0.0245				YES	YES
5	Nom.	325	12,350	11,274	2,239	0.252	0.0235	YES	YES	YES		
6	Nom.	327	12,640	11,525	2,237	0.252	0.0235	YES	YES	YES		
7	Nom.	328	12,200	11,216	2,252	0.251	0.0245				YES	YES
8	Nom.	324	12,270	11,177	2,248	0.252	0.0236				YES	YES
9	Cold	310	11,300	10,307	2,270	0.2509	0.0249	YES	YES	YES		
10	Cold	316	11,960	10,923	2,274	0.2507	0.0251	YES	YES	YES		
11	Cold	317	11,830	10,741	2,286	0.2512	0.0246				YES	YES
12	Cold	319	12,100	11,001	2,269	0.2506	0.0252				YES	YES
13	*Cold	285	10,110	9,200	2,278	0.2501	0.0259	YES	YES	YES		
14	*Cold	290	10,640	9,700	2,271	0.2504	0.0255				YES	YES
15	Hot	338	12,740	11,650	2,224	0.2565	0.0188	YES	YES	YES		
16-1	Hot	337	12,690	11,661	2,219	0.2562	0.0192	YES	YES	YES		
18-1	Hot	341	12,390	11,762	2,219	0.2564	0.0188				YES	YES
993-04	Hot	338	13,070	11,800	2,209	0.2563	0.0186				YES	YES

* Out of spec. range. All welds made using 97% heat and 25 cycles welding time.

TABLE 2
Test Base Dimensions and Usage
for Reclamation Welds

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Test Base Serial No.	"B" C'sink Diameter (0.275"-0.294") 0.275-0.281=S 0.282-0.287=M 0.288-0.294=L	"C" C'bore Diameter (0.249-0.257") 0.249-0.253=S 0.254-0.257=L	"D" C'bore + C'sink Depth (0.088"-0.094") 0.088-0.091=S 0.092-0.094=L	"E" C'bore Depth Only (*0.074"-0.076")	Usage	Test Type	Other Information
2B	0.279 S	0.2504 S	0.092 L	0.075	Test 14 w #191	Metallography	Test 14 OK, cold
3B	0.286 M	0.2562 L	0.093 L	0.075	Test 16 w #194	Not Tested	Hold - 300 Amps too low
4B	0.285 M	0.2565 L	0.091 S	0.075	Test 15 w 169	L, P, B	Test 15 OK, hot
5B	^ 0.279 S	0.2509 S	0.091 S	0.075	Test 9 w 104	L, P, B	Test 9, cold
6B	0.286 M	0.2503 S	0.091 S	0.075	Test 993-02 w/ #134	Burst Test Only	Do not use, met no target
7B	^ 0.285 M	0.2564 L	0.093 L	0.075	Test 18 w 149	Not Tested	Hold - 300 Amps too low
8B	0.284 M	0.2502 S	0.091 S	0.075	Test 993-03 w/ #119	Burst Test Only	Do not use, met no target
9B	0.286 M	0.256 L	0.091 S	0.075	Test 993-04 w/ #111	No hardness, Metallography	Test 17 OK, hot
10B	0.286 M	0.2563 L	0.091 S	0.075	Test 993-01 w/ #122	No hardness, Metallography	Low F, low Amps, do not use
11B	^ 0.287 M	0.2555 L	0.092 L	0.075	Test 16.1 w 135	L, P, B	Test 16.1 OK, hot, 2 nd try at 16
12B	^ 0.285 M	0.2561 L	0.092 L	0.075	Test 18.1 w 181	Metallography	Test 18.1 OK, hot, 2 nd try at 18
13B	^ 0.280 S	0.2501 S	0.092 L	0.075	Test 13 w 131	L, P, B	Test 13 OK, cold, out of spec.
3*	0.286 M	0.251S	0.092 L	-	Test 1 w 176	L, P, B	Test 1, OK, nom.
4*	0.283 M	0.252 S	0.091 S	-	Test 6 w 173	L, P, B	Test 6 OK, nom.
7*	0.290 L	0.251S	0.094 L	-	Test 7 w 185	Metallography	Test 7 OK, hot
12*	0.282M	0.251S	0.091 S	-	Test 4 w 145	Metallography	Test 4 OK, hot
15*	0.280 S	0.252 S	0.089 S	-	Test 8 w 124	Metallography	Test 8 OK, nom
16*	0.280 S	0.253 S	0.090 S	-	Test 3 w 136	L, P, B	Test 3 OK, hot
18*	0.285 M	0.252 S	0.092 L	-	Test 5 w 171	L, P, B	Test 5 OK, nom.
20*	0.287 M	0.252 S	0.092 L	-	Test 2 w 139	L, P, B	Test 2 OK, nom.
21	^ 0.282 M	0.2507 S	0.092 L	0.075	Test 10 w 167	L, P, B	Test 10 OK, cold
23	^ 0.280 S	0.2506 S	0.091	0.075	Test 12 w 110	Metallography	Test 12 OK, cold
24	^ 0.282 M	0.2512 S	0.093	0.075	Test 11 w 178	Metallography	Test 11 OK, cold
spare1	NA	NA	NA	-	Setup #107	None	Initial Demo Setup
spare2	NA	NA	NA	-	Setup #108	None	Initial Demo Setup

* Transcribed from originals by Stan Howard, 7/9/97, from SOP RF-H-208 r. 4, Test Weld Data Sheet.

^ Transcribed from metrologist report, 7/11/97 SRH.

- Measurement not taken, as all previous were exactly as required.

TABLE 3
Fill Stem Dimensions and Usage
 316SS Stems for Reclamation Welds
 Part Number 458572-00

Fill Stem Serial No.	Stem Foot Size, inches	Usage
X102	0.2757	SRTC RW Setup #107
X104	0.2758	Test 9 w/Base 5B
X110	0.2758	Test 12 w/Base 23
X111	0.2749	T 993-04 w/Base 9B (17)
X119	0.2761	Test 993-03 w/Base 8B
X122	0.2753	Test 993-01 w/Base 10B
X124	0.2756	Test 8 w/Base 15
X128	0.2756	SRTC RW Setup
X131	0.2760	Test 13 w/Base 13B
X134	0.2760	Test 993-02 w/Base 6B
X135	0.2754	Test 16.1 w/Base 11B
X136	0.2756	Test 3 w/Base 16
X139	0.2755	Test 2 w/Base 20
X145	0.2755	Test 4 w/Base 4
X149	0.2752	Test 18 w/Base 7B
X165	0.2755	SRTC RW Setup #108
X167	0.2758	Test 10 w/Base 21
X169	0.2753	Test 15 w/Base 4B
X171	0.2755	Test 5 w/Base 18
X173	0.2755	Test 6 w/Base 4
X176	0.2756	Test 1 w/Base 3
X178	0.2758	Test 11 w/Base 24
X181	0.2753	Test 18.1 w/Base 12B
X185	0.2755	Test 7 w/Base 7
X191	0.2759	Test 14 w/base 2B
X194	0.2754	Test 16 w/base 3B

Measured by Gregg Goff, 6/13/97, digital micrometer # EA-115, cal. due date 12/18/97.
 Checked by Stan Howard, 6/13/97.

Attachment A

Task Plan for Reclamation Welding Test Bases with 316 SS Stems

No.	TB* or Other	Voltage Range	Current Target Range	Force	Time	C'Bore Size	Stem Foot Size	Leak Test	Proof Test	Burst Test	Metallography
1	TB	TBD	Nom.	Nom.	Nom.	Nom.	a*	X	X	X	
2	TB	TBD	Nom.	Nom.	Nom.	Nom.	a*	X	X	X	
3	TB	TBD	Nom.	Nom.	Nom.	Nom.	a*				X
4	TB	TBD	Nom.	Nom.	Nom.	Nom.	a*				X
5	TB	TBD	Nom.	Nom.	Nom.	Nom.	a*	X	X	X	
6	TB	TBD	Nom.	Nom.	Nom.	Nom.	a*	X	X	X	
7	TB	TBD	Nom.	Nom.	Nom.	Nom.	a*				X
8	TB	TBD	Nom.	Nom.	Nom.	Nom.	a*				X
9	TB	TBD	Low	High	Nom.	Min.	a*	X	X	X	
10	TB	TBD	Low	High	Nom.	Min.	a*	X	X	X	
11	TB	TBD	Low	High	Nom.	Min.	a*				X
12	TB	TBD	Low	High	Nom.	Min.	a*				X
13	TB	TBD	L (out of spec)	High	Nom.	Min.	a*	X	X	X	
14	TB	TBD	L (out of spec)	High	Nom.	Min.	a*				X
15	TB	TBD	High	Low	Nom.	Max.	a*	X	X	X	
16	TB	TBD	High	Low	Nom.	Max.	a*	X	X	X	
17	TB	TBD	High	Low	Nom.	Max.	a*				X
18	TB	TBD	High	Low	Nom.	Max.	a*				X
19	NA										
20	NA										

a - KC produced WR stems to be sorted by foot diameter and selected to produce the desired effects on a best effort basis.

NA- not specified

(sequence of welding to be randomized)