This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U.S. Department of Energy.

WSRC-TR-2005-00434

Evaluation of Constant Current Weld Control for Pinch Welding

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September 2005

Westinghouse Savannah River Company
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Prepared for the U.S. Department of Energy
under Contract DE-AC09-96SR18500

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MST
MATERIALS SCIENCE and TECHNOLOGY

Keywords: Stainless steel
Fill Stems
Pinch welds

Retention: Permanent

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Title: **Evaluation of Constant Current Weld Control for Pinch Welding**

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9-28-2005

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Evaluation of Constant Current Weld Control for Pinch Welding

Abstract

Modern weld controllers typically use current to control the weld process. SRS uses a legacy voltage control method. This task was undertaken to determine if the improvements in the weld control equipment could be implemented to provide improvements to the process control. The constant current mode of operation will reduce weld variability by about a factor of 4. The constant voltage welds were slightly hotter than the constant current welds of the same nominal current. The control mode did not appear to adversely affect the weld quality, but appropriate current ranges need to be established and a qualification methodology for both welding and shunt calibrations needs to be developed and documented.

Background

Pinch welding has been successfully used to close and seal tritium containing reservoirs for over 50 years. The mechanical objects used to seal the vessels have changed over time and the electrical equipment has been modified and replaced . Today, the pinch welding process uses a commercial, solid state weld controller to function as a simple switch to turn welding current on and off for a precise interval. The weld heat, measured in terms of weld current, must be varied to address the process variables. An operator controls the weld heat by manually setting the output voltage with a variable transformer called a Powerstat. This control mechanism is known as a constant voltage weld process. The voltage and the cumulative series resistance of the system determine the resulting weld current. Weld qualifications are established by demonstrating the weld integrity produced by welding within certain force and voltage parameters for a specified number of weld cycles. The welding engineer must use prior experience and previous weld data to determine the controlling voltage as a starting point with test welds and then control the voltage to achieve the desired weld current in the process. Since the current is really the primary welding variable, a controller that controls current should result in more reproducible weld conditions.

Powerstats are used at SRS for historical reasons. Today, those reasons are no longer present. Like most commercial weld controllers, the Medar controllers that are in use in the loading lines in Defense Programs are capable of controlling the weld heat by varying the phase angle of firing of the SCRs (silicon control rectifiers). The Medar controller also has the capability of introducing a feedback mechanism using the measured weld current to control the actual current or %I (percent current), real-time during the weld, to drive the current to a programmed target value. This technique has been successfully demonstrated with the reclamation weld process and is in use in production.

This PDRD task was undertaken to investigate the suitability of using constant current to control pinch welding. Test welds were made to evaluate the reproducibility of the process and to determine the effects on the bond. All welds were confined pinch welds using a nominal 1250 lbs force, 12 cycles, and current as indicated. The welds were made in both air (constant current and welds identified only as CV ####-3) and nitrogen (welds identified as DOEx-2).

Results

Preliminary work was conducted to determine the relative stability of the process and to see if the constant current process offered improvements over the constant voltage mode of operation. These preliminary results are indicted in Table 1 which shows that the constant current mode of operation reduces the variability of the current from a maximum of 125 A to less than 25 A. Based on these results additional machine and metallurgical tests were performed. In the testing reported for the latest study, the set-point voltage was not altered between welds so the resultant current for the constant voltage control was more consistent than indicated in Table 1.

The test matrix used for this study is shown in Tables 2 and 3 for both the machine settings and results. Welds were made under cold (3200 A), Nominal (3750 A) and Hot (4000 A) conditions for both constant current and constant voltage control using the same weld control program at 1250 Lbs force and 12 cycles with 3/16” radius tungsten tipped copper electrodes. The different control methods exhibit distinct electrical characteristics for delivering the current to the welder. In the constant voltage mode, the current data forms a continuous sinusoidal wave while the constant current mode results in a chopped wave as shown in Figure 1a and 1b. The current data for two data series are overlaid in Figure 2. The chopped sine wave is apparent in both Figures 1 and 2.

The effect of the different control methods on the metallurgical bond was evaluated by examining both transverse and longitudinal cross-sections of the tubes. It is apparent that the weld heat for the constant voltage mode is somewhat greater than that for the constant current mode due to the presence of melting. This attribute is especially obvious for the welds made at nominally 4000 A in which the constant voltage mode has a sizeable weld nugget and the constant current sample does not, as shown in Figure 3. The calculated weld heat is similar for both the constant current and constant voltage controlled welds.

The relative difference in weld heat can also be noted by the closure length data listed in Table 3. The closure length data comparing the two methods is shown graphically in Figure 4. The closure length is consistently greater for the constant voltage by 0.016 to .008” between 3200 and 4000 A. Note that the closure lengths for the constant current test welds are more consistent than those for the constant voltage test welds.

Conclusions

The constant current mode of control for pinch welds exhibits less variability than constant voltage control when the set-point is changed for each weld.

The current control welds in this study were cooler than the voltage control welds.

The weld closure lengths for the constant current welds were more consistent than the closure lengths for the constant voltage welds.

Recommendations

The constant current mode of control offers improvements in weld consistency. However, additional testing is needed to develop comparable weld heats for the two control methods. Also, the effects of different weld heads or system inductance on weld consistency for constant current control needs to be determined since all of these welds were made under nearly identical conditions on a single weld head.

Acknowledgements

The authors would like to acknowledge financial support from Defense Programs under the auspices of PDRD and R. Rabun. We would also like to thank Tony Curtis for his metallographic sample preparation and photography. We would also like to acknowledge J.M. Tarpley for his electrical engineering design and implementation and contributions to the project.

Table 1. Initial data sets showing relative improvement of constant current control over constant voltage control, **bold** values are for comparison..

Current	CPW Tube	UPW Tube	UPW Stem	CPW Stem	CV Min	CV Max	CC CPW	CC min	CC max
3000	3097	3002	2896		2884.7	3104	3097.6	3094.6	3108.5
3000	3104	2928	2976		**Range**	**219.3**	3108.5	**Range**	**13.9**
3000		3061	2886.5				3094.6		
3000		3053	2968.8				3105		
3000		3060	2884.7				3104.3		
3000			2961						
3500	3515	3543	3453		3441.4	3543	3587	3562.1	3587
3500			3441.4		**Range**	**101.6**	3562.1	**Range**	**24.9**
3500			3443.6				3580.4		
3500			3445.3						
4000	3956	3913	3894	4086	3869	4121	3991	3986	3995.6
4000	3966	3931	4002	4121	**Range**	**252**	3995.6	**Range**	**9.6**
4000	3869	4080	3908.9	4011.4			3986		
4000	3876	3926	4018.9	4057.3					
4000		3958	3903.7	4047.4					
4000			4003.7	4049.4					

Table 2. Weld conditions and weld machine outputs for test matrix

Sample ID	Target I	Setpoint I	Target V	Actual I	Actual V	Force (lbs)	Net Disp. (in)	Dyn. Res. (m•)	Energy (J)
CV 3200-3	3200	NA	311.65	3071.4	311.41	1294	0.0177	0.222	394
CV 3200-2 (DOEx-2 1)	3200	NA	311.65	3203.9	311.87	1291	0.0224	0.228	449
CV 3200-1 (DOEx-2 6)	3200	NA	311.65	3210.8	312.35	1290	0.0225	0.231	455
Average				3162.0	311.88	1292	0.0209	0.227	432
CC 3200-2	3200	3070	465	3214.9	475.66	1262	0.0188	0.219	426
CC 3200-3	3200	3070	465	3234.0	473.39	1294	0.0192	0.219	429
CC 3200-1	3200	3070	465	3234.9	473.38	1290	0.0171	0.218	430
Average				3227.9	474.14	1282	0.0183	0.219	428
CV 3750-3	3750	NA	358.90	3730.7	359	1268	0.0249	0.206	562
CV 3750-2 (DOEx-2 16)	3750	NA	358.90	3751.5	359.32	1249	0.0291	0.213	576
CV 3750-1 (DOEX-2 15)	3750	NA	358.90	3752.5	359.39	1247	0.0289	0.213	573
Average				3744.9	359.24	1255	0.0276	0.211	570
CC 3750-4	3750	3630	465	3746.1	473.19	1264	0.0210	0.207	552
CC 3750-1	3750	3630	465	3737.3	473.21	1296	0.0211	0.205	563
CC 3750-3	3750	3630	465	3737.6	473.36	1295	0.0228	0.203	537
Average				3740.3	473.25	1285	0.0216	0.205	551
CV 4000-3	4000	NA	380.37	3844.9	380.58	1267	0.0257	0.204	589
CV 4000-2 (DOEx-2 22)	4000	NA	380.37	4008.2	381.32	1247	0.0307	0.206	630
CV 4000-1 (DOEx-2 23)	4000	NA	380.37	4012.4	381.62	1288	0.0297	0.201	633
Average				3955.2	381.17	1267	0.0287	0.204	618
CC 4000-1	4000	3920	465	3990.3	461	1261	0.0273	0.209	625
CC 4000-2	4000	3920	465	4000.7	475.53	1292	0.0239	0.201	603
CC 4000-3	4000	3920	465	4000.7	474.7	1293	0.0243	0.199	619
Average				3997.2	470.41	1282	0.0251	0.203	616

Table 3. Weld quality metrics

Sample ID	**Electr. Align (<.01")**	**Closure len. (in)**	**Extrusion**	**Extrusion to base (<1)**	**10 mil ball (in)**	**Bond rating**	**Comments**	**Weld thick. (in)**	**Weld Width (in) <.130**
CV 3200-3	0.004	0.0604	N/A	N/A	Fails	3	Longitudinal	0.055	0.126
CV 3200-2 (DOEx-2 1)	0.001	0.0904	N/A	N/A	Fails	3	Continuous interface	0.055	0.126
CV 3200-1 (DOEx-2 6)	0.001	0.0937	N/A	N/A	Fails	3	Some broken up interface at ends	0.0555	0.127
Average		0.0815							
CC 3200-2	0.001	0.0733	N/A	N/A	Fails	3		0.055	0.125
CC 3200-3	0.001	0.0771	N/A	N/A	Fails	3		0.055	0.126
CC 3200-1	0	0.0762	N/A	N/A	Fails	NA		0.055	0.126
Average		0.0755							
CV 3750-3	0.007	0.1450	0.0049	0.36	N/A	2		0.049	0.124
CV 3750-2 (DOEx-2 16)	0.004	0.1545	0.02	0.89	N/A	2	slight melting	0.051	0.126
CV 3750-1 (DOEX-2 15)	0.003	0.1540	0.0168	0.77	N/A	2	Slight melting	0.05	0.126
Average		0.1512							
CC 3750-4	0.001	0.1410	0.0049	0.32	N/A	2	Longitudinal	0.051	0.126
CC 3750-1	0.003	0.1405	0.0039	0.29	N/A			0.05	0.126
CC 3750-3	0.005	0.1382	0.0025	0.23	N/A	2	No melt	0.05	0.126
Average		0.1399							
CV 4000-3	0.007	0.1537	0.0133	0.72	N/A	2	Longitudinal	0.048	0.126
CV 4000-2 (DOEx-2 22)	0.005	0.1691	0.0273	1.08	N/A	1	Nugget, some non linear decoration in centerline	0.048	0.126
CV 4000-1 (DOEx-2 23)	0.005	0.1686	0.0244	0.97	N/A	2	Nugget discontinuous interface	0.048	0.126
Average		0.1638							
CC 4000-1	0.004	0.1635	0.0116	0.59	N/A	2		0.046	0.124
CC 4000-2	0.001	0.1597	0.0125	0.59	N/A	2		0.046	0.125
CC 4000-3	0.001	0.1601	0.0148	0.81	N/A	2	Longitudinal	0.046	0.125
Average		0.1611							

Limits and notes: Electrode alignment <0.010", minimum wall thickness 0.020", Closure length 0.100" minimum, Extrusion ratio <1, Bond rating 1 or 2, thickness 0.045-0.070", width < 0.130".

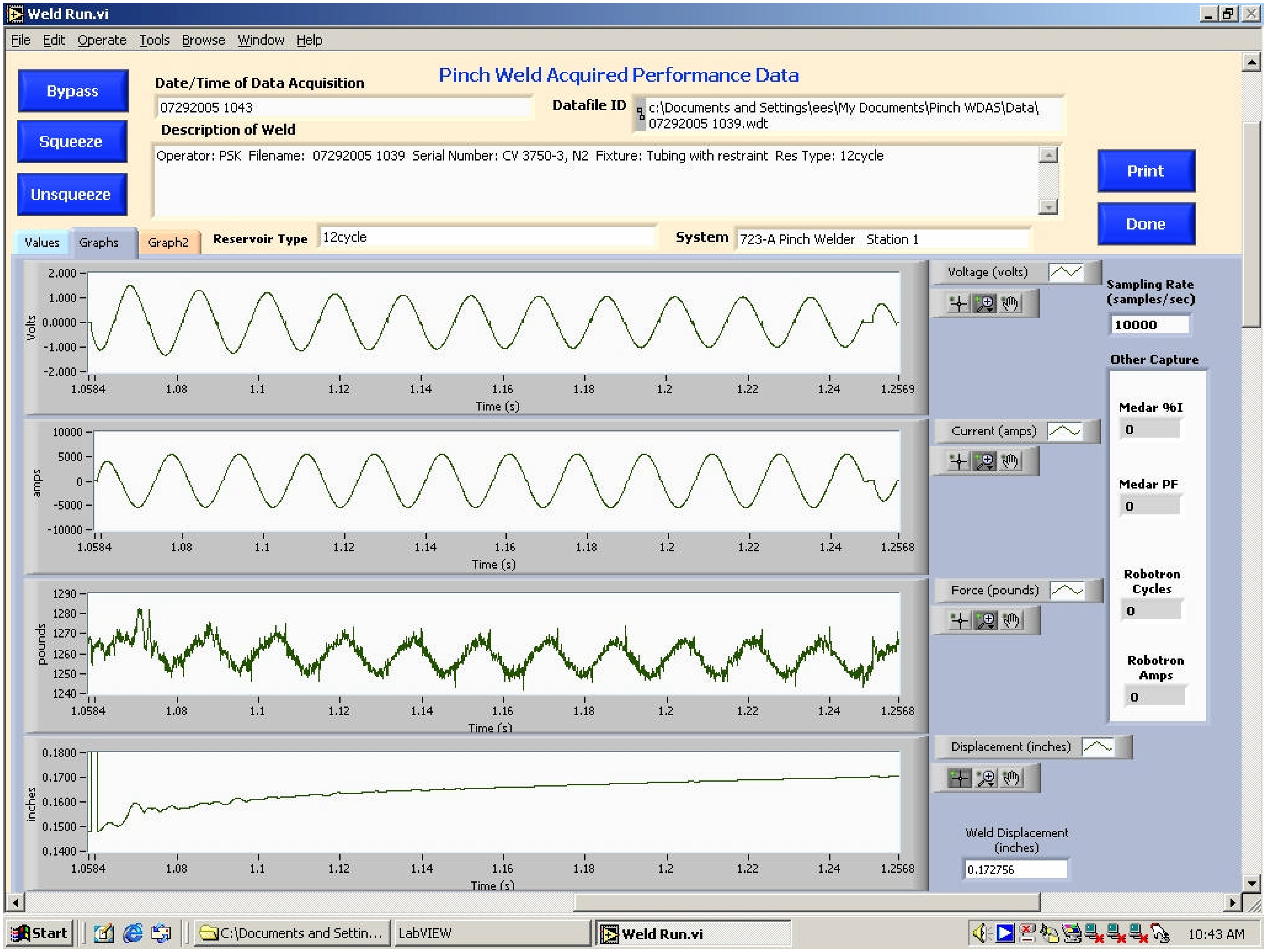
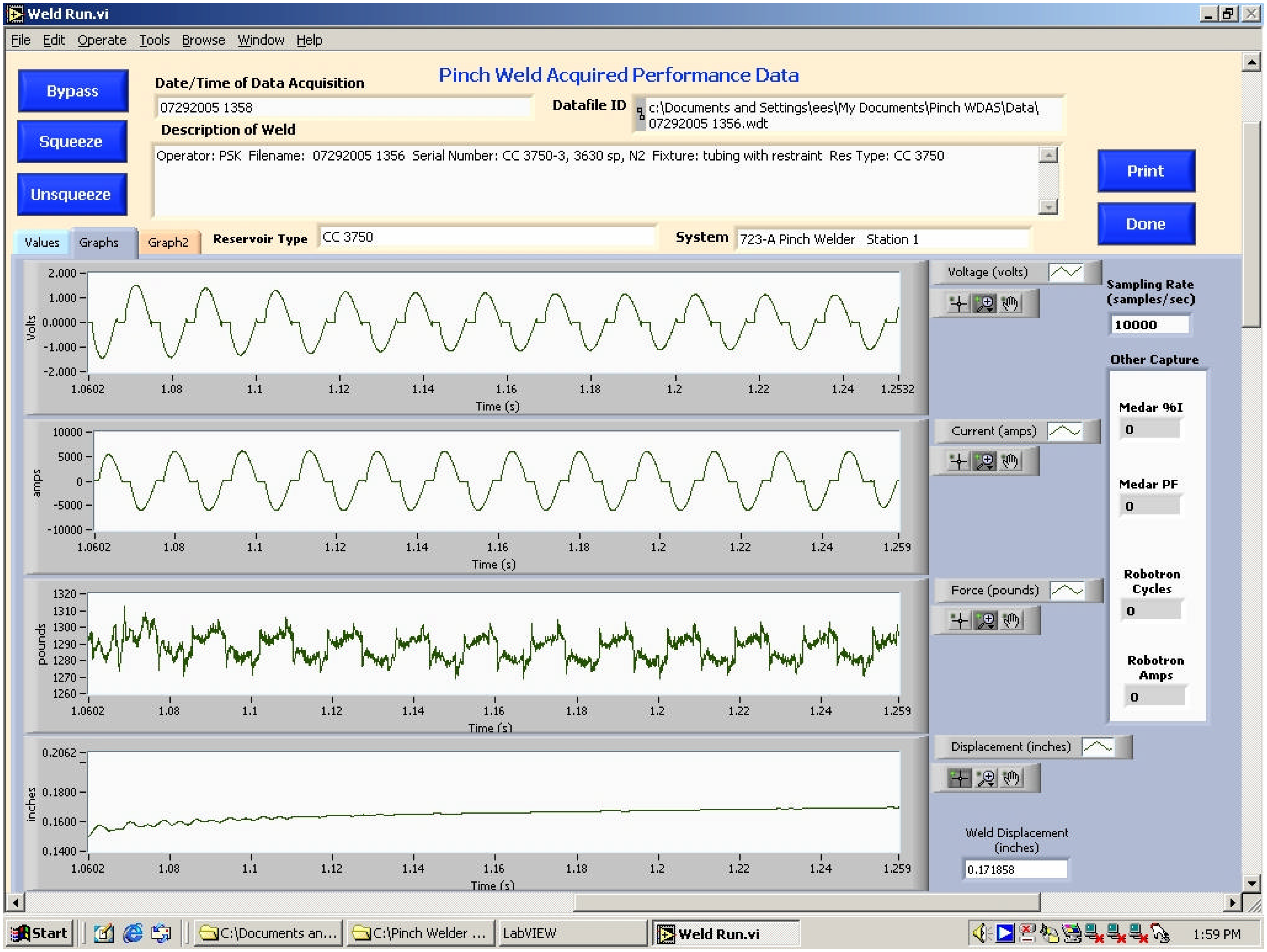


Figure 1(a) Typical data acquisition curves for a constant voltage control pinch weld



(b)

Figure 1. Typical data acquisition curves for (a) constant voltage and (b) constant current control pinch welds.

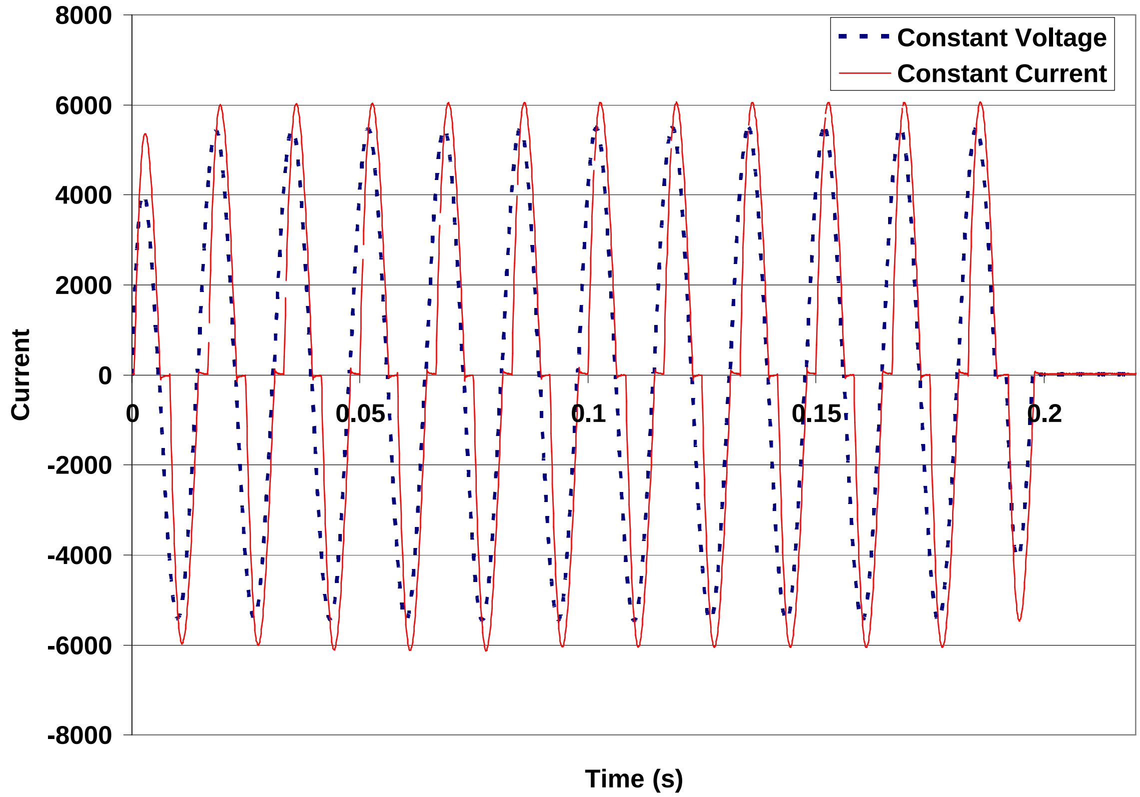
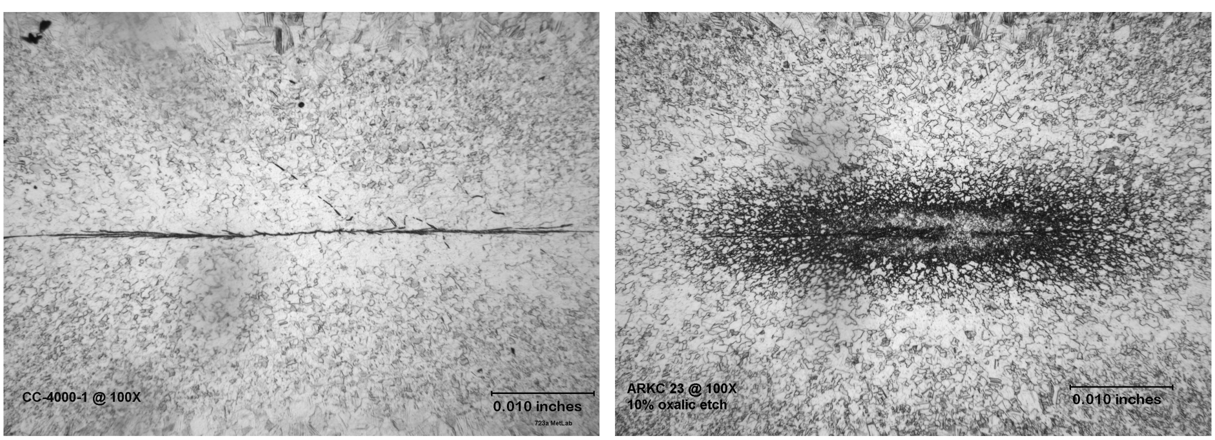


Figure 2. Overlay of current data for constant current and constant voltage control for the nominal 3750 A welds. Note that current is reported as RMS current not instantaneous current as shown in graph.



(a) (b)

Figure 3. Comparison of (a) constant current and (b) constant voltage micrograph after welding at nominally 4000 A. The weld heat delivered for constant current is apparently lower than for constant voltage based on presence of nugget despite exhibiting comparable calculated energy.

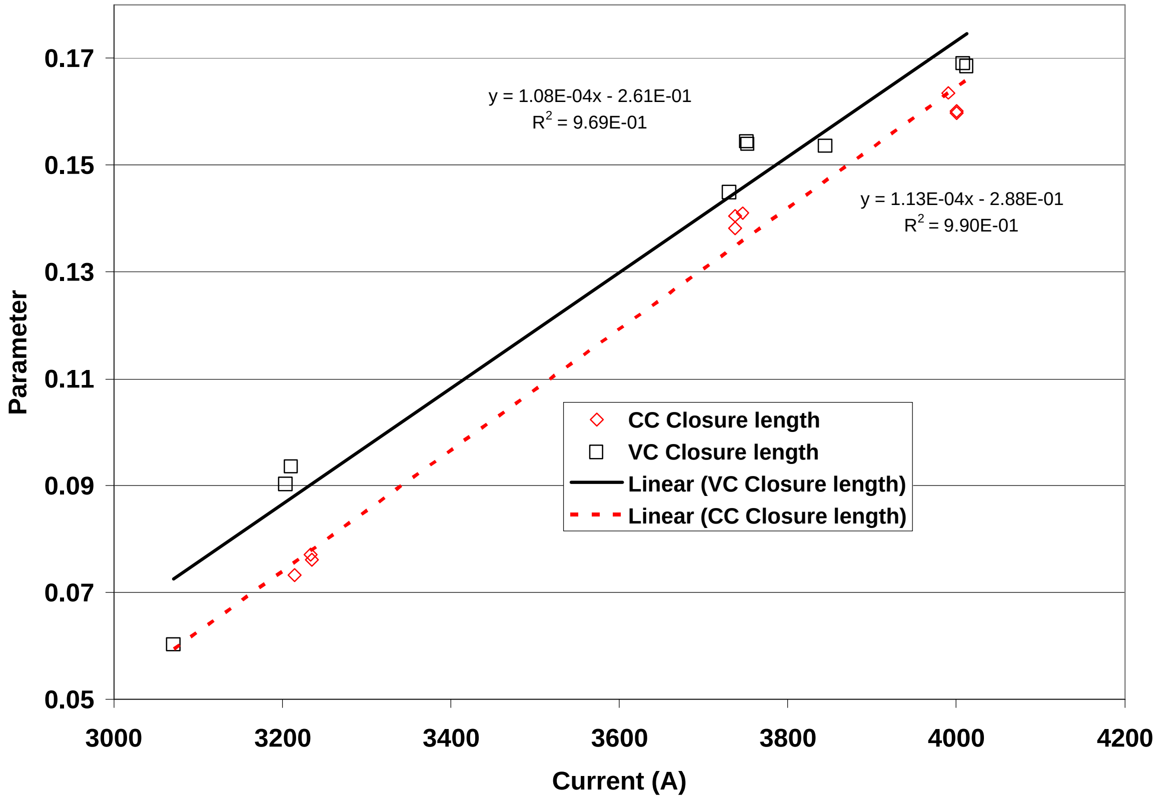


Figure 4. Comparison of closure length for current and voltage control.

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