Cold-Wire-Feed Submerged-Arc Welding of HSLA-100 Steel

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Presentation Summary

- INTRODUCTION
- COLD-WIRE FEED SAW
- CONCLUSIONS

Introduction

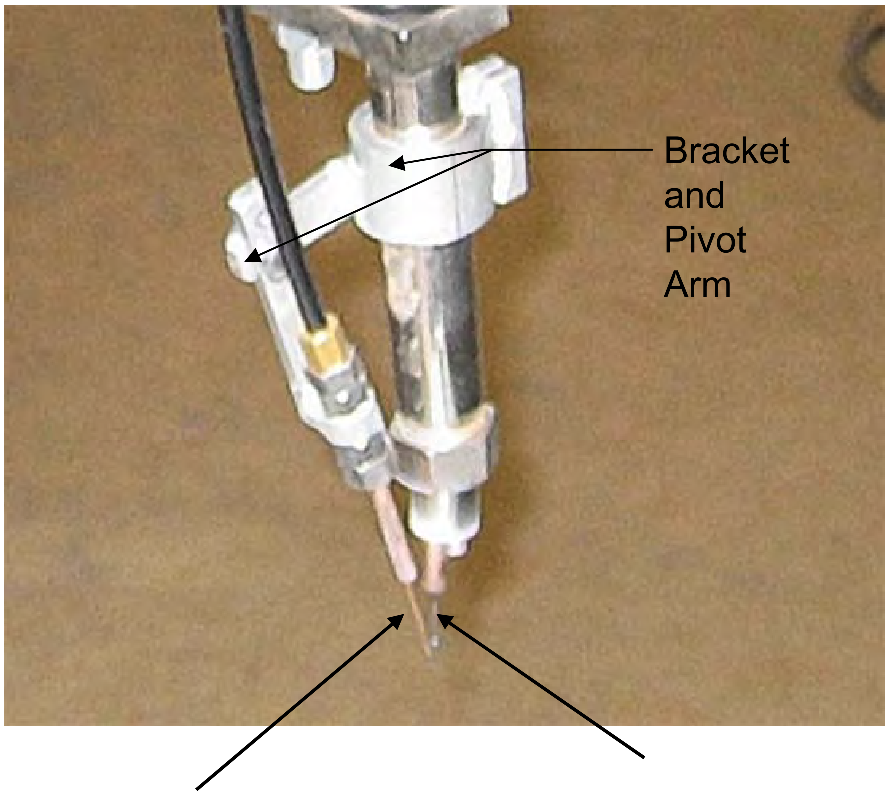
- To achieve the required strength and toughness in the weld metal of HSLA steels, maximum weld energy inputs must be observed which results in:
  - Reduced deposition rates
  - Many beads and layers of weld metal
- The large volume of weld metal needed to weld heavy sections results in reduced productivity and high fabrication cost

Introduction

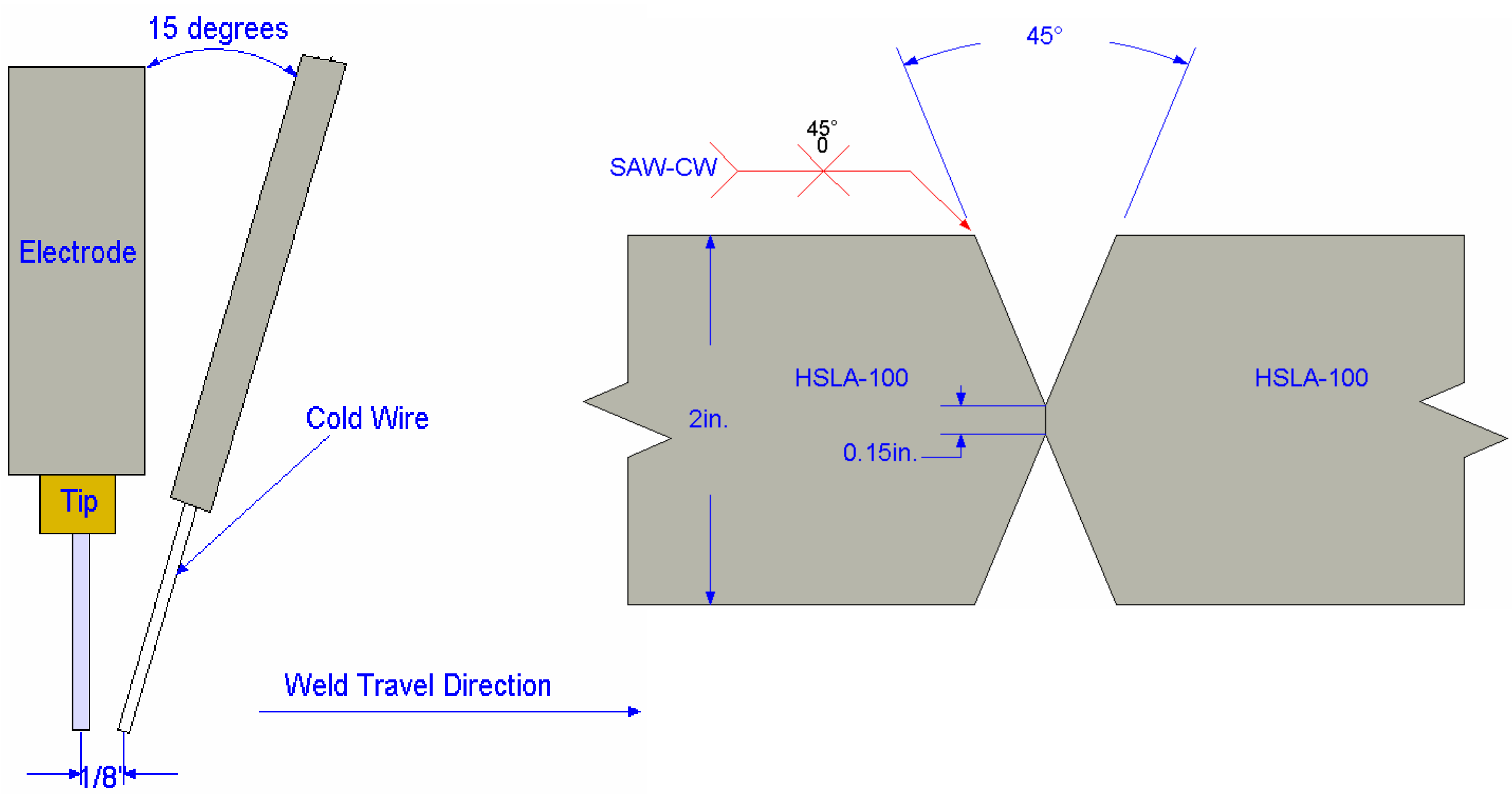
- The cold-wire feed submerged-arc-welding (SAW) process was used to deposit additional filler metal
- Weldments were made in two-inch-thick HSLA-100 steel with MIL-100S-1 electrodes and MIL-100S-1F flux

Cold-Wire Feed (CWF) SAW

- Adds a second cold wire to the single-wire SAW
- Current is fed to the electrode from a single power source.
- Cold wire speed is separate from electrode



CWF Torch and Joint Configuration for CTC-014/015



Heat Input Reduction Factor

Electrode volume per unit time

$$e_{vol} = d_e^2 \cdot e_{speed}$$

Cold-wire volume per unit time

$$cw_{vol} = d_{cw}^2 \cdot cw_{speed}$$

Reduction factor calculation (C_{f_mod})

$$C_{f\_mod} = \frac{e_{vol}}{\left(e_{vol} + cw_{vol}\right)}$$

CWF Welding Parameters CTC-014

Wire Size (in)		Current	Amps	Volts	Travel Speed (ipm)	Wire Speed (ipm)		Preheat/ Interpass Temp. (°F)
Electrode	Cold Wire					Electrode	Cold Wire	
0.0625	0.045	DCEP	400	35	10	293	90/160	175/275

Heat Input Electrode (kJ/in)	Reduction Factor		Effective Heat Input (kJ/in)		Deposition Rate (lb/hr)	
	Root Pass	Fill and Cap Passes	Root Pass	Fill and Cap Passe	Root Pass	Fill and Cap Passes
83.16	0.863	0.779	71.7	64.81	17.52	19.39

Percent Increase in Deposition Rates for CWF CTC-014

	Deposition Rate Single Electrode (lb/hr)	Deposition Rate Cold-Wire Process (lb/hr)	Percent Increase in Deposition Rate
Root Pass	15.1	17.5	15.9%
Fill Passes	15.1	19.4	28.5%

$$DepRate_{Dep} := \pi \cdot \left(\frac{d_e}{2}\right)^2 \cdot e_{speed} \cdot \rho \cdot E + \pi \cdot \left(\frac{d_{cw}}{2}\right)^2 \cdot cw_{speed} \cdot \rho \cdot E$$

CWF Welding Parameters CTC-015

Wire Size (in)		Current	Amps	Volts	Travel Speed (ipm)	Wire Speed (ipm)		Preheat/ Interpass Temp. (°F)
Electrode	Cold Wire					Electrode	Cold Wire	
0.0625	0.045	DCEP	400	35	10	293	160/240	175/275

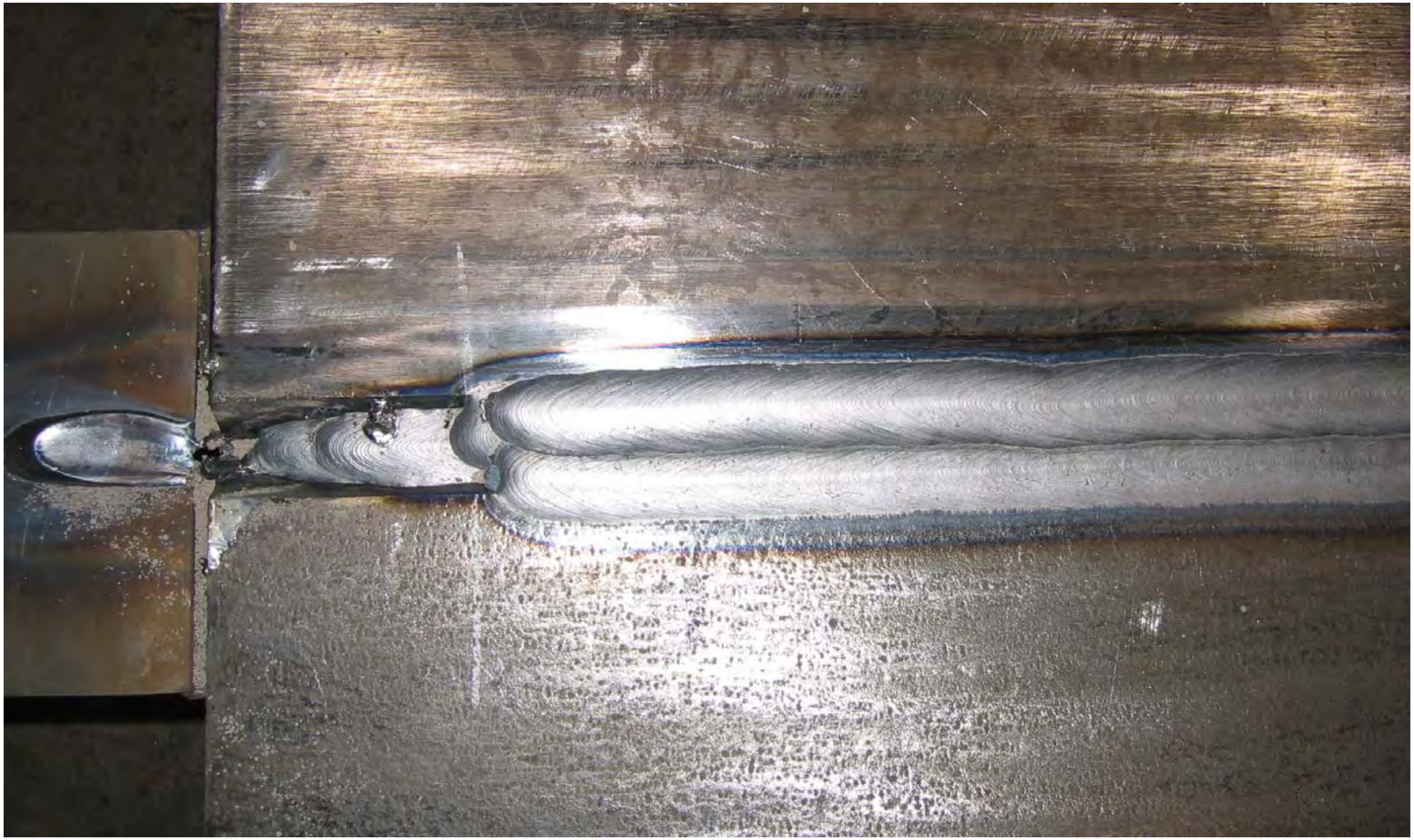
Heat Input Electrode (kJ/in)	Reduction Factor		Effective Heat Input (kJ/in)		Deposition Rate (lb/hr)	
	Root Pass	Fill and Cap Passes	Root Pass	Fill and Cap Passe	Root Pass	Fill and Cap Passes
83.16	0.779	0.702	64.81	58.37	19.39	21.53

Percent Increase in Deposition Rates for CWF CTC-015

	Deposition Rate Single Electrode	Deposition Rate Cold-Wire	Percent Increase in Deposition
Root Pass	15.1	19.4	28.5%
Fill Passes	15.1	21.5	42.5%

$$DepRate_{Dep} := \pi \cdot \left(\frac{d_{e}}{2}\right)^{2} \cdot e_{speed} \cdot \rho \cdot E + \pi \cdot \left(\frac{d_{cw}}{2}\right)^{2} \cdot cw_{speed} \cdot \rho \cdot E$$

Weld Mock-Up of SAW CWF



All Weld Metal Tensile Properties of CTC-014/015

Specimen Identification	Ultimate Tensile Strength (ksi)	0.2% Offset Yield Strength (ksi)	Elongation in 2 inches (%)	Reduction of Area (%)
TS1-14	117.5	106.5	24.5	69.7
TS2-14	112.6	101.8	24	69.4
TS3-14	108.6	98.8	23.5	68.1
TS4-14	107.6	97.8	24.5	70.6
Mean	**111.6**	**101.2**	**24.1**	**69.5**
TS1-15	110.1	102.5	14	41.9
TS2-15	111.7	101.3	24	70.3
TS3-15	108.9	98.5	11.5	33
TS4-15	114.2	102.6	24	69.1
Mean	**111.2**	**101.2**	**18.4**	**53.6**

CVN Test Results
CTC-014 / 015

Specimen Identification	Test Temperature (°F)	Absorbed Energy (ft-lbs)
CV1-14	0	104
CV2-14	0	106
CV3-14	0	124
CV9-14	0	116
CV10-14	0	130
Mean at 0 °F		**116**
CV4-14	–60	58
CV5-14	–60	48
CV6-14	–60	45
CV7-14	–60	61
CV8-14	–60	41
Mean at –60 °F		**50.6**

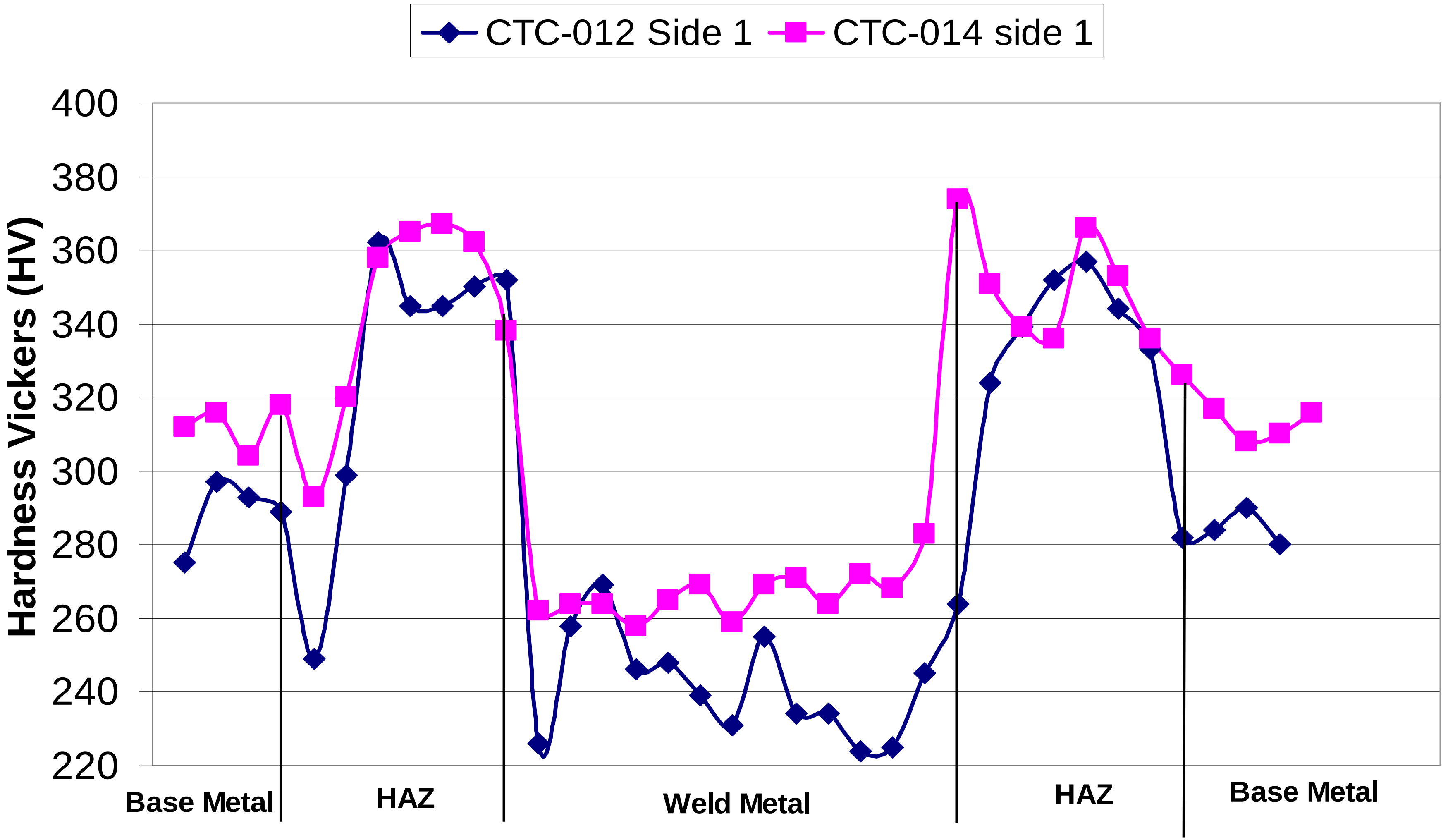
Specimen Identification	Test Temperature (°F)	Absorbed Energy (ft-lbs)
CV1-15	0	128
CV2-15	0	130
CV3-15	0	134
CV9-15	0	120
CV10-15	0	124
Mean at 0 °F		**127.2**
CV4-15	–60	41
CV5-15	–60	52
CV6-15	–60	54
CV7-15	–60	45
CV8-15	–60	42
Mean at –60 °F		**46.8**

Dynamic Tear Test Results For CTC-014/015

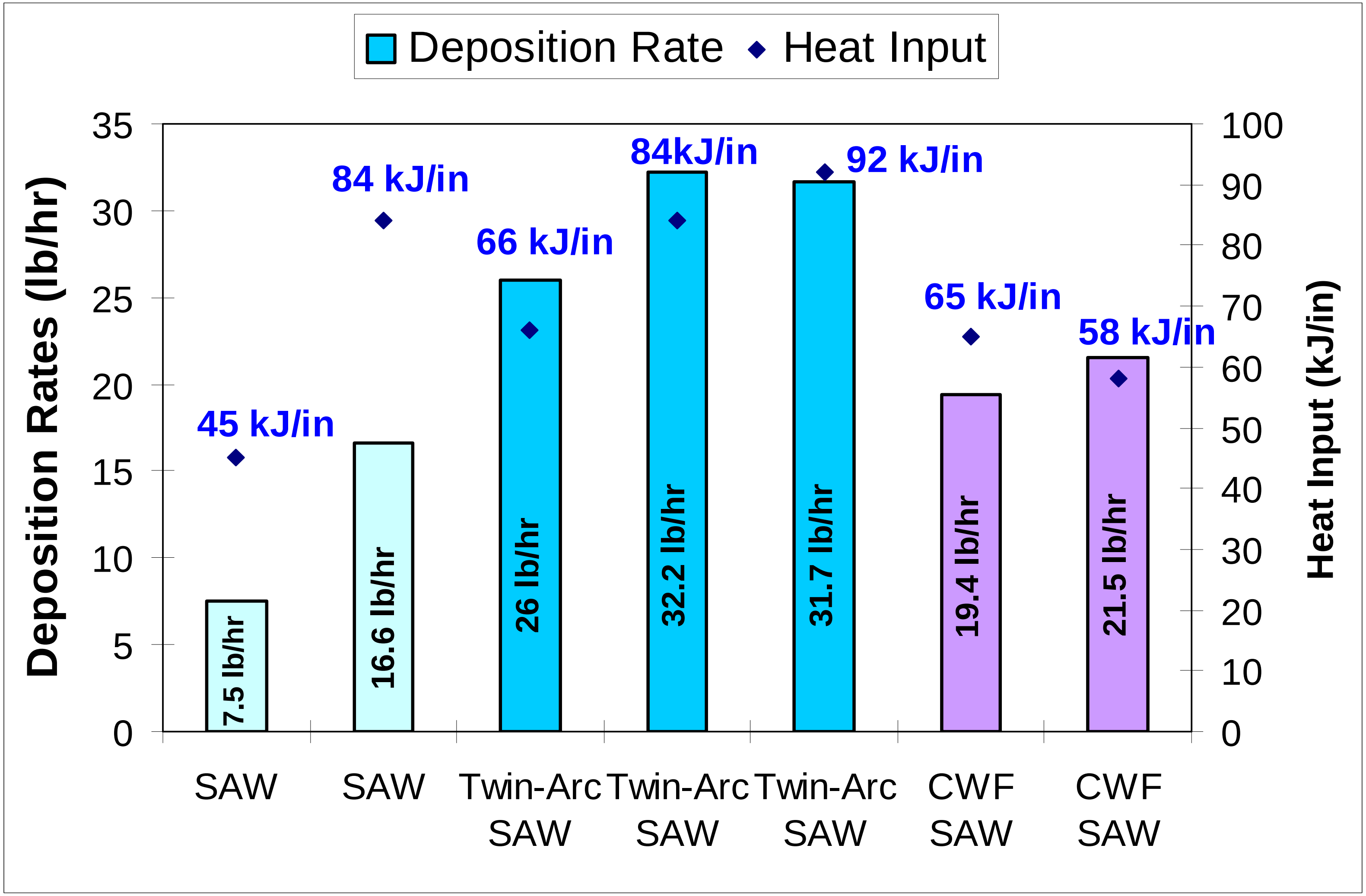
Specimen Identification	Test Temperature (°F)	DT Energy (ft-lb)
DT1-14	30	1283
DT2-14	30	1403
DT5-14	30	1261
DT6-14	30	1357
Mean at 30 °F		**1326**
DT3-14	–20	917
DT4-14	–20	670
DT7-14	–20	1175
DT8-14	–20	1474
Mean at –20 °F		**1060**

Specimen Identification	Test Temperature (°F)	DT Energy (ft-lb)
DT1-15	30	1365
DT2-15	30	1233
DT5-15	30	1194
DT6-15	30	1157
Mean at 30 °F		**1238**
DT3-15	–20	777
DT4-15	–20	1189
DT7-15	–20	1094
DT8-15	–20	990
Mean at –20 °F		**1013**

Hardness Profile of CTC-012 vs. CTC-014



Deposition Rate Trends



Conclusions

- The Cold-wire feed SAW process is a viable candidate for improved productivity in fabricating heavy-section weldments
- Weldments made with the cold-wire SAW process showed excellent mechanical properties while increasing deposition rates and lowering effective heat input
- Based on the mechanical properties, increase in deposition rates and ease of use, the cold-wire SAW process appears to be an excellent candidate to improved welding productivity