
# High Heat Input/Reduced Preheat Welding of HSLA-100

## Provo, Utah
## April 4-5, 2006

# High Heat Input/Reduced Preheat Welding of HSLA-100

## Objectives

- Evaluate feasibility of welding thick HSLA-100 using 60°F preheat and high heat inputs
- Demonstrate that higher heat input can be used to compensate for low preheat
- Establish criteria for extending thickness for SAW and GMAW-P above current limits using 60°F preheat

## Expected Benefits

Lower ship construction costs through:

- Lower energy costs
- Lower labor costs for heater bar installation
- Higher welder productivity
- Positive impact on weld quality
- Less re-work

# Project Phases

- Phase I – Literature search
- Phase II – Gapped Bead on Plate Testing
- Phase III – Full scale weldments
  - GMAW-P and SAW weldments on 2”, 3”, and 4” thick HSLA-100 with 60°F preheat/interpass
  - Evaluating NDT results, mechanical properties, and evidence of hydrogen cracking (macro specimens, fracture surfaces of tensiles)

# Phase 1: Literature Review

Objective: Determine extent of prior testing and its possible contribution to the evaluation. Specifically, testing with high strength steels and the Gapped Bead on Plate weldability test.

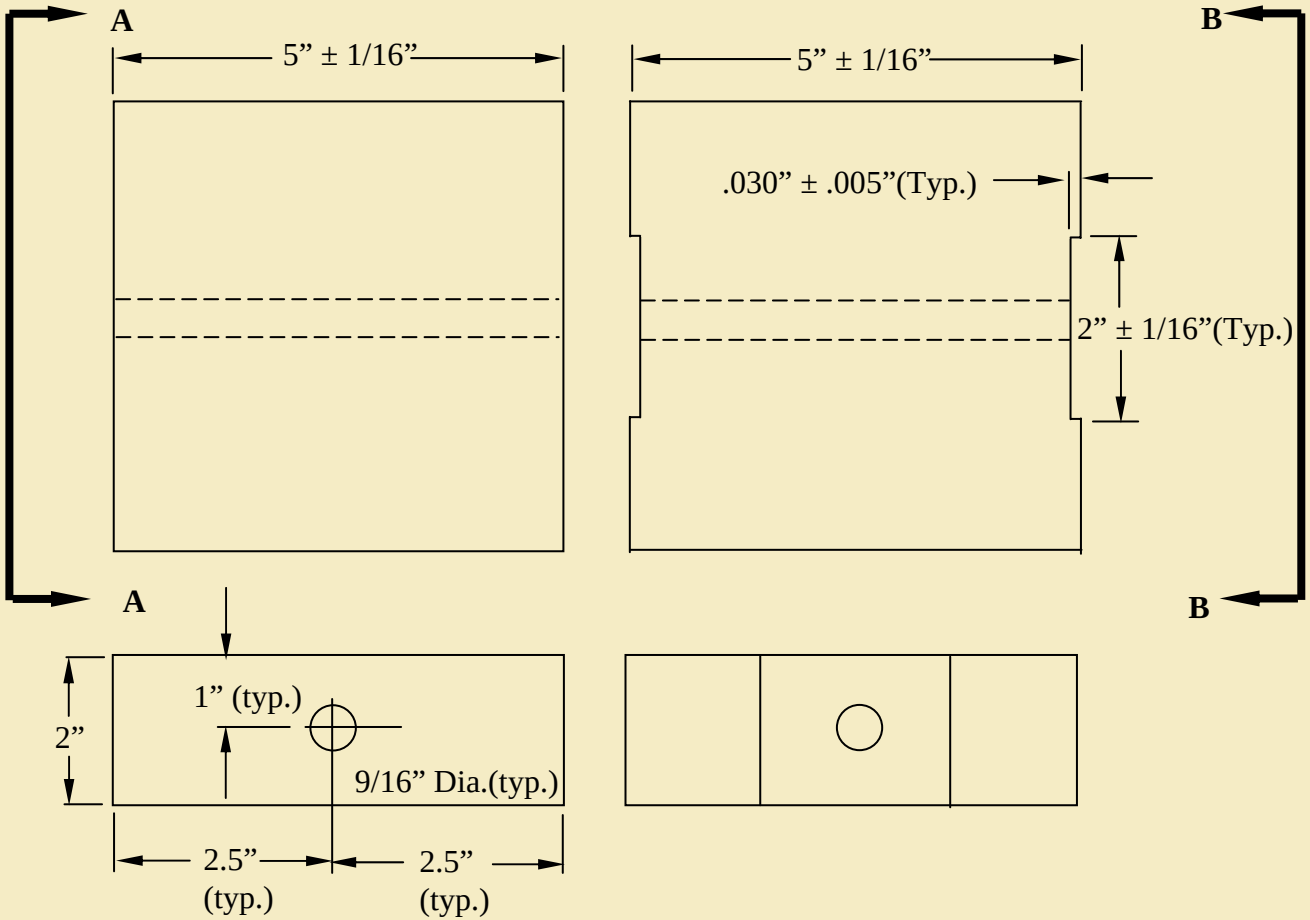
- Hydrogen cracking has been approached from many different directions.
- Due to the many factors affecting cracking, most procedural recommendations are understandably conditional and conservative.
- Most closely related work done by Dr. Adonyi at LeTourneau University.
- In general, the literature supports the concept of using high heat input to compensate for reduced preheat.

# Phase 2: G-BOP Testing

Objective: Evaluate cracking susceptibility of SAW and GMAW-P at various heat inputs using the Gapped Bead on Plate Test

- Will increasing heat input result in decreasing cracking?
- What is a workable heat input for the root pass?

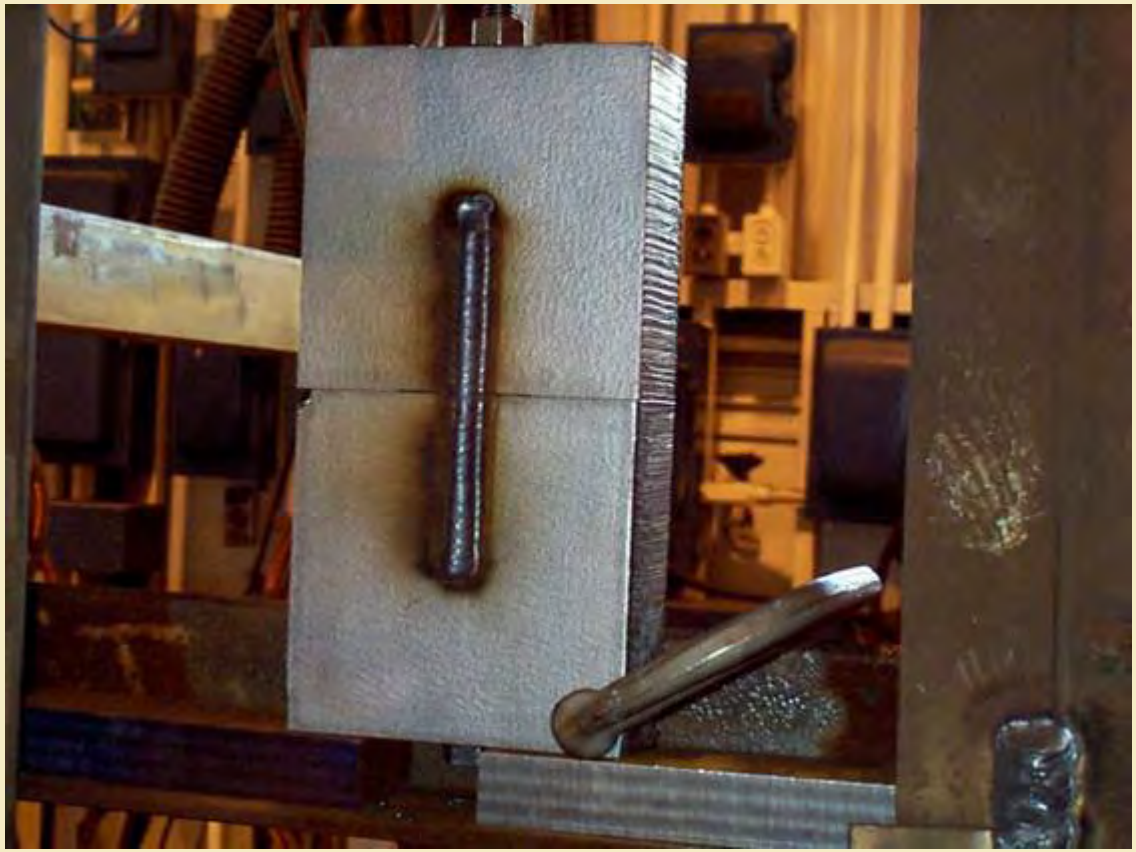
# Gapped Bead on Plate Test Dimensions




Section **A-A**

Section **B-B**

# G-BOP Testing



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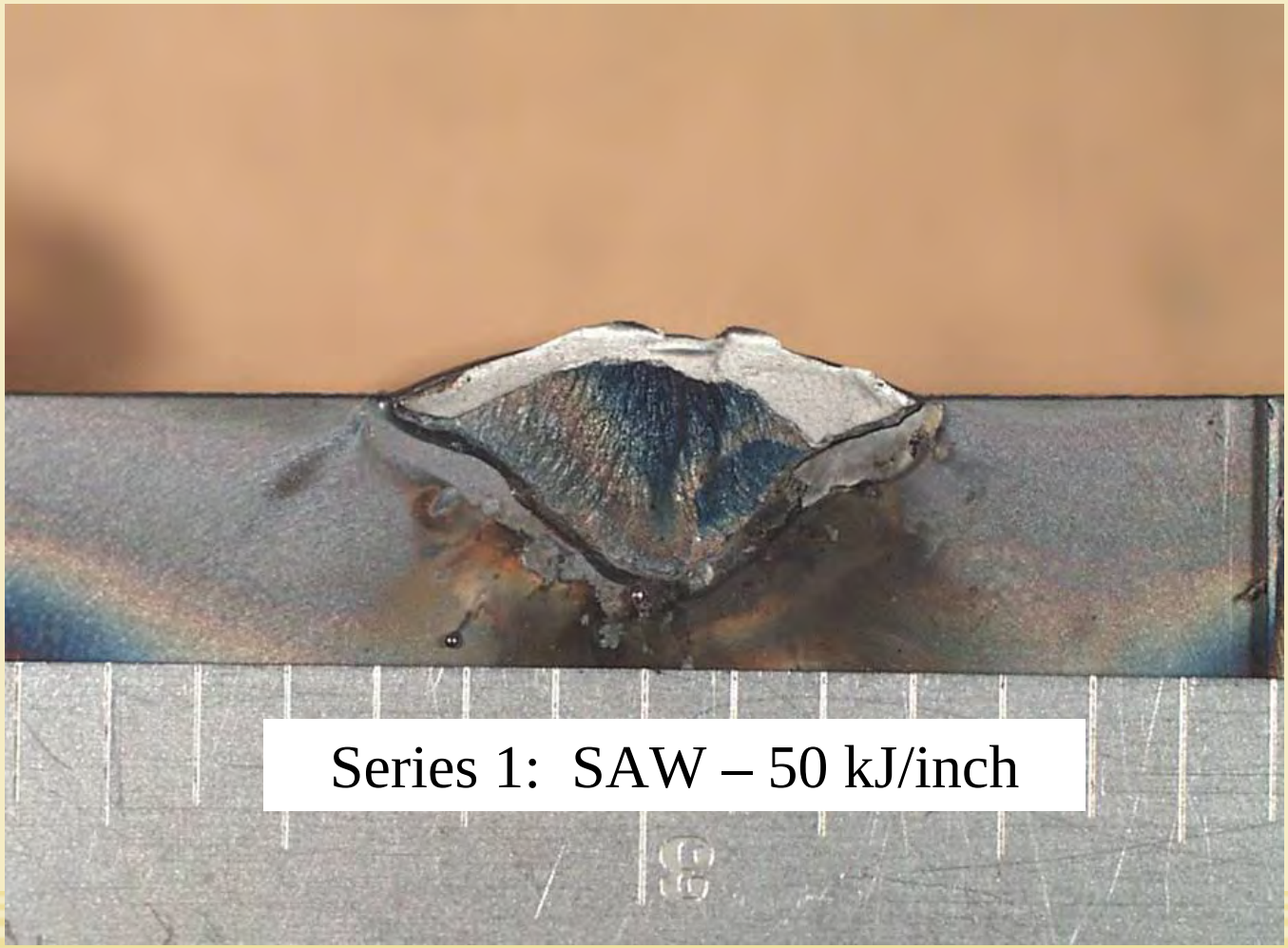

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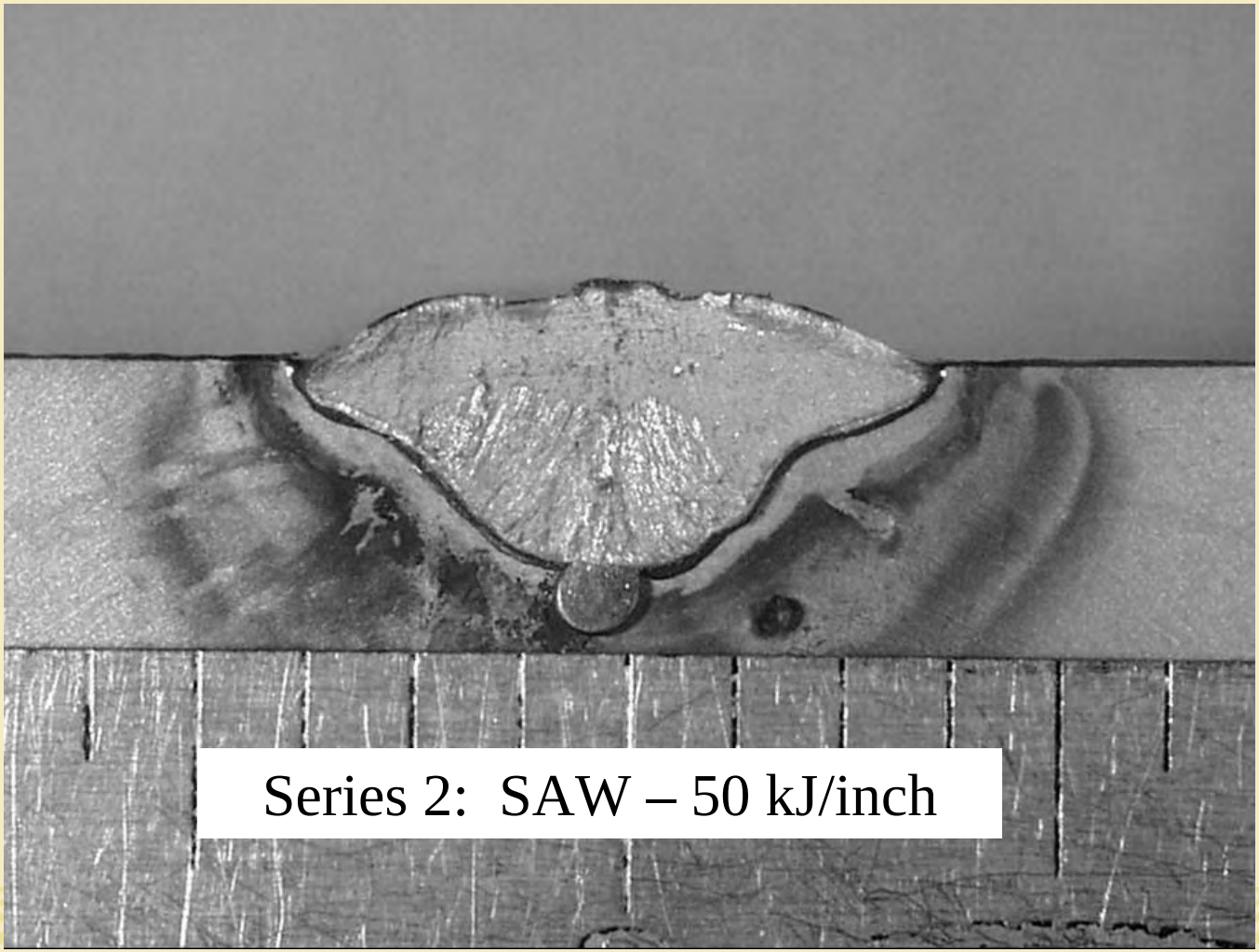
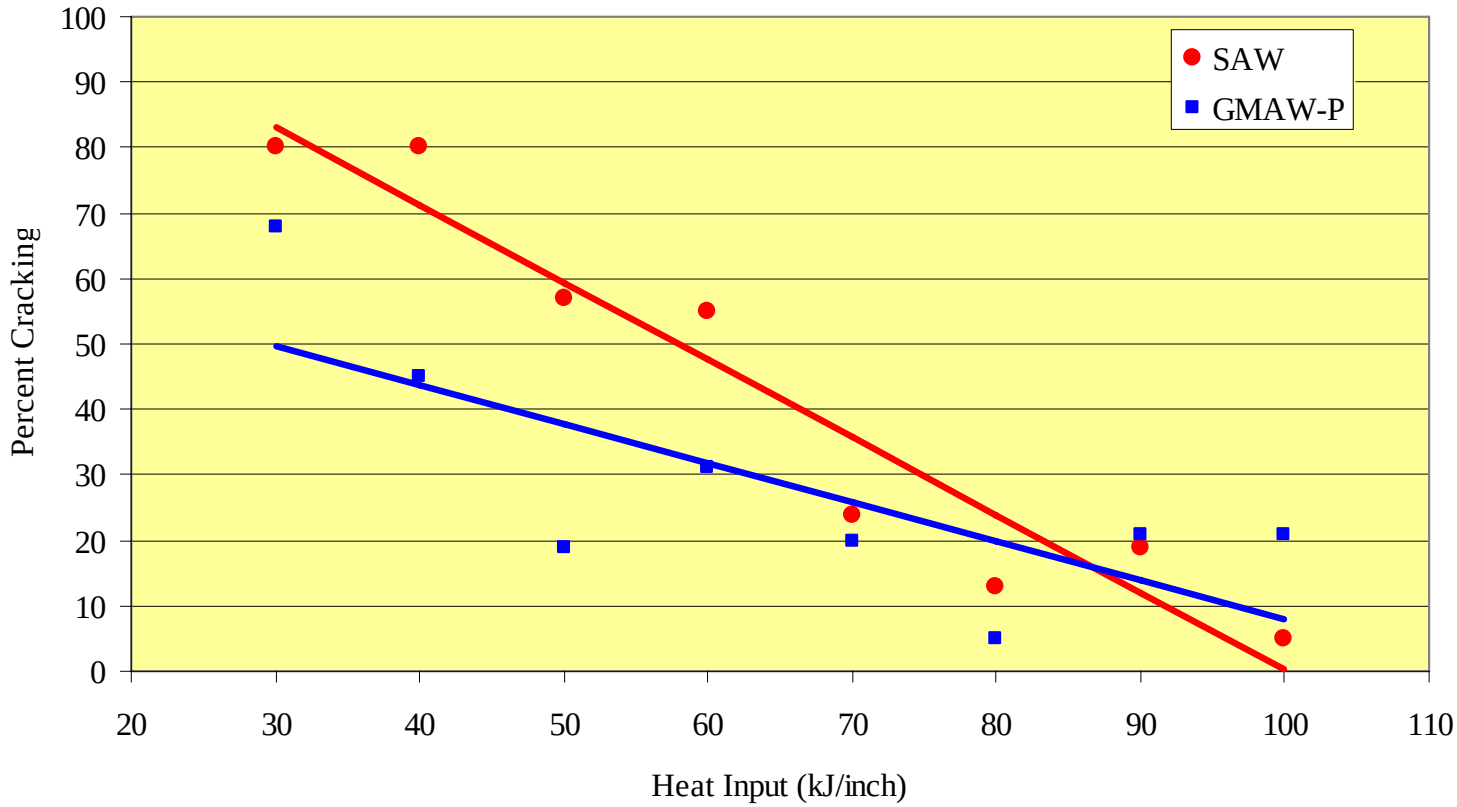


# G-BOP Testing

**Figure 8: G-BOP Test Results**



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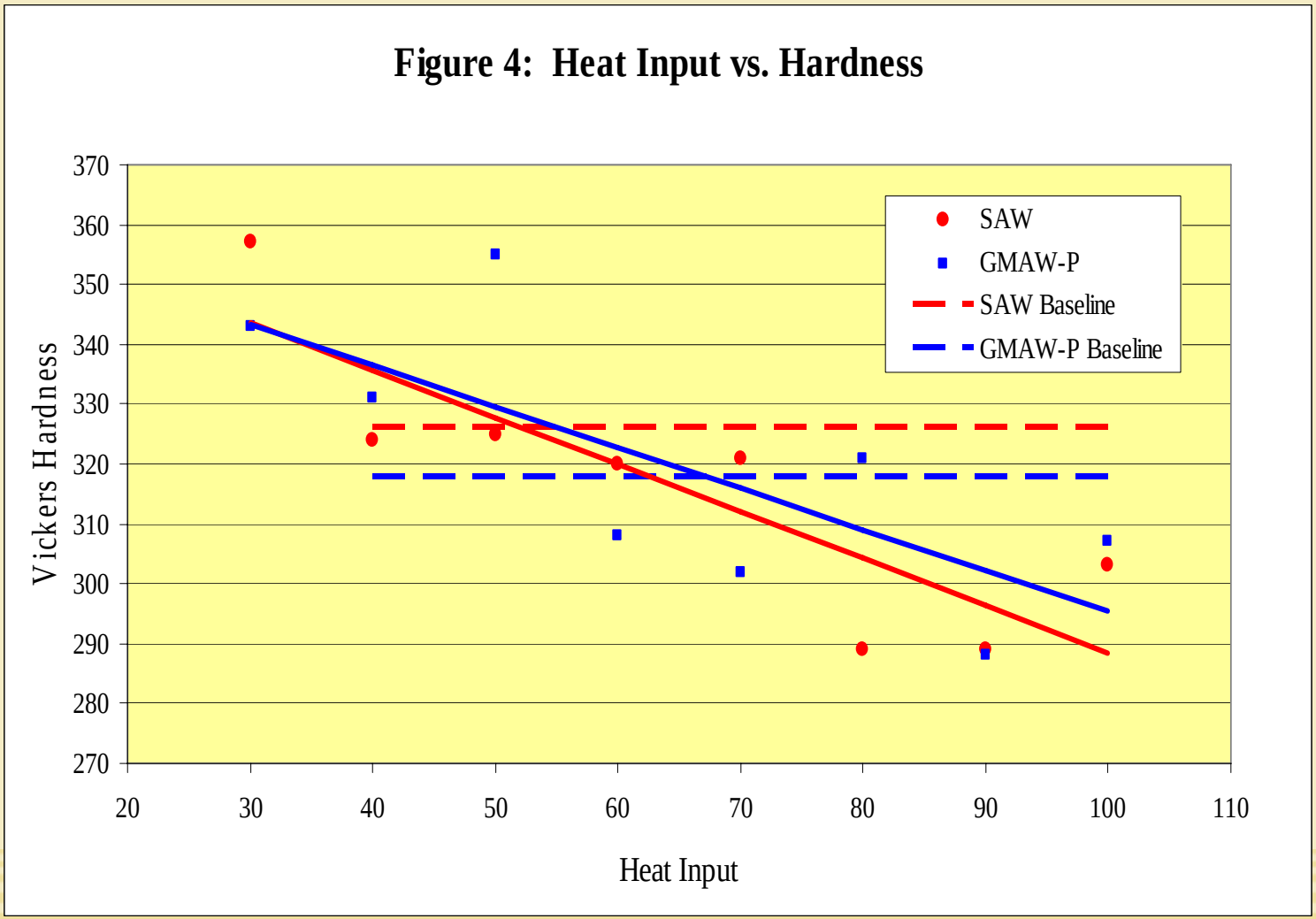


# Phase 3:

Objective: Evaluate cracking susceptibility on full scale weldments

- Two wire SAW and GMAW-P weldments on 2” thick HSLA-100
- NDT:
  - Root VT and MT (including MT prior to arc gouging)
  - Final VT, MT, RT, UT, TCC-7
- Destructive Testing:
  - 2 All Weld Metal Tensiles
  - 5 Weld CVNs @ 0°F and 5 Weld CVNs @ -60°F
  - Transverse and Longitudinal macros of weld and fusion line

If successful, 3” and 4” weldments will be evaluated.

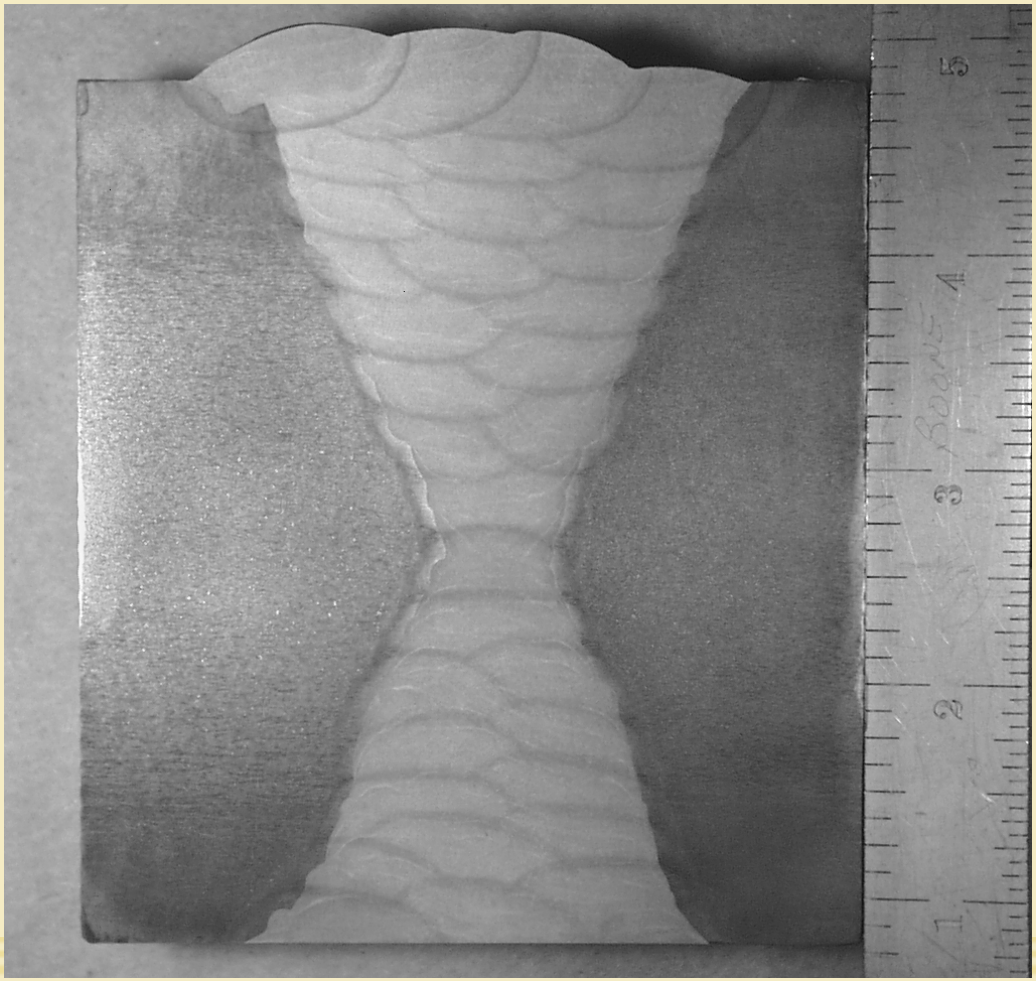
# Full Scale Weldments
# NDT Results for GMAW-P

| | Root & Final MT | RT | UT | Enhanced UT |
|---|---|---|---|---|
| 2” GMAW-P | ✓ | ✓ | ✓ | ✓ |
| 3” GMAW-P | ✓ | ✓ | ✓ | ✓ |
| 4” GMAW-P | ✓ | ✓ | ✓ | ✓ |

# Full Scale Weldments Mechanical Test Results

| | Yield Strength (ksi) | Elongation (%) | CVN @ 0°F (ft-lbs) | CVN @ -60°F (ft-lbs) |
|---|---|---|---|---|
| 2” GMAW-P | 103 | 23 | 132 | 58 |
| 3” GMAW-P | 102 | 24 | 130 | 113 |
| 4” GMAW-P | 107 | 24 | 103 | 73 |
| Specification Requirement | 88 min. | 16 min | 60 | 35 |

# 4” Thick GMAW-P Weld Transverse Macro



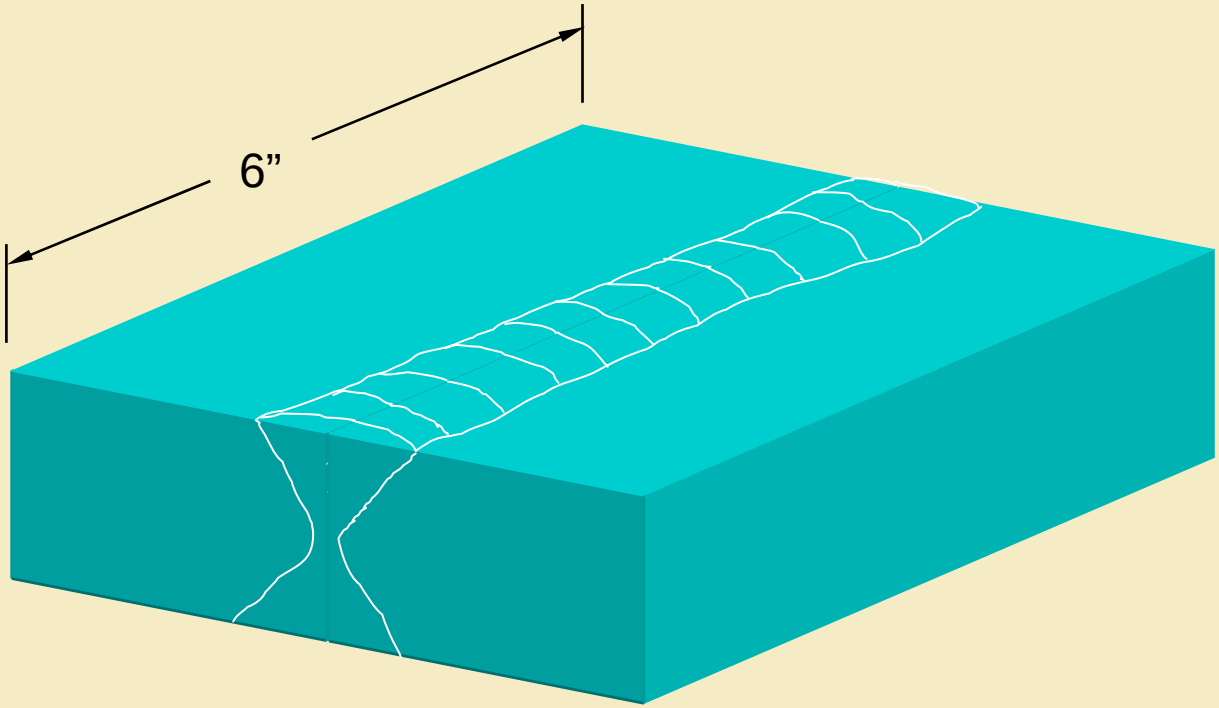
# Full Scale Weldments
# NDT Results

| | Root & Final MT | RT | UT | Enhanced UT |
|---|---|---|---|---|
| 2” SAW | ✓ | ✓ | ✓ | ✗ |
| 2” SAW (Revised parameters) | ✓ | ✓ | ✗ | ✓ |
| 3” SAW | ✓ | -- | ✗ | ✓ |

# Full Scale Weldments Mechanical Test Results

| | Yield Strength (ksi) | Elongation (%) | CVN @ 0°F (ft-lbs) | CVN @ -60°F (ft-lbs) |
|---|---|---|---|---|
| 2” SAW | 107 | 24 | 103 | 73 |
| 2” SAW (Revised Parameters) | 107 | 23 | 117 | 78 |
| Specification Requirement | 88 min. | 16 min | 60 | 35 |

# Macro Test Results



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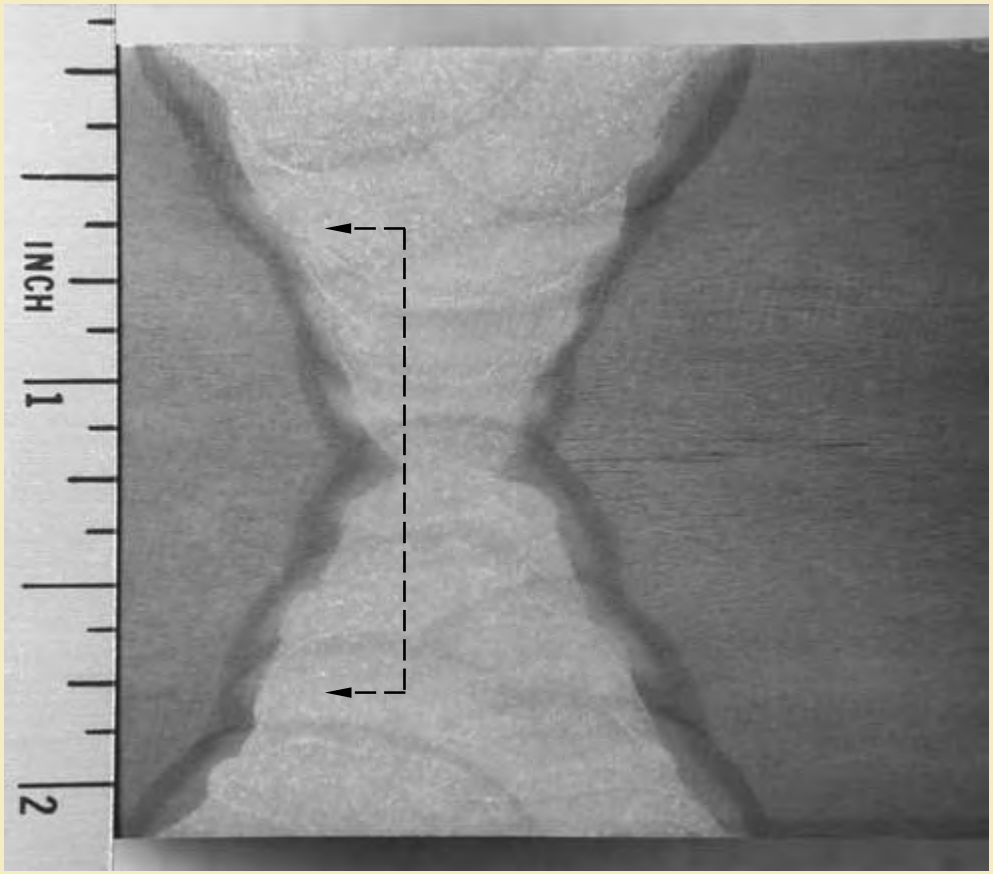
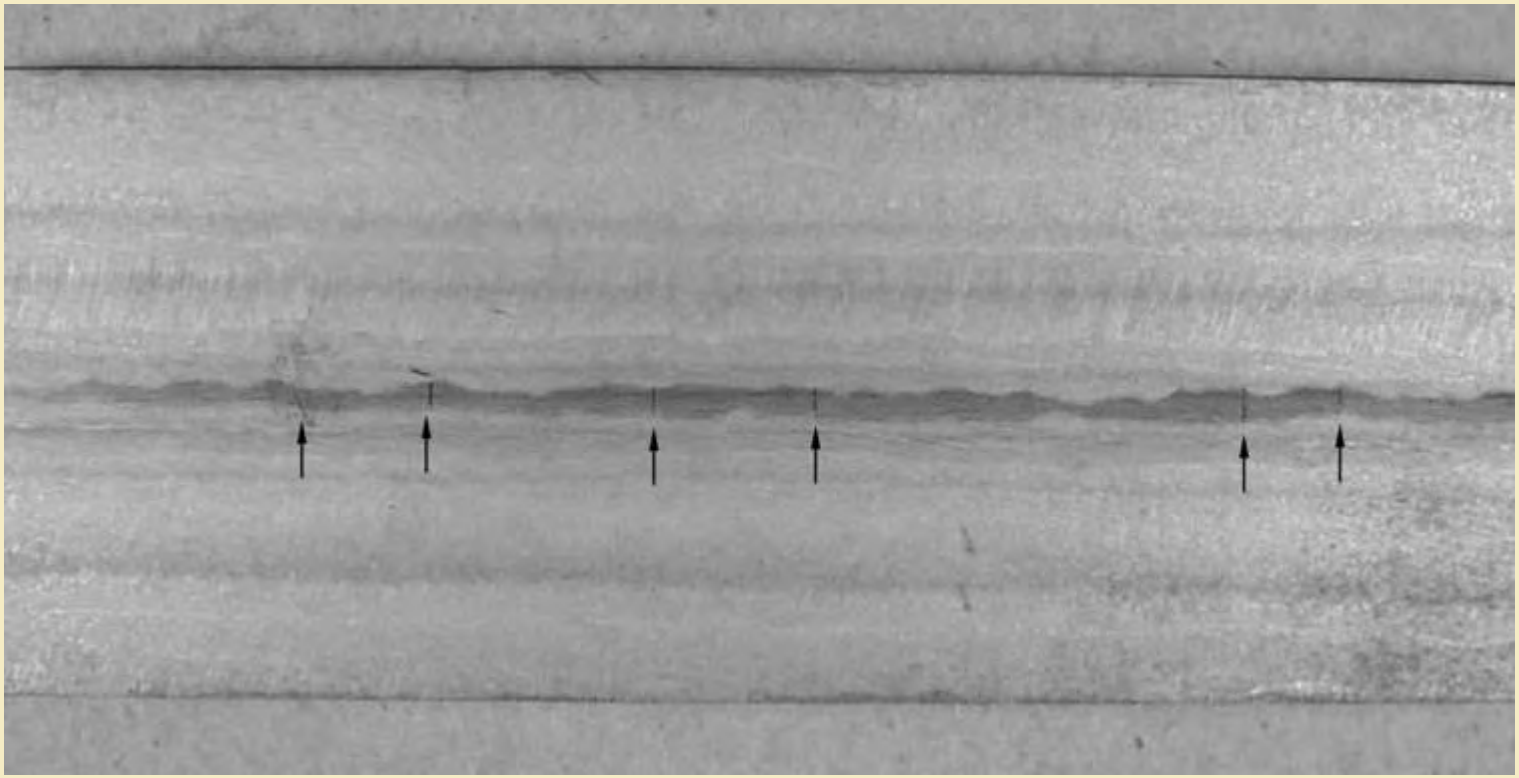


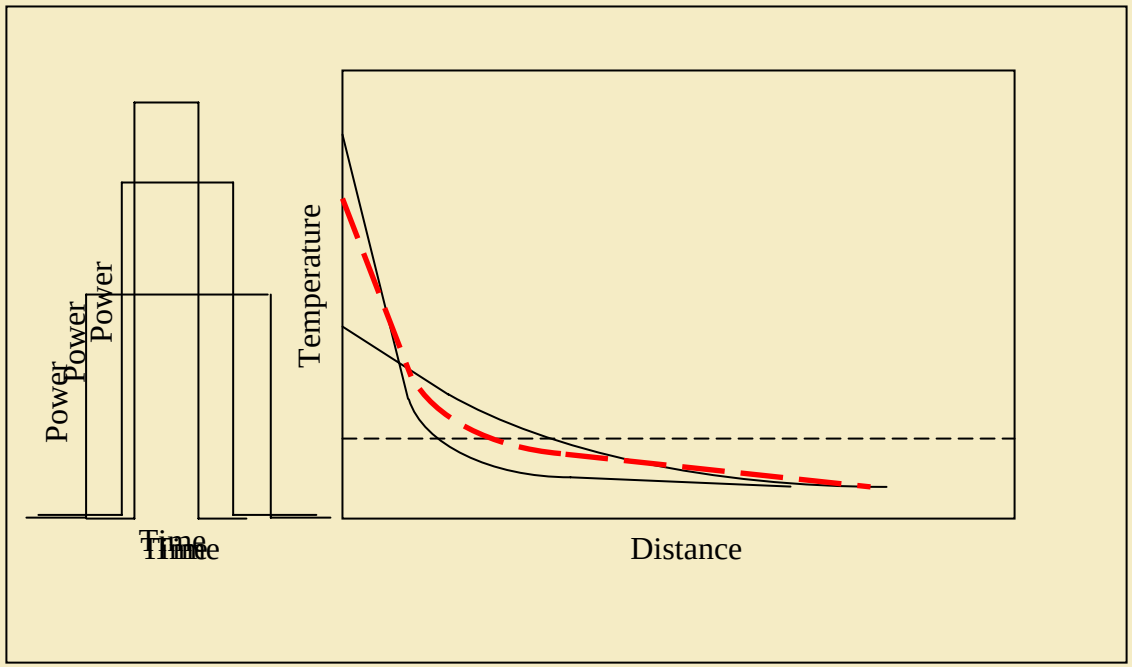
# Macro Test Results

Initial 2” Thick SAW Weldment



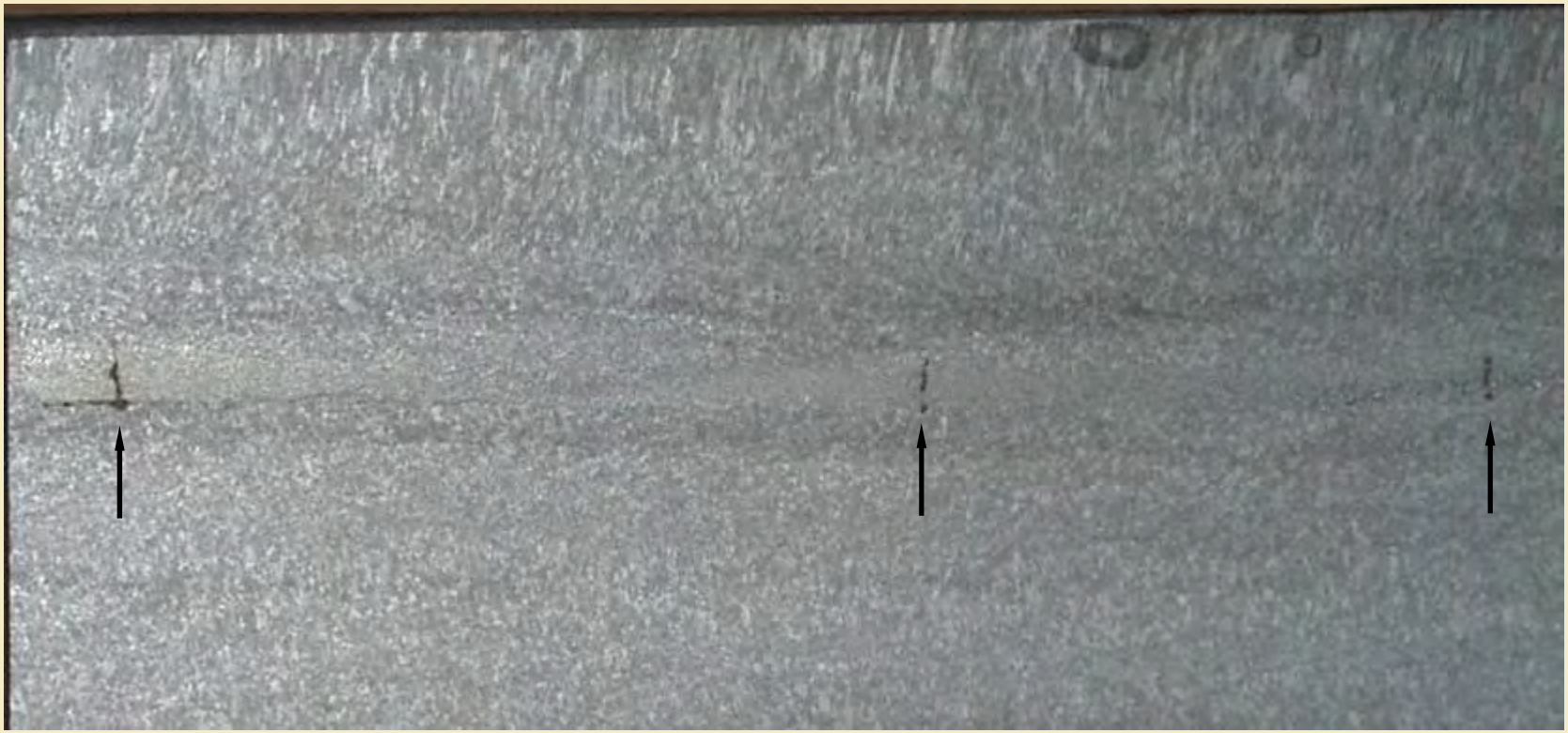
# Resistance Weld Setup

## 6450 amps, 22 volts, 18 ipm travel speed



# Macro Test Results

2” Thick SAW Weld with Revised Parameters

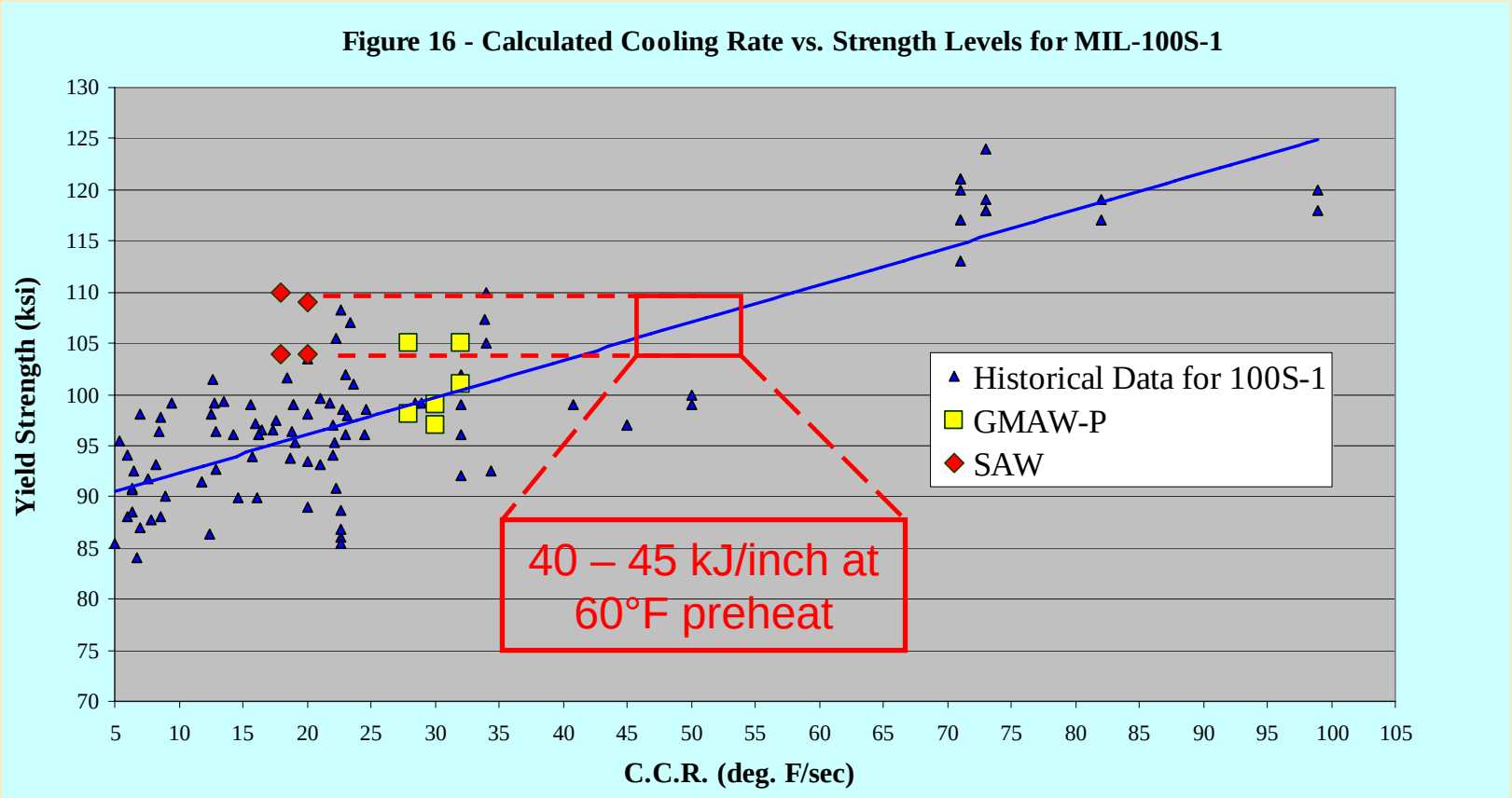


# Macro Test Results

# Summary of Macro Test Results

- Macro results satisfactory on 2”, 3” and 4” GMAW-P weldments
- Longitudinal macro on both 2” SAW weldments revealed base metal HAZ cracking in the root area.
- Cracks were transverse to the weld which is typical of hydrogen cracking

# Full Scale Weldments Mechanical Test Results

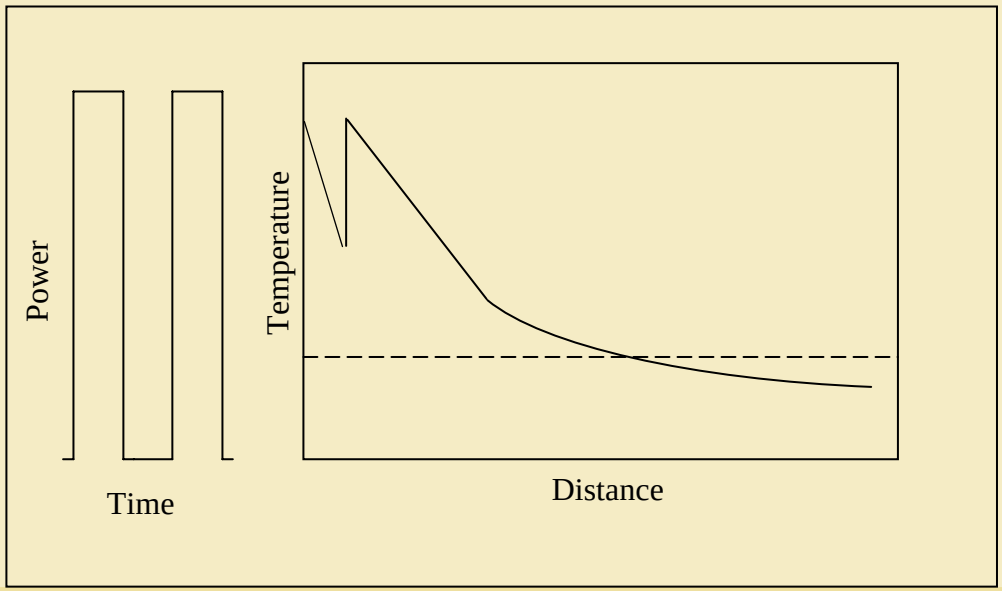


# Results to Date

- High heat input SAW (single or twin wire) not feasible with 60°F preheat.
- GMAW-P feasible up to 4” thick with 60°F.
- “Green labor” issues with GMAW-P
  - Increased training costs
  - Higher UT reject rates

# Future Work

- Investigate tandem arc SAW
  - Two separately powered arcs as much as 5” apart.
  - Initial arc would act as a “preheating” arc resulting in a flatter cooling curve



# Future Work

- Investigate FCAW
  - Parameters very similar to GMAW-P
  - Should give similar cooling curve
  - Mechanical property issues?

# Questions?