TITANIUM PIPE JOINING STUDIES AT ARGONNE USING A COMMERCIAL SWAGELOK ORBITAL WELDER

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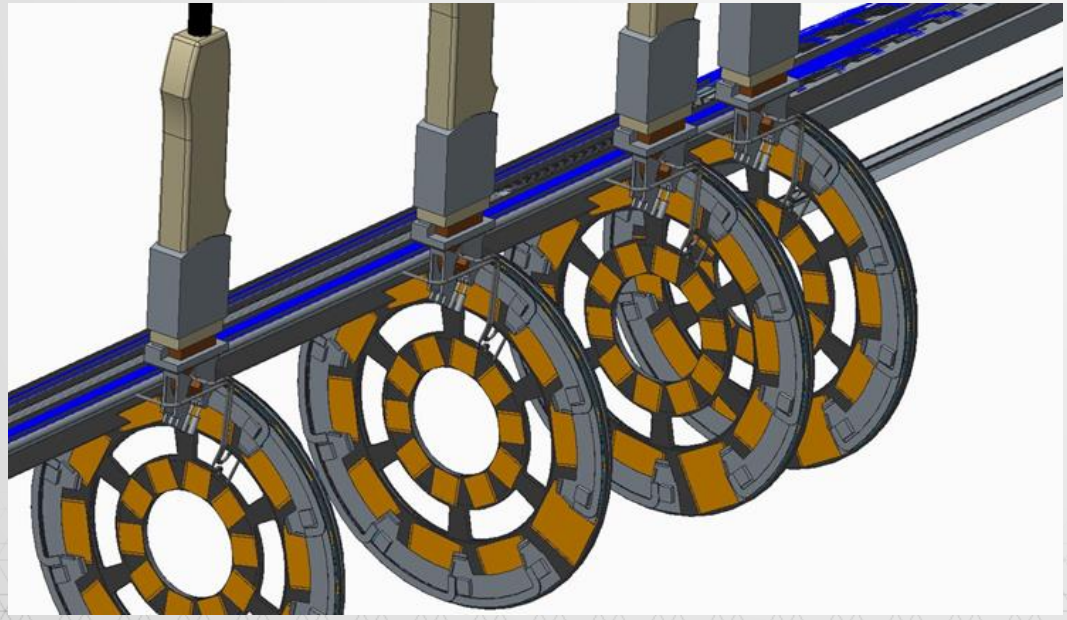
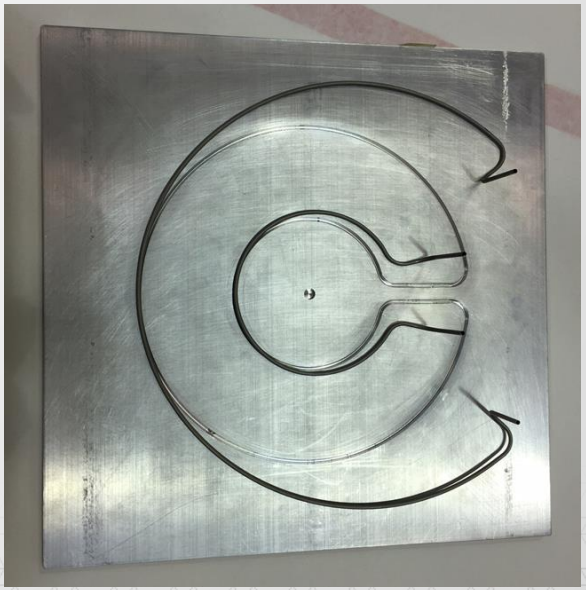
OUTLINE

- Background and Motivation
- Swagelok orbital welding system setup
- Sleeve design and tube preparation
- Weld setup
- Weld Inspection
- Future work
- Summary

BACKGROUND

- Argonne is responsible for the evaporators and manifolds for the inner system.
- As part of these, we are responsible for the connections of the tubes and electrical breaks.

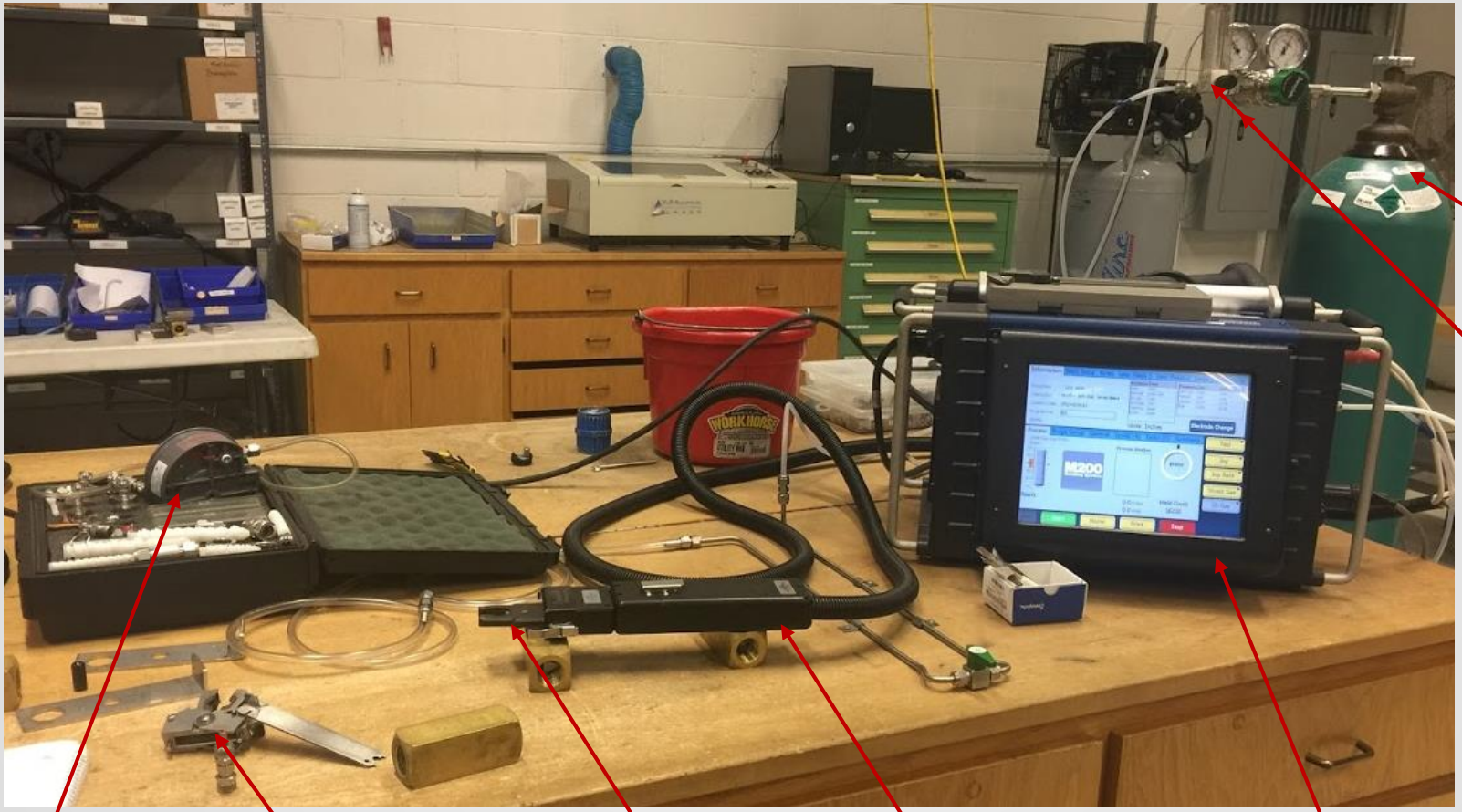




WELD MOTIVATION

- We want to weld titanium tubes with OD 2.5mm/ID 2.2mm using commercial available welding system.
- Swagelok orbital welding system is inexpensive and capable to weld tube down to 3mm tubes of varieties of materials, but it is hard to weld thin wall tube with thickness of 200 um or less reliably.
- Add a sleeve on top of tubes to increase material around weld area.
- Sleeve also enable better tube alignment

SWAGELOK ORBITAL WELDING SYSTEM SETUP

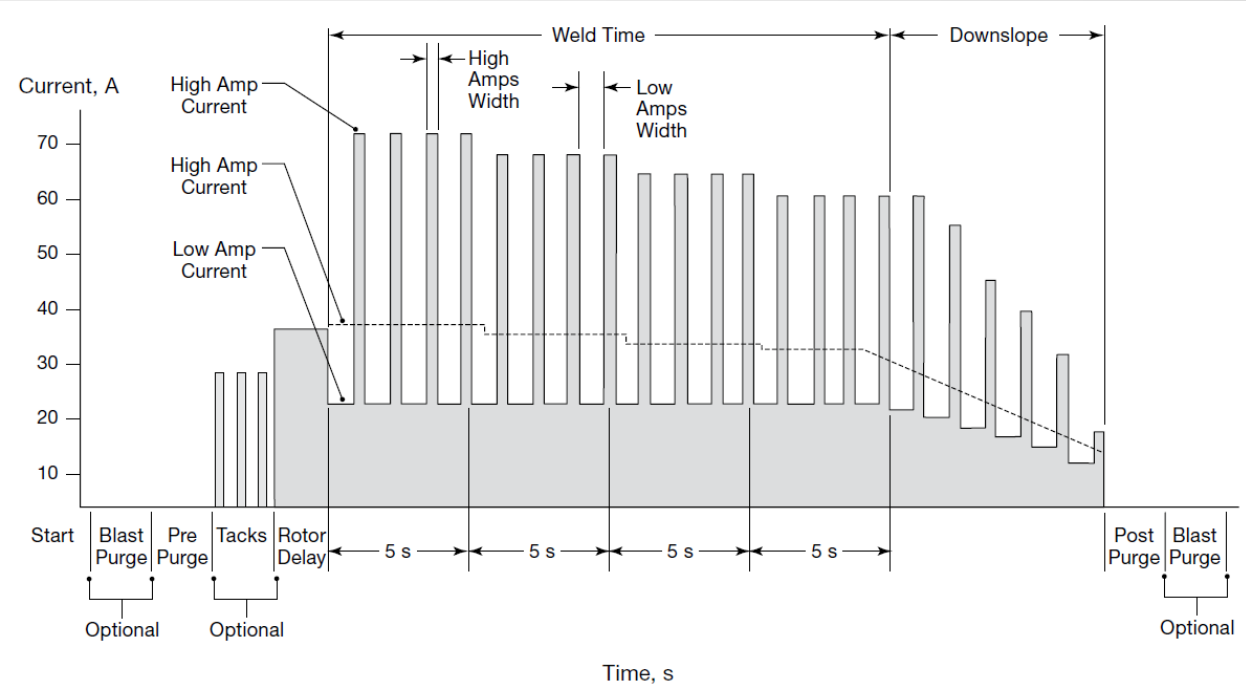


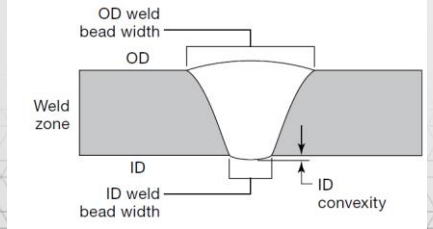
SET UP GAS SUPPLY

- UHP Argon Supply
  - Supply shield gas
  - Supply purge gas, pressure and minimum flow rate
  - Pressure gauge of purge gas while shield gas is on

WELD PARAMETER DEVELOPMENT

- For standard size of tubing which Swagelok supplies, all the setting is programmed and ready to use.
- Weld parameters include
  - Dwelling time, power input when moving…
  - Purge gas supply pressure and flow rate
  - Electrode setting

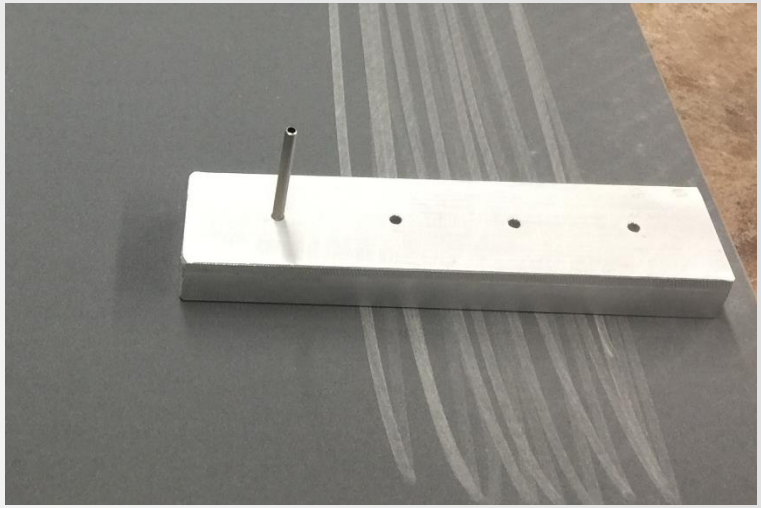


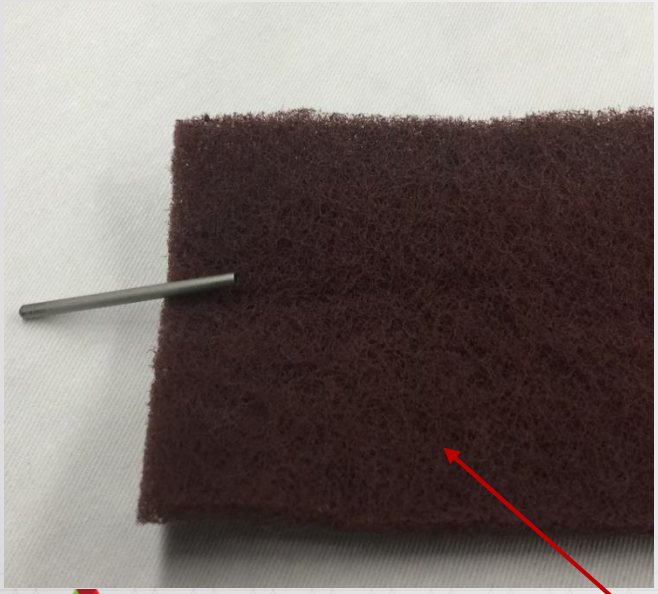


Parameter	1	2	3	4
High Amps, A	71.7	68.1	64.5	60.9
Low Amps, A	21.7	21.7	21.7	21.7
Weld Time, s	5.0	5.0	5.0	5.0
Ramp Time, s	0.0	0.0	0.0	0.0
Pulse Rate, Hz	4.0	4.0	4.0	4.0
High Amps Width, %	28.0	28.0	28.0	28.0
High Amps Speed, rpm	3.5	3.5	3.5	3.5
Low Amps Speed, rpm	3.5	3.5	3.5	3.5
Average Amps, A	35.7	34.7	33.7	32.7

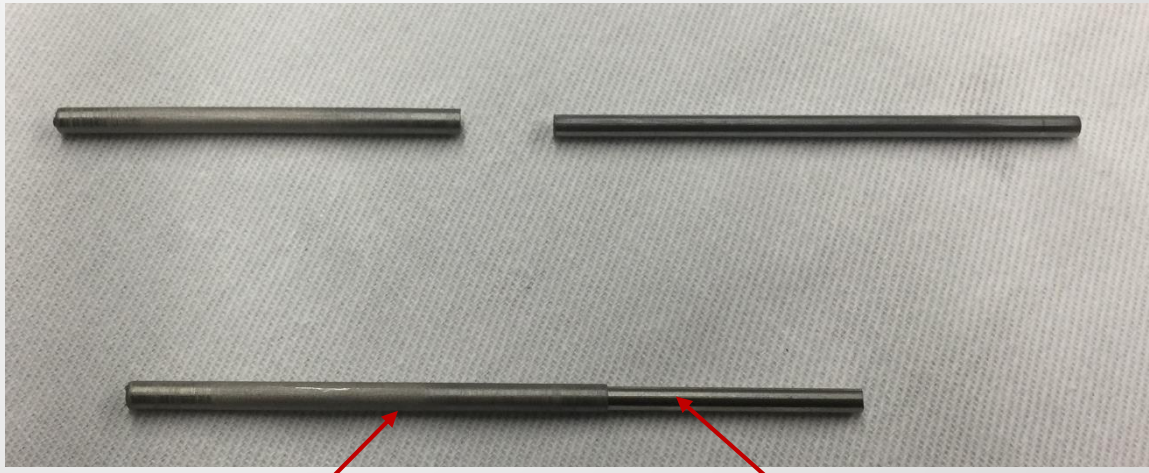
TUBE PREPARATION

- Cross-section roundness
- Tube Straightness
- End Squareness
- Cleanness





Scotch-Brite



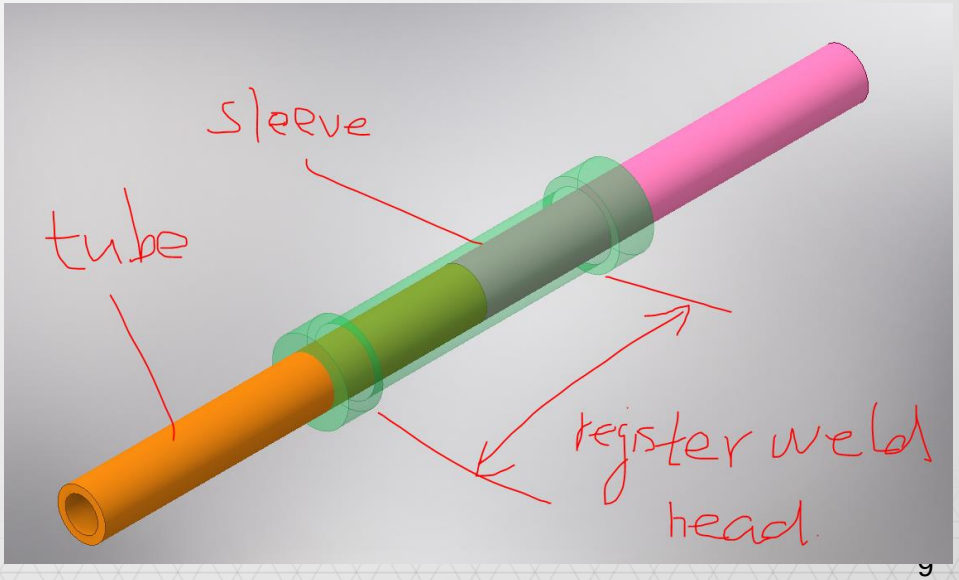
Tube

Gauge Pins

SLEEVE DESIGN

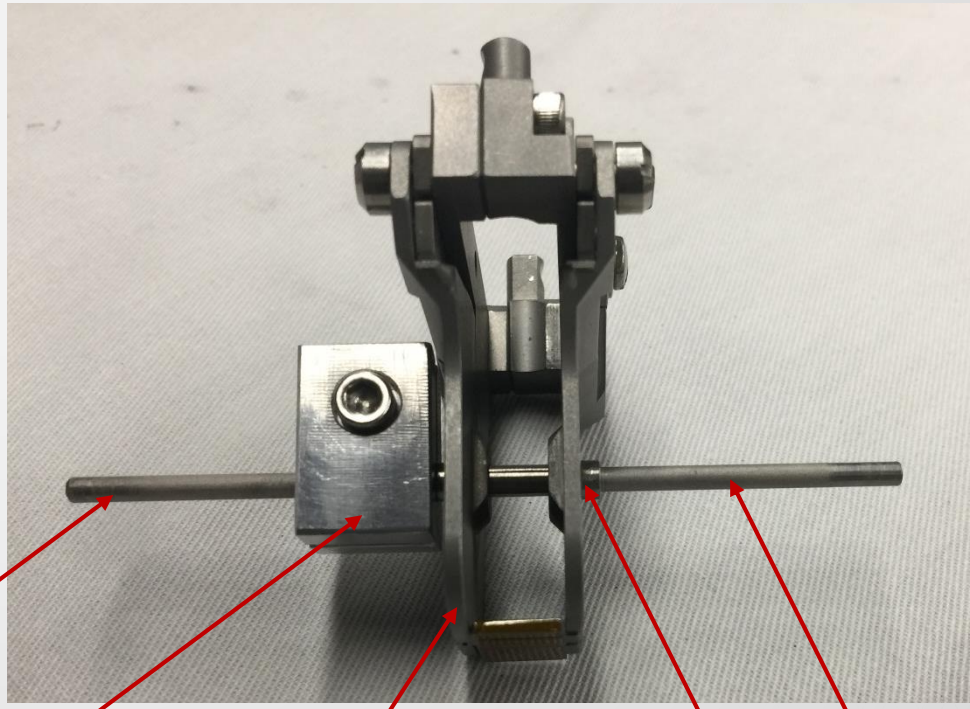
- Tubes meet at the center of sleeve
- Steps on sleeve match weld head

- Machine sleeve out of titanium rod
- ID of sleeve is about 25 um bigger than OD of tube to enable tight fit
- Properly cleaned before welding



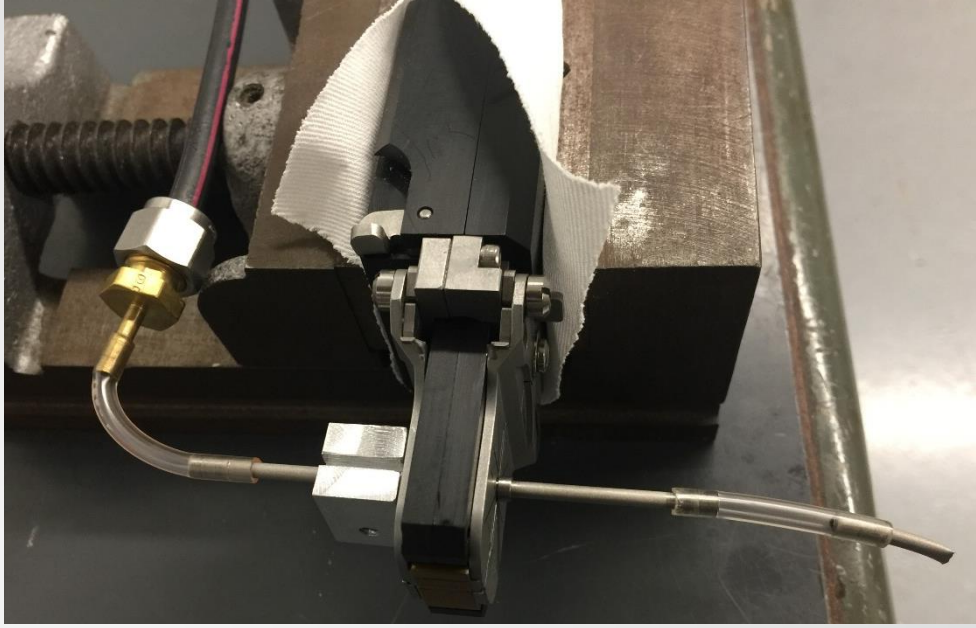
SLEEVE IN FIXTURE

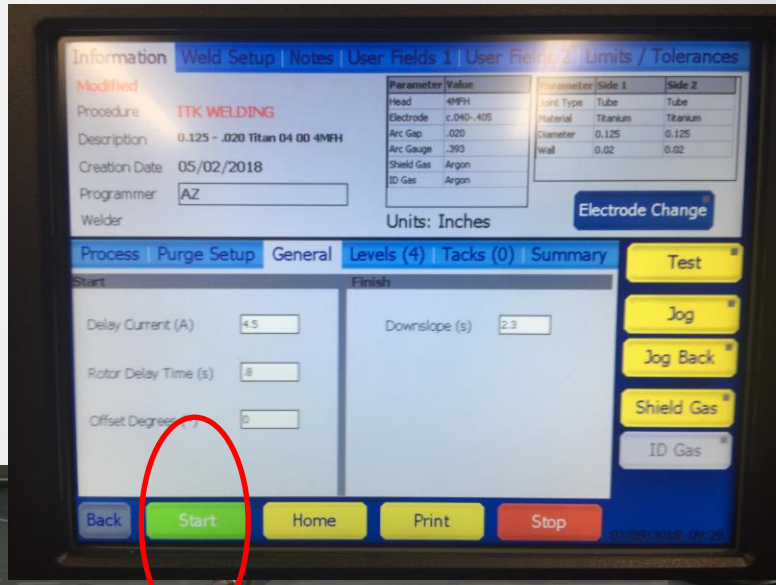
- Clamp fixture to register the weld area on tube 1
- Insert sleeve
- Insert tube 2 to contact tube 1
- Clamp the sleeve into the weld fixture

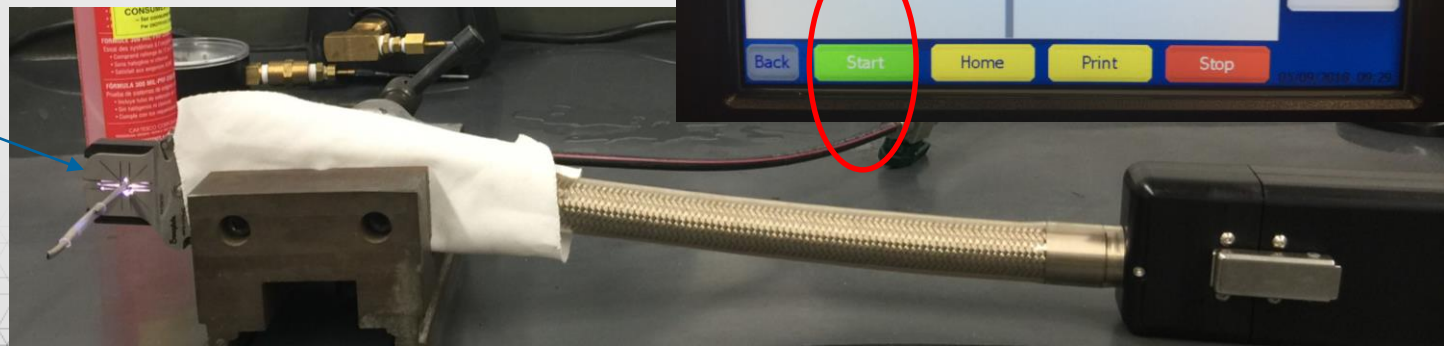


WELDING

- Connect tubes to purge gas
- Insert fixture to the flexible drive and the motor module
- Hit start button





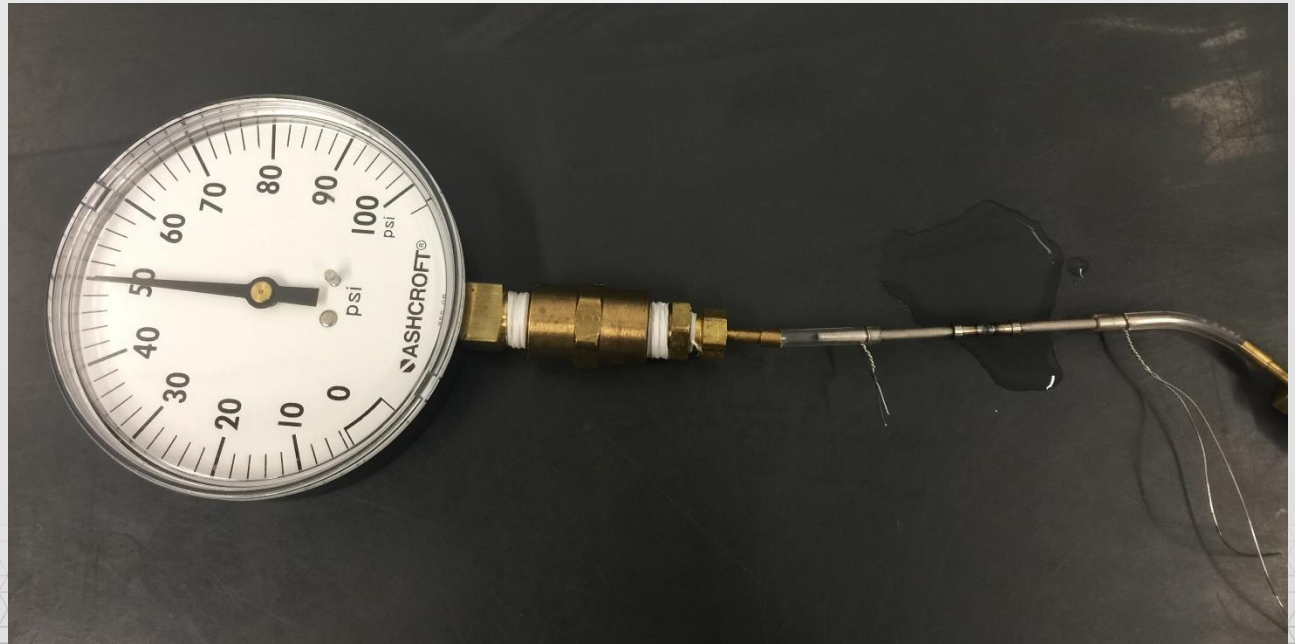


REPEAT WELD

- What if weld is not good?
- One solution with minimum effort is to do the weld a second time using the same weld parameters
- Start weld point will be offset 180 degree from the first
- We see successful trials.
- Reasons:
  - Quite more material around weld area, the second weld will not burn through
  - Make weld more uniform
  - More material can flow to the defect

WELD INSPECTION

- Visual inspection
- Pressure test up to 50 psi due to connection limits
- Use gauge pins to measure the inner diameter of the weld - 125 um diameter reduction



FUTURE WORK

- High pressure test – 130 bars (UMASS)
- Metallurgic test
- Minimize heat power, test different weld orientation
- Optimize the welding parameter based on metallurgic test
- Estimate the reliability by doing ~100 welds

SUMMARY

- Sleeve weld of the thin tube using commercial available orbital welding system is possible
- Tube and sleeve has be carefully prepared and cleaned prior to welding
- Welding parameters have to be tuned to get good weld
- Multiple time weld on one sleeve is possible to remedy bad weld