New Test Part for
Ultrasonic Welding Characterization

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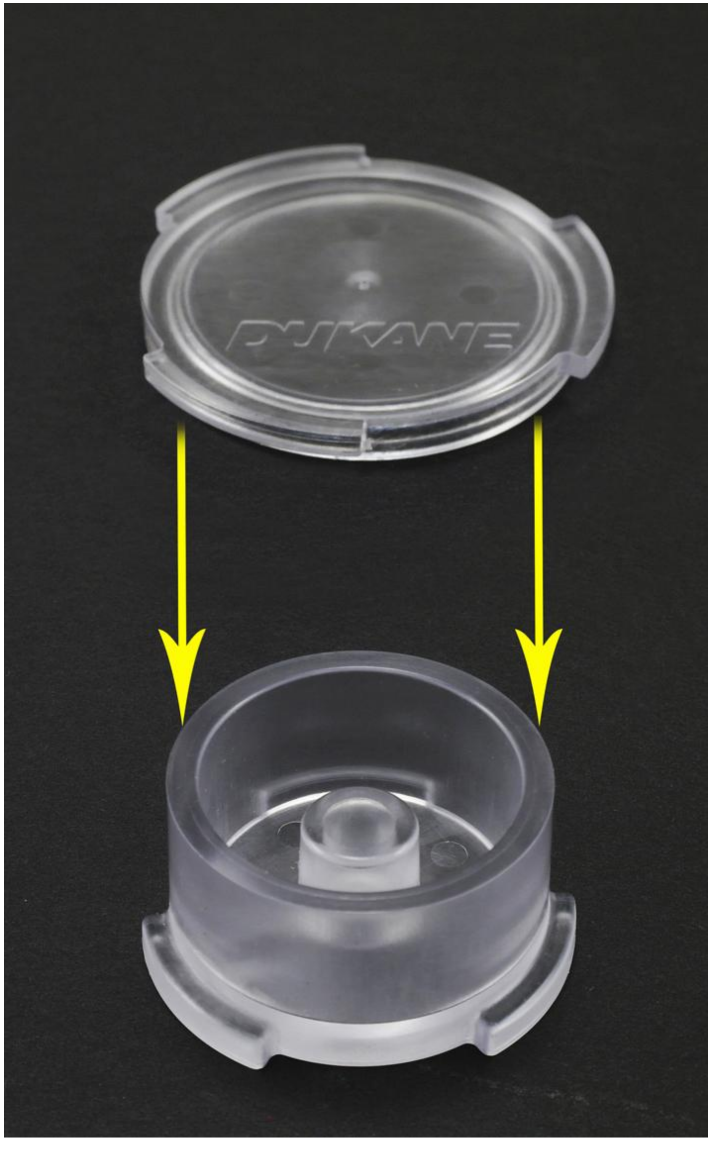
Agenda

- ISTeP Description
- I-Beam Description
- DOE
- Test results and analysis
- Summary
- Future improvements
- Dukane iQ Servo Welder overview

ISTeP



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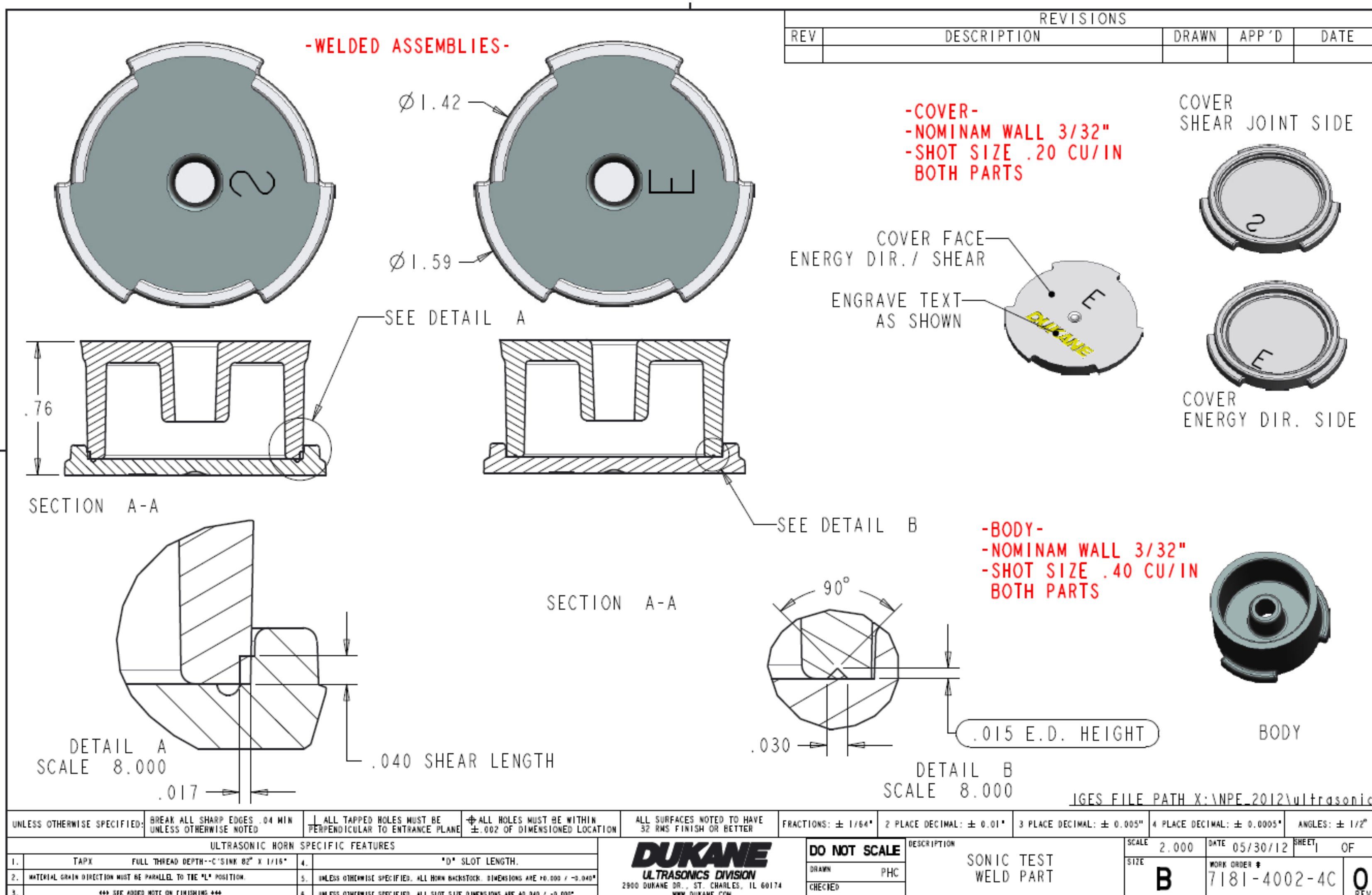
ISTeP


REVISIONS
REV
DESCRIPTION
DRAWN
APP'D
DATE
-WELDED ASSEMBLIES-
Ø1.42
Ø1.59
SEE DETAIL A
.76
SECTION A-A
SEE DETAIL B
-COVER-
-NOMINAM WALL 3/32"
-SHOT SIZE .20 CU/IN
BOTH PARTS
COVER
SHEAR JOINT SIDE
COVER FACE
ENERGY DIR./ SHEAR
ENGRAVE TEXT
AS SHOWN
COVER
ENERGY DIR. SIDE
-BODY-
-NOMINAM WALL 3/32"
-SHOT SIZE .40 CU/IN
BOTH PARTS
BODY
SECTION A-A
90°
DETAIL A
SCALE 8.000
.017
.040 SHEAR LENGTH
.030
.015 E.D. HEIGHT
DETAIL B
SCALE 8.000
IGES FILE PATH X:\NPE_2012\ultrasonic
UNLESS OTHERWISE SPECIFIED:
BREAK ALL SHARP EDGES .04 MIN UNLESS OTHERWISE NOTED
ALL TAPPED HOLES MUST BE PERPENDICULAR TO ENTRANCE PLANE
ALL HOLES MUST BE WITHIN ±.002 OF DIMENSIONED LOCATION
ALL SURFACES NOTED TO HAVE 32 RMS FINISH OR BETTER
FRACTIONS: ± 1/64"
2 PLACE DECIMAL: ± 0.01"
3 PLACE DECIMAL: ± 0.005"
4 PLACE DECIMAL: ± 0.0005"
ANGLES: ± 1/2°
ULTRASONIC HORN SPECIFIC FEATURES
1. TAPX FULL THREAD DEPTH--C'SINK 82° X 1/16"
2. MATERIAL GRAIN DIRECTION MUST BE PARALLEL TO THE "L" POSITION.
3. *** SEE ADDED NOTE ON FINISHING ***
4. "D" SLOT LENGTH.
5. UNLESS OTHERWISE SPECIFIED, ALL HORN BACKSTOCK, DIMENSIONS ARE +0.000 / -0.040"
6. UNLESS OTHERWISE SPECIFIED, ALL SLOT SIZE DIMENSIONS ARE +0.040 / -0.000"
DUKANE
ULTRASONICS DIVISION
2900 DUKANE DR., ST. CHARLES, IL 60174
WWW.DUKANE.COM
DO NOT SCALE
DRAWN PHC
CHECKED
DESCRIPTION
SONIC TEST
WELD PART
SCALE 2.000
DATE 05/30/12
SHEET 1 OF
SIZE B
WORK ORDER # 7181-4002-4C
0
REV

AWS I-Beam

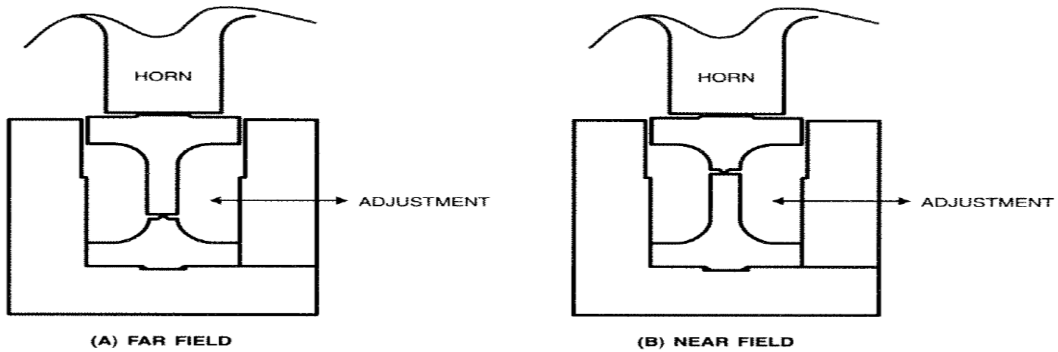


Figure 5—Energy Director Butt Joint Welding

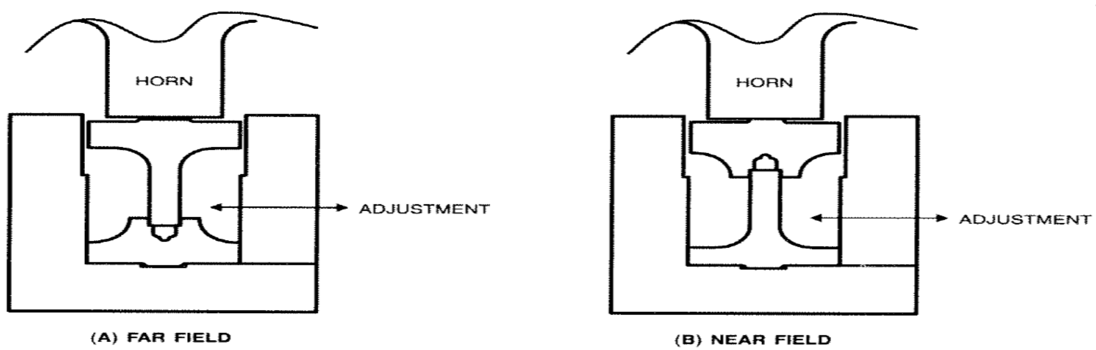


Figure 6—Double Shear Joint Welding

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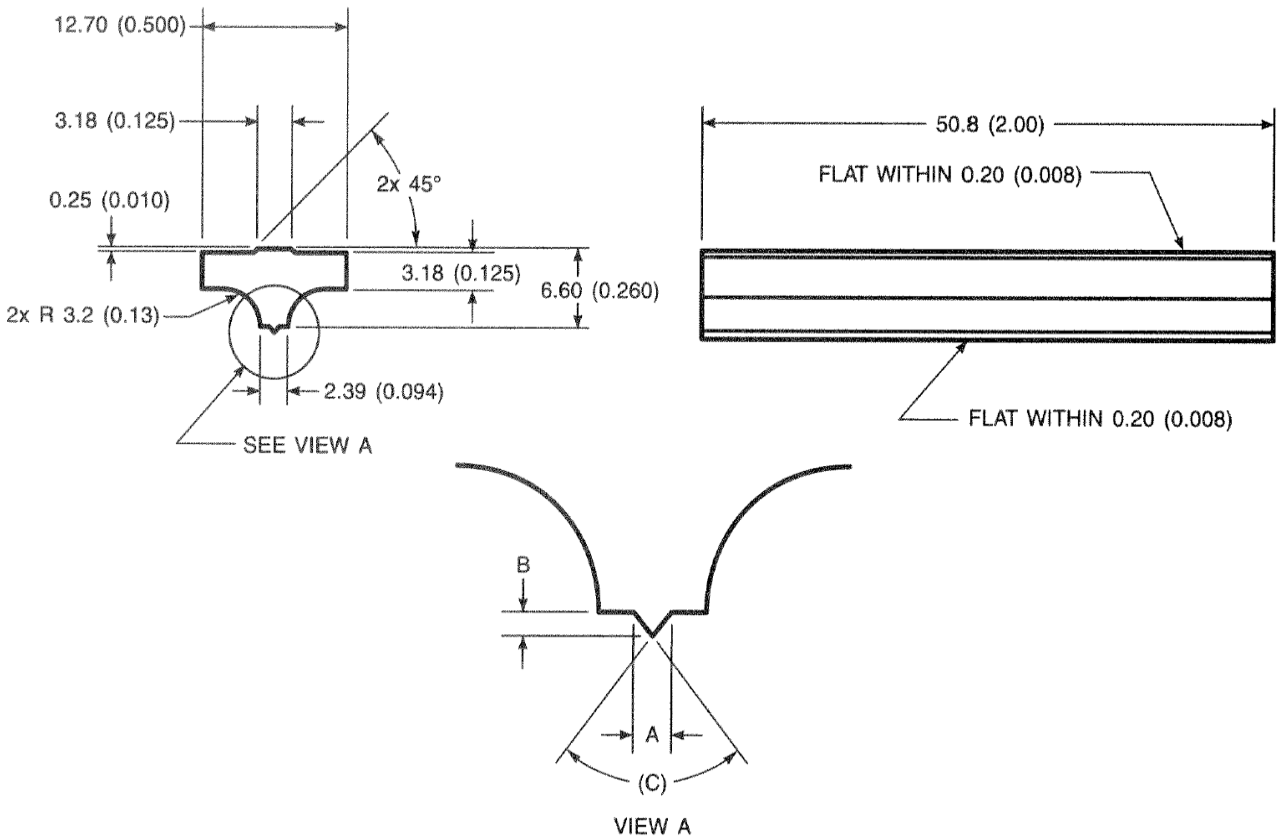
AWS I-Beam

AWS G1.2M/G1.2:1999



Notes:
1. All dimensions mm (in.)
2. Tolerances: x.x … ±0.2 (0.008)
x.xx … ±0.05 (0.002)

Profile	A	B	Ref. C
Small Energy Director	0.61 (0.024)	0.30 (0.012)	90°
Large Energy Director	0.81 (0.032)	0.51 (0.020)	77°

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Dukane Announces ISTeP – an Advanced Test Part!

- Dukane Corporation has taken a significant step to improve the ultrasonic industry’s standard test part. We are calling it the ISTeP – Industrial Standard Test Part.
- It is two-piece cylindrical part used to test a variety of welded parts’ characteristics. With ISTeP ultrasonic weld quality can be determined with enhanced confidence.
- **Outside the I-Beam** – By rethinking the design of the existing industry standard part (I-Beam)currently used for testing, it became clear there was room for improvement. Consider ISTeP’s cylindrical shape.

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ISTeP

- Dukane’s investment in the development of a better industry standard test part included a fresh part design and also production of a quality injection mold. The ISTeP team created the mold so that gates and knits insured a uniform mold fill, especially in the joint area. There are three joint design options – 60° or 90° energy directors, and a standard shear joint. In addition, the mold has inserts for the joint area. These allow for additional options manufacturers and designers may bring in the future that are unique to their weld joint specifications.
- **Pressure/Burst/Leak Testing** - An integral port in ISTeP’s lower portion makes it easy to insert an air tube for a variety of checks that can be made.

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ISTeP

- **Pull Testing** is simplified by the use of ISTep's unique tabs, three on the top piece, and three on the lower portion. The tabs help reduce time spent assembling the test part into it's pull test fixture.
  - Bond strength of different plastic resins can be compared - polycarbonate vs. ABS as an example.
  - When parts come apart under testing, they will do so avoiding the so-called "zipper effect" that was previously common.

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ISTeP

Testing Weld Processes and Features – Welding methods each have their distinct advantages. To find which combination of process and features work best, ISTeP could be used with pneumatic and servo welders, using features such as amplitude profiling or Melt-Match® technology, for instance. Dukane's enhanced ***iQ Series*** generators and software are available to provide even more versatility and possibility to make the testing process complete and comprehensive.

Mold Availability – ISTeP's injection mold is available from Dukane for firms interested in obtaining test parts molded in their resin of choice. Dukane Corporation offers expertise and know-how for your application.

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DOE – Design of Experiment

- The same 20 kHz iQ Servo Driven Press system is used
- O-Ring Booster and Resonant mount Boosters were tested
- Horns for I-Beam and ISTeP have similar gain – amplitude for both parts was very close
- Same weld set-up parameters were used to weld both part in sets 1, 2 and 3. Deeper collapsed distance was used for ISTeP in set # 4 to accommodate part's taller Energy Director
- Parts were measured before and after the weld and the difference was calculated (actual collapsed distance). This value was then compared against the welder readings
- The same pull test fixture was used with part holders that were made to match ISTeP and I-Beam respectively
- ISTeP – Lexan12R; I-Beam – Lexan141 – similar properties

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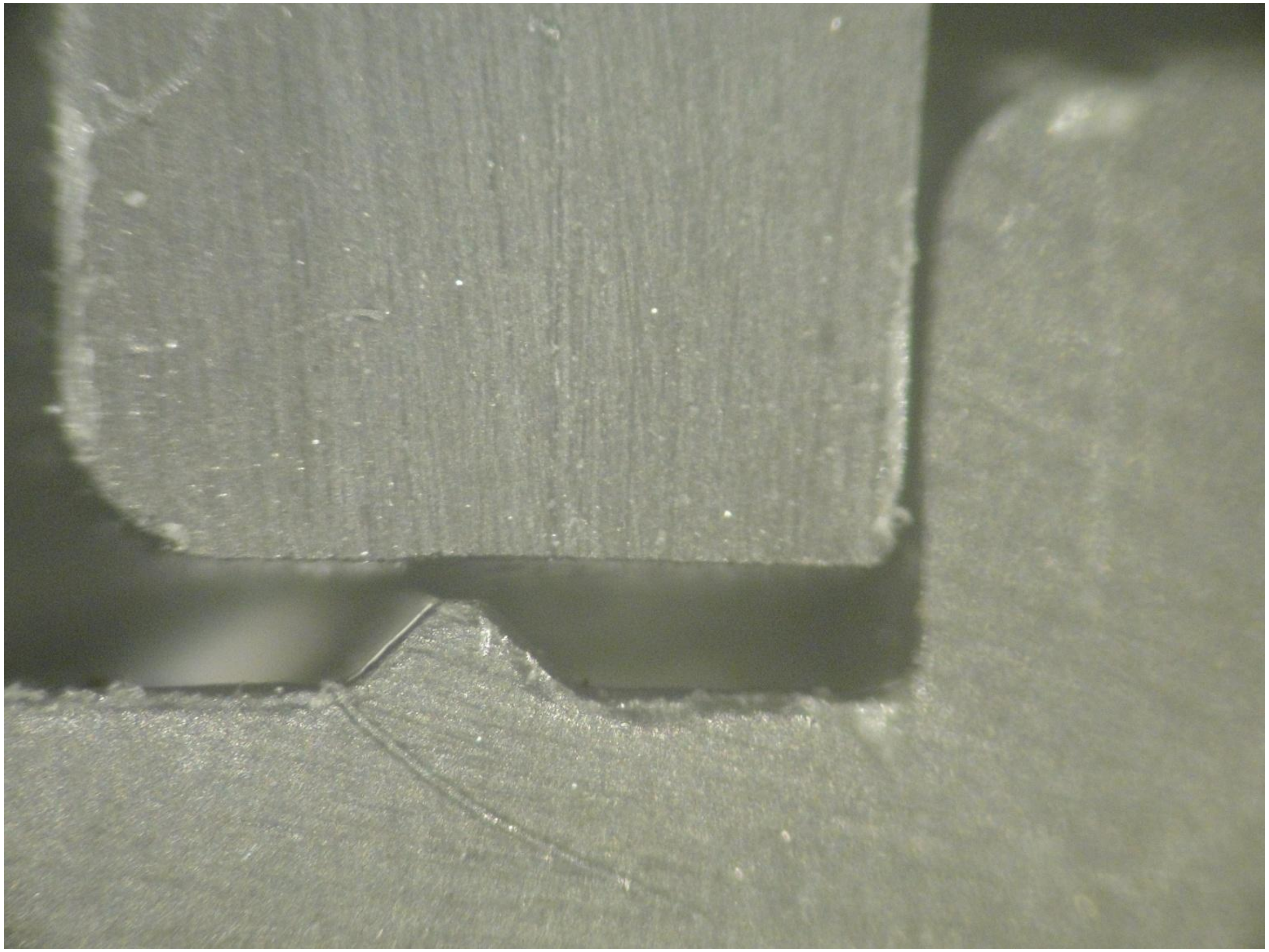
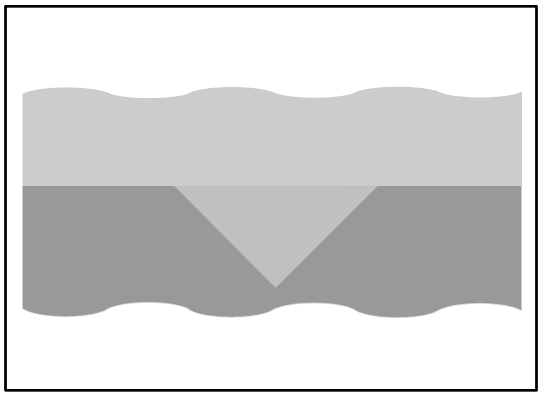
ISTeP Energy Director

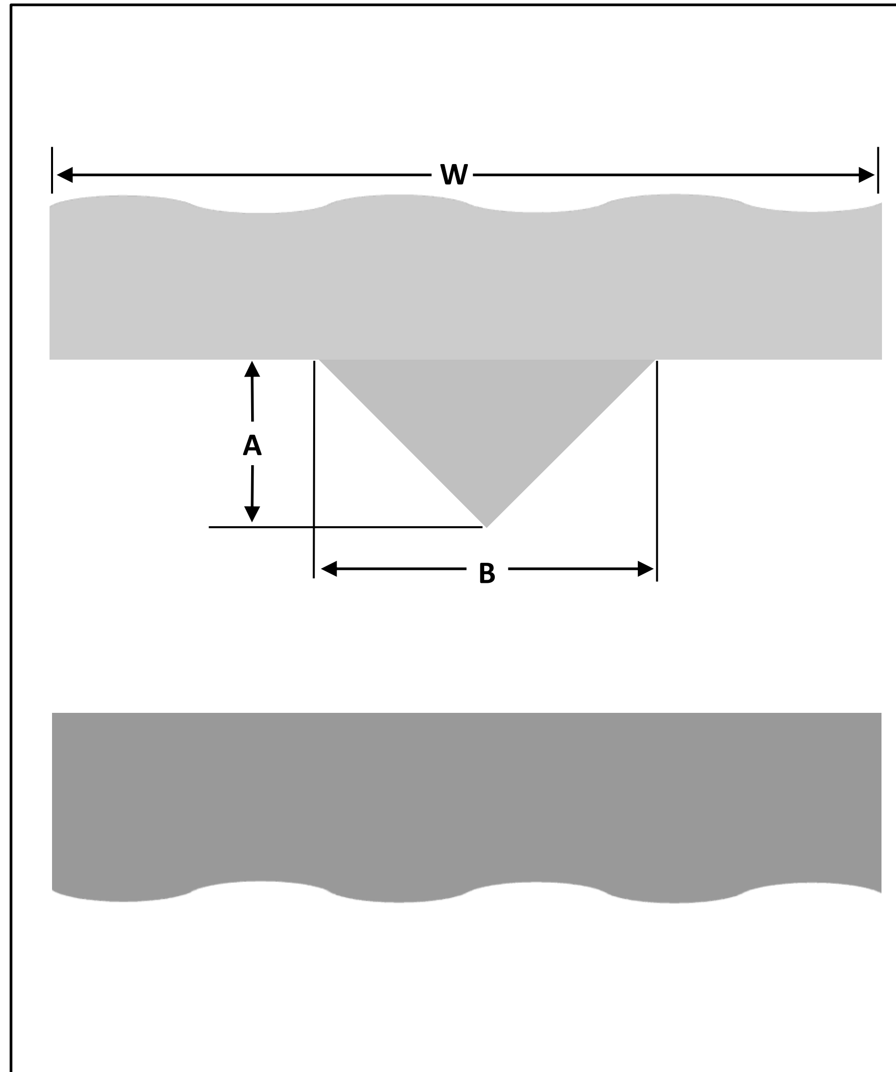
Photo from a microscope



Ultrasonic Welding Joints

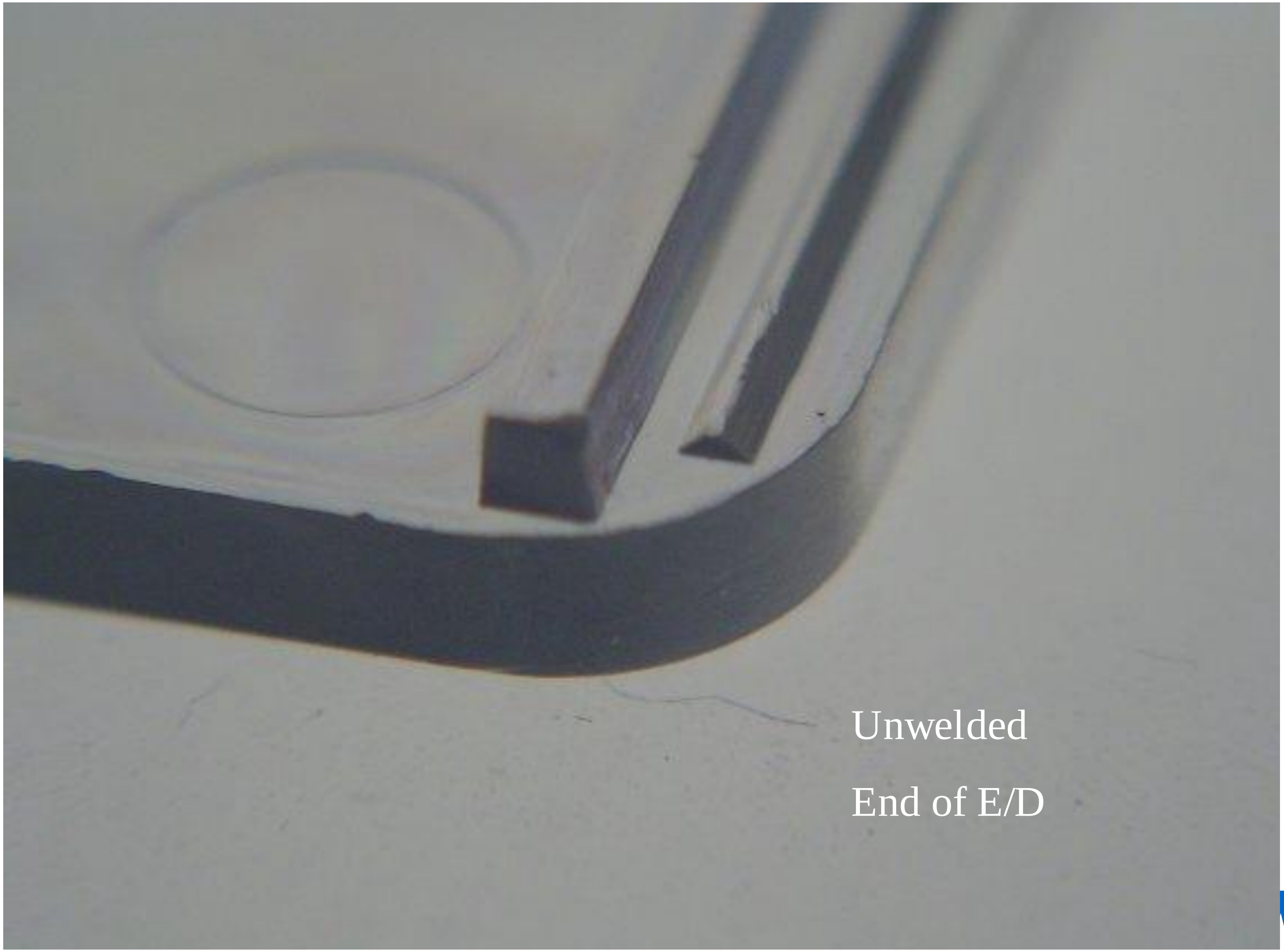
Energy Director



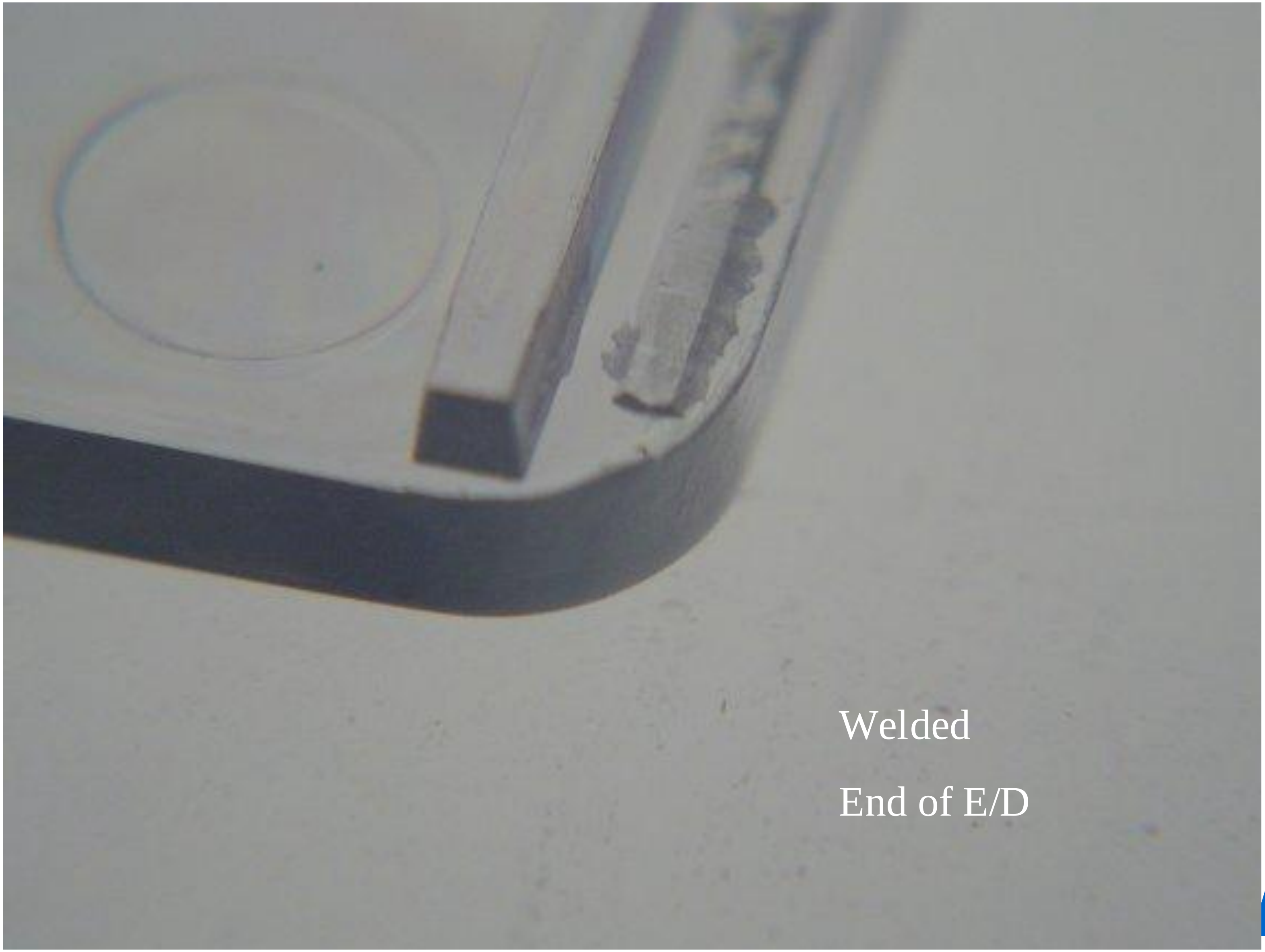


	Dimension	General Guidelines
W	Wall Thickness	Minimum 0.090"
B	Energy Director Base Width	W/4 to W/5
A	Energy Director Height	B/2 or 0.866B
E	Energy Director Angle	60° or 90°

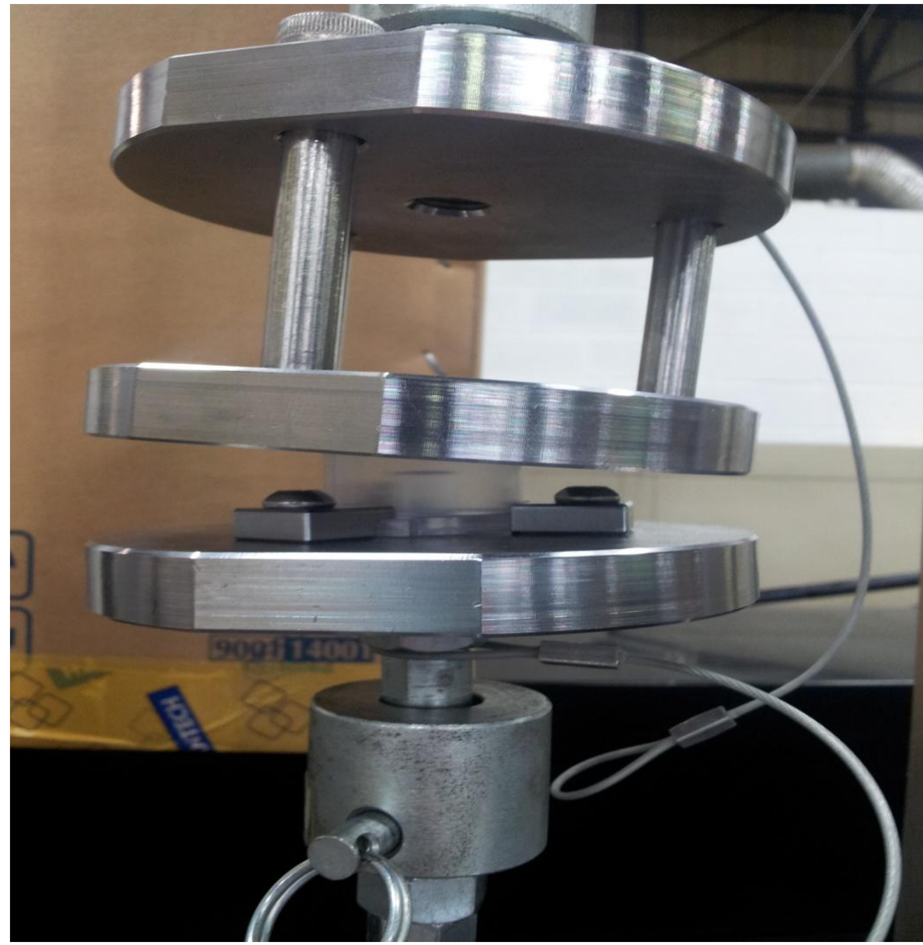
Typical Energy Director Unwelded



Typical Energy Director Welded



DOE – ISTeP Pull Test Fixture



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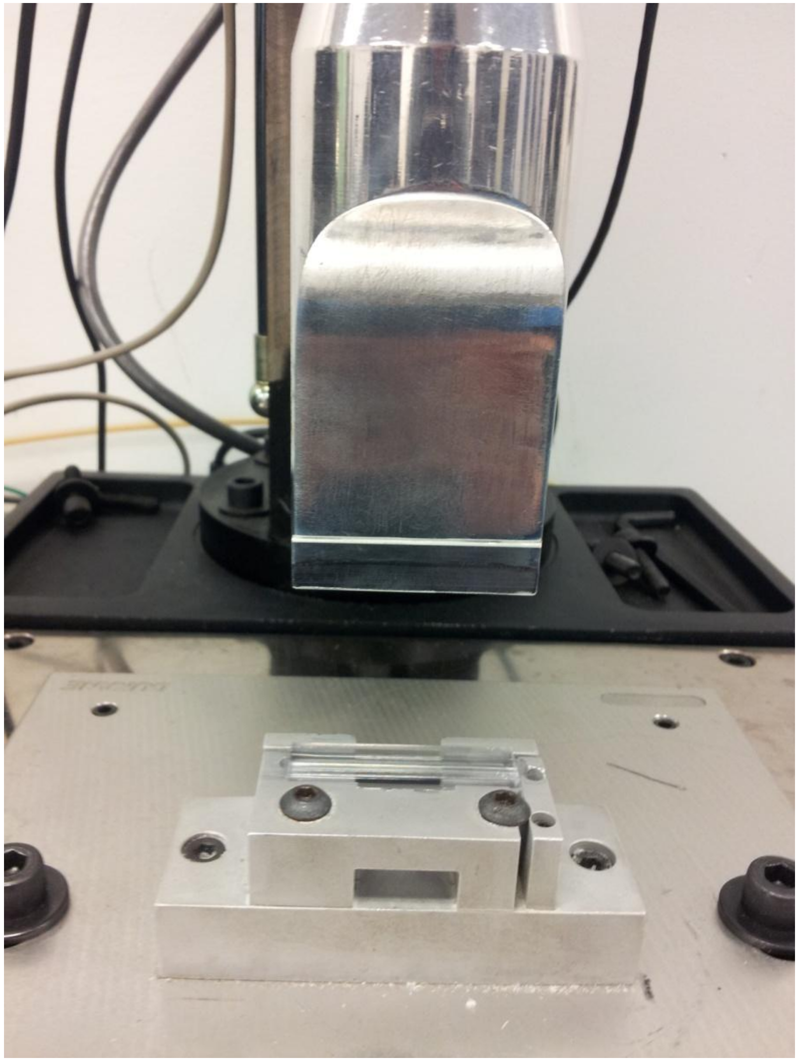
DOE – I-Beam Pull Test Fixture

DOE – I-Beam Welding Setup



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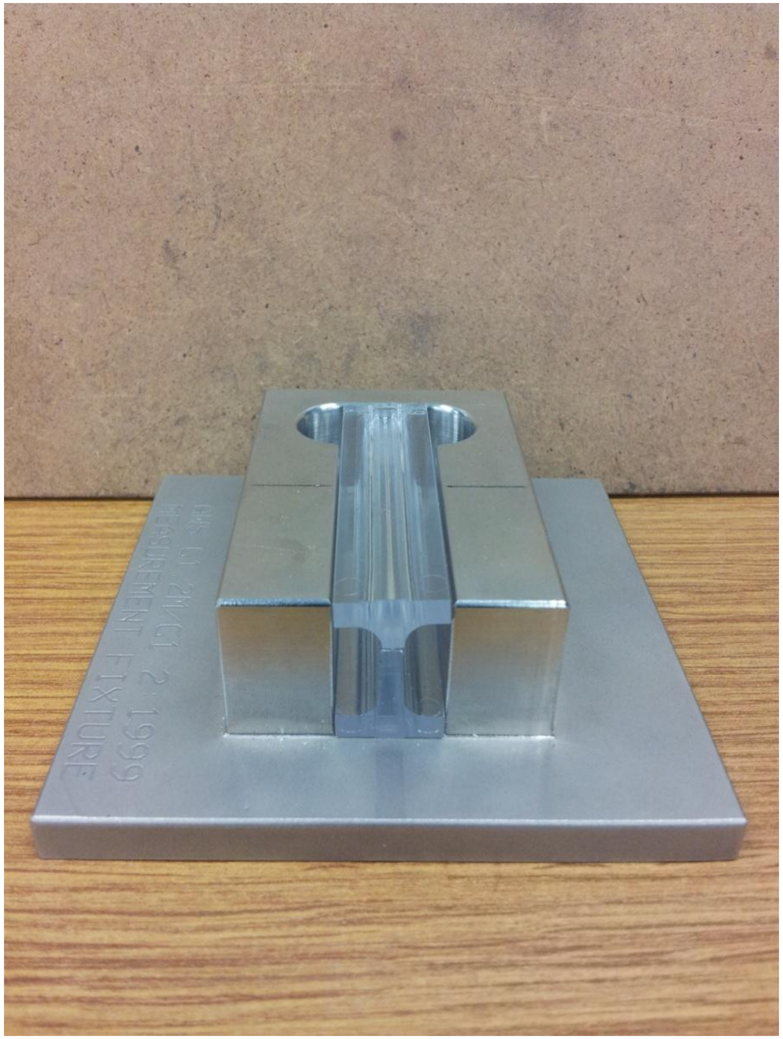
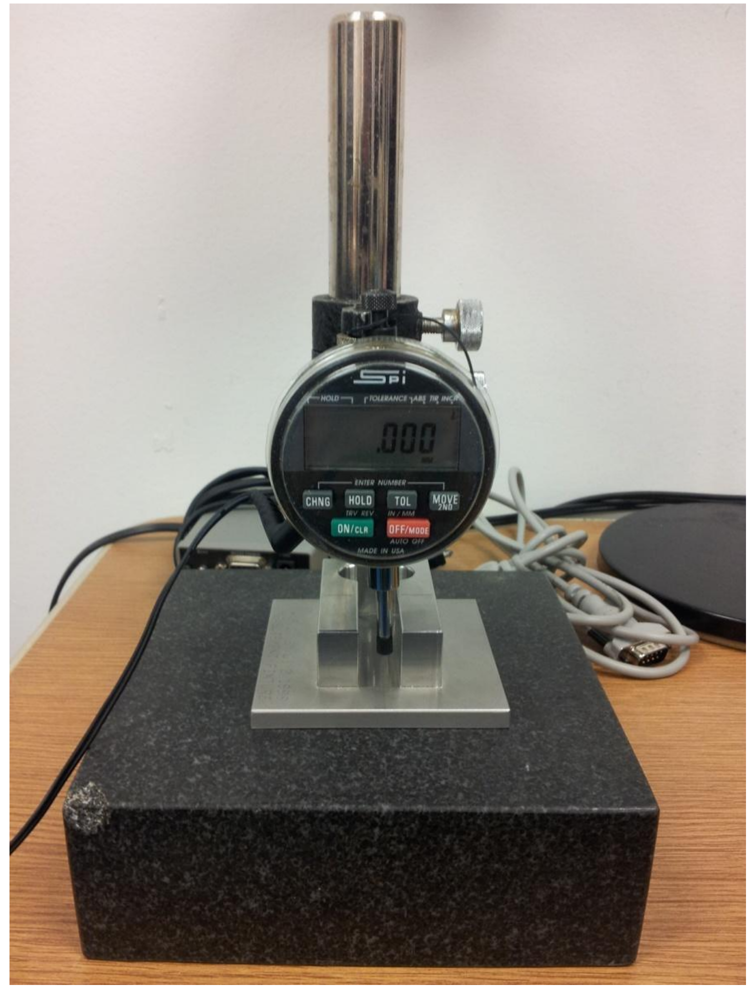
DOE – I-Beam Height Measurement Fixture





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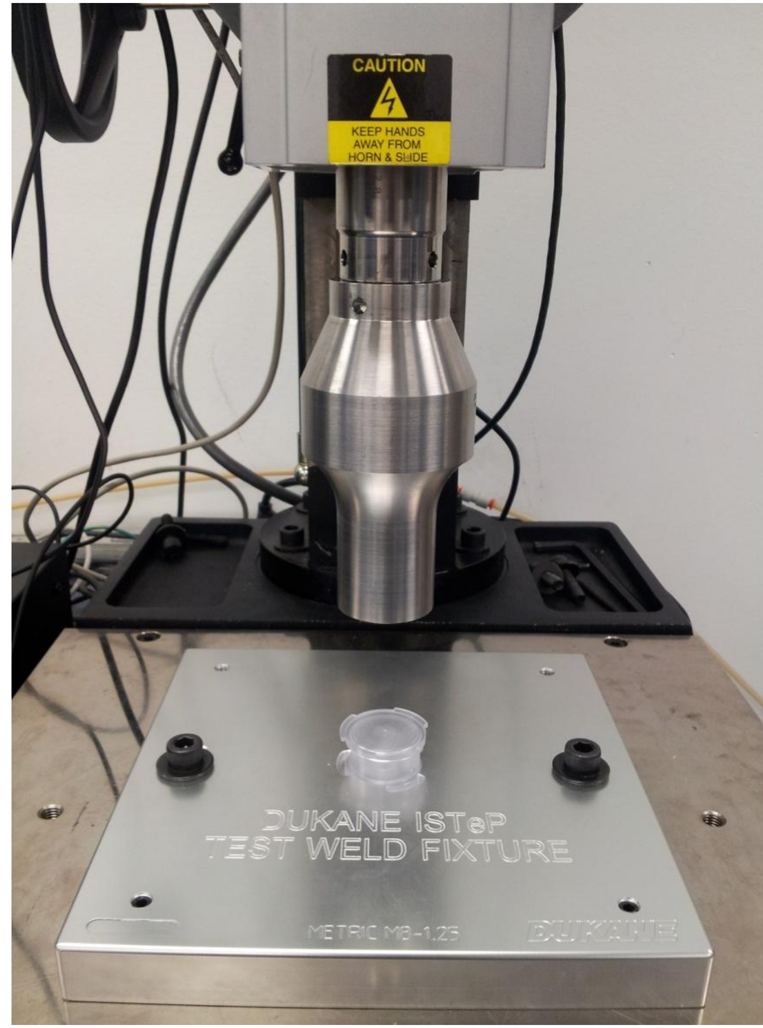
DOE – ISTeP Welding Setup



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DOE – Welding Setup Parameters
I-Beam Set # 1, 2

Servo Press
With O-Ring Booster
Trigger Type Force Trigger Force 250.0 N
Sensing Start
Position 92.161 mm
Sensing Speed 1.270 mm/s

Weld Settings
Weld Method Distance 0.300 mm
Enable Melt Detect Enabled After Force Drops By 10 %
Weld Motion Control Speed 10.000 mm/s
Weld Amplitude 100 %

Hold Settings
Dynamic Hold Method Distance 0.050 mm
Hold Constant Speed 12.700 mm/s
Max Hold Time 1.000 s
Static Hold Method Time 0.500 s
Travel Limit 96.268 mm

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DOE – Welding Setup Parameters
ISTeP Set # 1, 2

Servo Press
With O-Ring Booster
Trigger Type Force Trigger Force 250.0 N
Sensing Start
Position 88.682 mm
Sensing Speed 1.270 mm/s

Weld Settings
Weld Method Distance 0.300 mm
Enable Melt Detect Enabled After Force Drops By 10 %
Weld Motion Control Speed 10.000 mm/s
Weld Amplitude 100 %

Hold Settings
Dynamic Hold Method Distance 0.050 mm
Hold Constant Speed 12.700 mm/s
Max Hold Time 1.000 s
Static Hold Method Time 0.500 s
Travel Limit 96.268 mm

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DOE – Welding Setup Parameters

I-Beam Set # 3

Servo Press

With O-Ring Booster

Trigger Type Force Trigger Force 250.0 N

Sensing Start

Position 36.805 mm

Sensing Speed 1.270 mm/s

Weld Settings

Weld Method Distance 0.250 mm

Enable Melt Detect Enabled After Force Drops By 5 %

Weld Motion Control Speed 2.000 mm/s

Weld Amplitude 90 %

Hold Settings

Dynamic Hold Method Distance 0.050 mm

Hold Constant Speed 5.000 mm/s

Max Hold Time 1.000 s

Static Hold Method Time 0.500 s

Travel Limit 42.265 mm

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DOE – Welding Setup Parameters
ISTeP Set # 3

Servo Press
With Resonant Booster
Trigger Type Force Trigger Force 250.0 N
Sensing Start
Position 63.006 mm
Sensing Speed 1.270 mm/s

Weld Settings
Weld Method Distance 0.250 mm
Enable Melt Detect Enabled After Force Drops By 5 %
Weld Motion Control Speed 2.000 mm/s
Weld Amplitude 90 %

Hold Settings
Dynamic Hold Method Distance 0.050 mm
Hold Constant Speed 5.000 mm/s
Max Hold Time 1.000 s
Static Hold Method Time 0.500 s
Travel Limit 71.151 mm

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DOE – Welding Setup Parameters
I-Beam Set # 4

Servo Press
With Resonant Booster
Trigger Type Force Trigger Force 250.0 N
Sensing Start
Position 41.542 mm
Sensing Speed 1.270 mm/s

Weld Settings
Weld Method Distance 0.250 mm
Enable Melt Detect Enabled After Force Drops By 5 %
Weld Motion Control Speed 2.000 mm/s
Weld Amplitude 90 %

Hold Settings
Dynamic Hold Method Distance 0.050 mm
Hold Constant Speed 5.000 mm/s
Max Hold Time 1.000 s
Static Hold Method Time 0.500 s
Travel Limit 45.564mm

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DOE – Welding Setup Parameters
ISTeP Set # 4

Servo Press
With Resonant Booster
Trigger Type Force Trigger Force 250.0 N
Sensing Start
Position 62.940 mm
Sensing Speed 1.270 mm/s

Weld Settings
Weld Method Distance 0.305 mm
Enable Melt Detect Enabled After Force Drops By 5 %
Weld Motion Control Speed 2.000 mm/s
Weld Amplitude 90 %

Hold Settings
Dynamic Hold Method Distance 0.050 mm
Hold Constant Speed 5.000 mm/s
Max Hold Time 1.000 s
Static Hold Method Time 0.500 s
Travel Limit 71.151 mm

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ISTeP vs. I-Beam
Weld Results Summary

	IStep_Set 1 (mm)			Computer Data	Difference Measured	Pull Strength	I-Beam_Set 1 (mm)			Computer Data	Difference Measured	Pull Strength
	Before Welding	After Welding	Difference	mm	mm	N	Before Welding	After Welding	Difference	mm	mm	N
Average	19.923	19.662	0.261	0.352	-0.091	712	19.615	19.410	0.206	0.352	-0.147	1529
Std. Dev	0.007	0.004	0.007	0.001		102	0.043	0.026	0.032	0.001		306

	IStep_Set 2 (mm)			Computer Data	Difference Measured	Pull Strength	I-Beam_Set 2 (mm)			Computer Data	Difference Measured	Pull Strength
	Before Welding	After Welding	Difference	mm	mm	N	Before Welding	After Welding	Difference	mm	mm	N
Average	19.926	19.665	0.261	0.353	-0.092	758	19.619	19.401	0.217	0.353	-0.135	1574
Std. Dev	0.007	0.005	0.008	0.001		79	0.040	0.026	0.037	0.002		356

	IStep_Set 3 (mm)			Computer Data	Difference Measured	Pull Strength	I-Beam_Set 3 (mm)			Computer Data	Difference Measured	Pull Strength
	Before Welding	After Welding	Difference	mm	mm	N	Before Welding	After Welding	Difference	mm	mm	N
Average	19.924	19.654	0.271	0.301	-0.030	1015	19.616	19.306	0.310	0.301	0.009	2617
Std. Dev	0.008	0.003	0.009	0.001		158	0.027	0.017	0.016	0.001		511

	IStep_Set 4 (mm)			Computer Data	Difference Measured	Pull Strength	I-Beam_Set 4 (mm)			Computer Data	Difference Measured	Pull Strength
	Before Welding	After Welding	Difference	mm	mm	N	Before Welding	After Welding	Difference	mm	mm	N
Average	19.922	19.629	0.293	0.355	-0.062	1612	19.610	19.297	0.313	0.301	0.012	2664
Std. Dev	0.006	0.004	0.006	0.001		326	0.015	0.012	0.012	0.001		932

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ISTeP vs. I-Beam
Weld Results Summary Set # 4

		Force at Trigger	Weld Time	Weld Energy	Weld Peak Power	Weld Peak Force	Weld Distance	Hold Distance	Weld + Hold Distance
		N	sec	J	W	N	mm	mm	mm
ISTeP	Average	250.733	0.235	195.503	2255.187	919.133	0.308	0.047	0.355
	Std. Dev	0.691	0.008	10.604	50.147	16.152	0.002	0.002	0.001
	Std. Dev %	**0.28%**	**3.27%**	**5.42%**	**2.22%**	**1.76%**	**0.57%**	**3.42%**	**0.21%**
I-Beam	Average	250.167	0.192	103.113	1446.490	567.867	0.254	0.047	0.301
	Std. Dev	0.379	0.006	5.837	74.153	122.471	0.002	0.002	0.001
	Std. Dev %	**0.15%**	**3.38%**	**5.66%**	**5.13%**	**21.57%**	**0.64%**	**3.38%**	**0.22%**

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ISTeP vs. I-Beam
Weld Results Summary

- Height Measurements
  - The ISTeP height measurements showed very consistent average and standard deviation from set to set.
  - The I-Beam have showed less consistent averages from set to set and increasingly better standard deviation.
  - In the set 1 the pre-welding height's standard deviation for the I-Beam parts were 4 times greater than for the ISTeP, in the last set it was only double. We believe that our operator has improved his consistency of assembling the I-Beam. This means that the I-Beam measurements have greater dependency on operator skill and are less accurate for short runs.
  - The ISTeP showed consistently lower standard deviation for both pre and post weld measurements.

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ISTeP vs. I-Beam
Weld Results Summary

- Weld Depth
  - In sets 1 & 2 both parts were measured to have less weld depth than was programmed (high compressibility in the O-Ring booster).
  - In sets 3 and 4 the I-Beams had a greater measured weld depth than programmed. Both sets were welded with lower velocity, but set 3 used O-Ring and set 4 used Resonant booster.
  - In sets 3 and 4 the I-Beams showed a closer correlation to programmed weld depth than the ISTeP parts
  - The ISTeP parts showed the best match to the programmed weld depth in set 3. Set 4 had deeper weld, and therefore larger force and larger deflection in the booster.

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ISTeP vs. I-Beam
Weld Results Summary

- Pull Strength
  - The I-Beam parts consistently showed greater pull force
  - The ISTeP parts broke the part rather than the weld in many of the last set of samples
    - Perhaps the pull features of the part should be modified?
  - The ISTeP parts showed a standard deviation of pull force of 20%, the I-Beams had 34%
- Peak Power and Peak Force during welding
  - The ISTeP had much more consistent results for sets 3 & 4, and higher average results
    - Perhaps the weld strength would be greater if the pull features of the test part were modified?
- Weld Energy
  - The ISTeP had greater values, but standard deviation was the same for both part styles.

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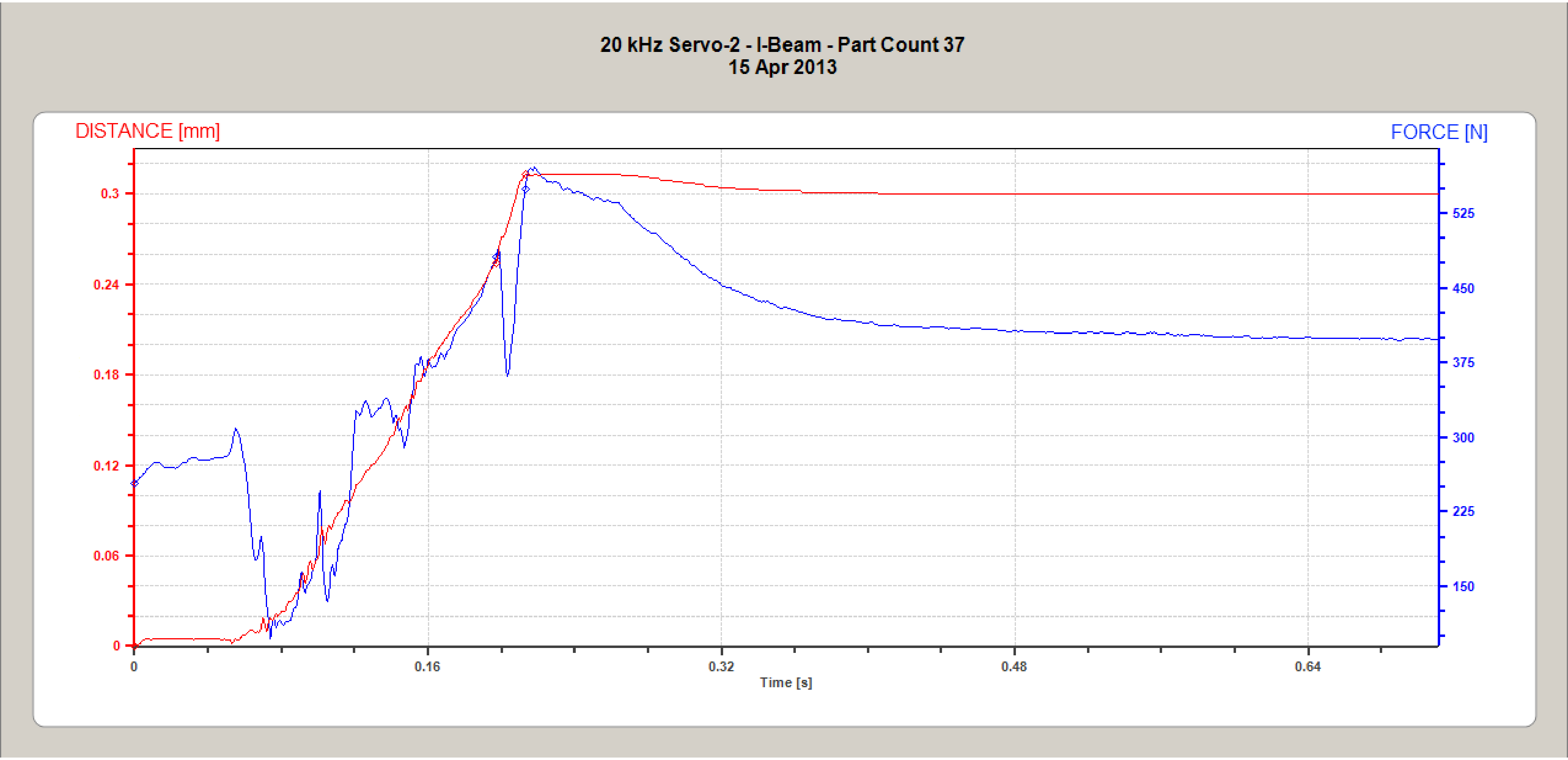
ISTeP vs. I-Beam
Weld Results Summary



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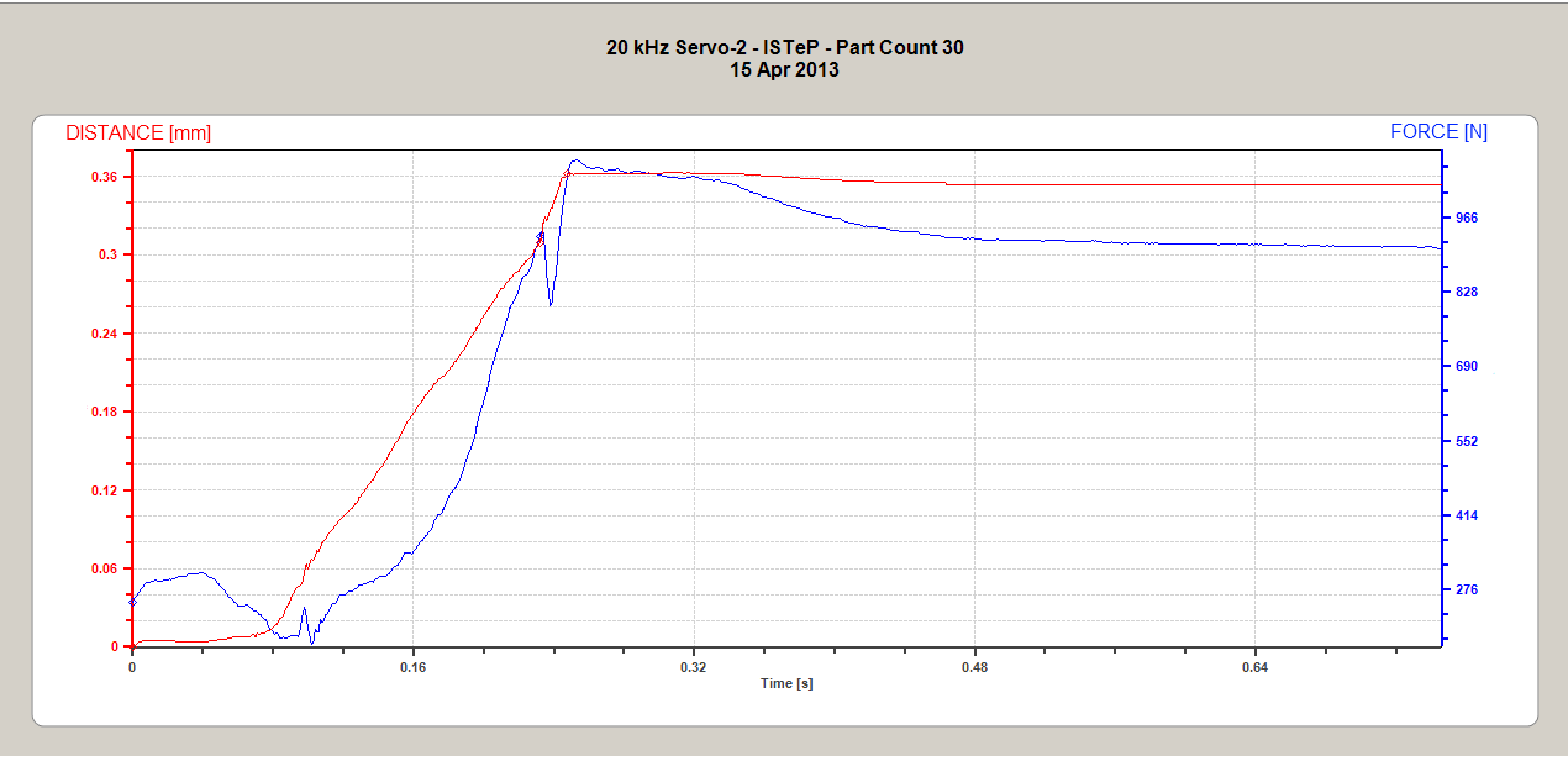
ISTeP vs. I-Beam
Weld Results Summary



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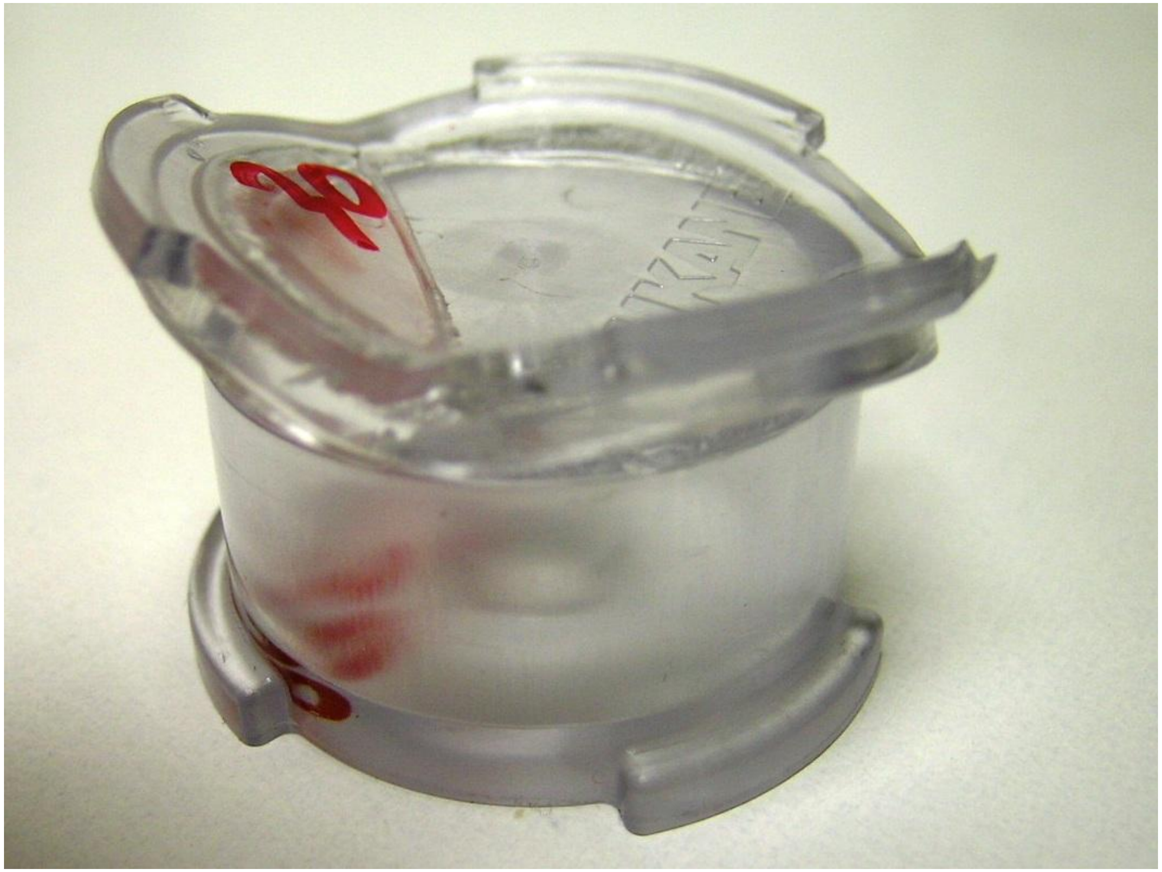
ISTeP vs. I-Beam
Weld Results Summary

- Our conclusion is that the ISTeP is a much more accurate and consistent part but we may need to improve the pull feature design to make it perform even better



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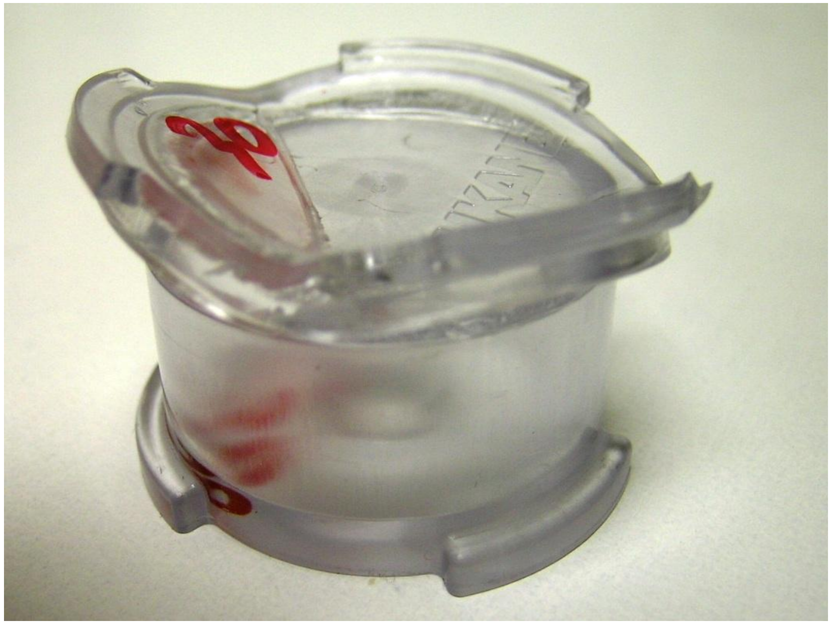
ISTeP vs. I-Beam
Future Development

- We will consider running similar tests with additional plastic materials
- We will consider optimizing ISTeP's pull features to make it perform even better
- We will investigate optimization of the weld parameters
- We will promote the usage of this parts by the industry and academia



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Ultrasonic Welding Process Optimization

Welder Control Features	BASIC	GOOD	BETTER	BEST
Trigger	Spring	Spring	Force xdcr	Force xdcr
Single Pressure	X	X	X	X
Dual Pressure		X	X	X
Time	X	X	X	X
Energy		X	X	X
Distance		X	X	X
Electronic Pressure			X	X
Pressure Profile			X	Servo Weld speed profile
Hydraulic Weld Speed Control		X	X	Servo Weld speed profile
Servo Speed Control				Servo Weld speed profile
Servo Speed Profile				X
Hold by Distance		X	X	X
Static Hold				X
Move after Force Drop (Melt-Detect)				X

iQ Servo Models

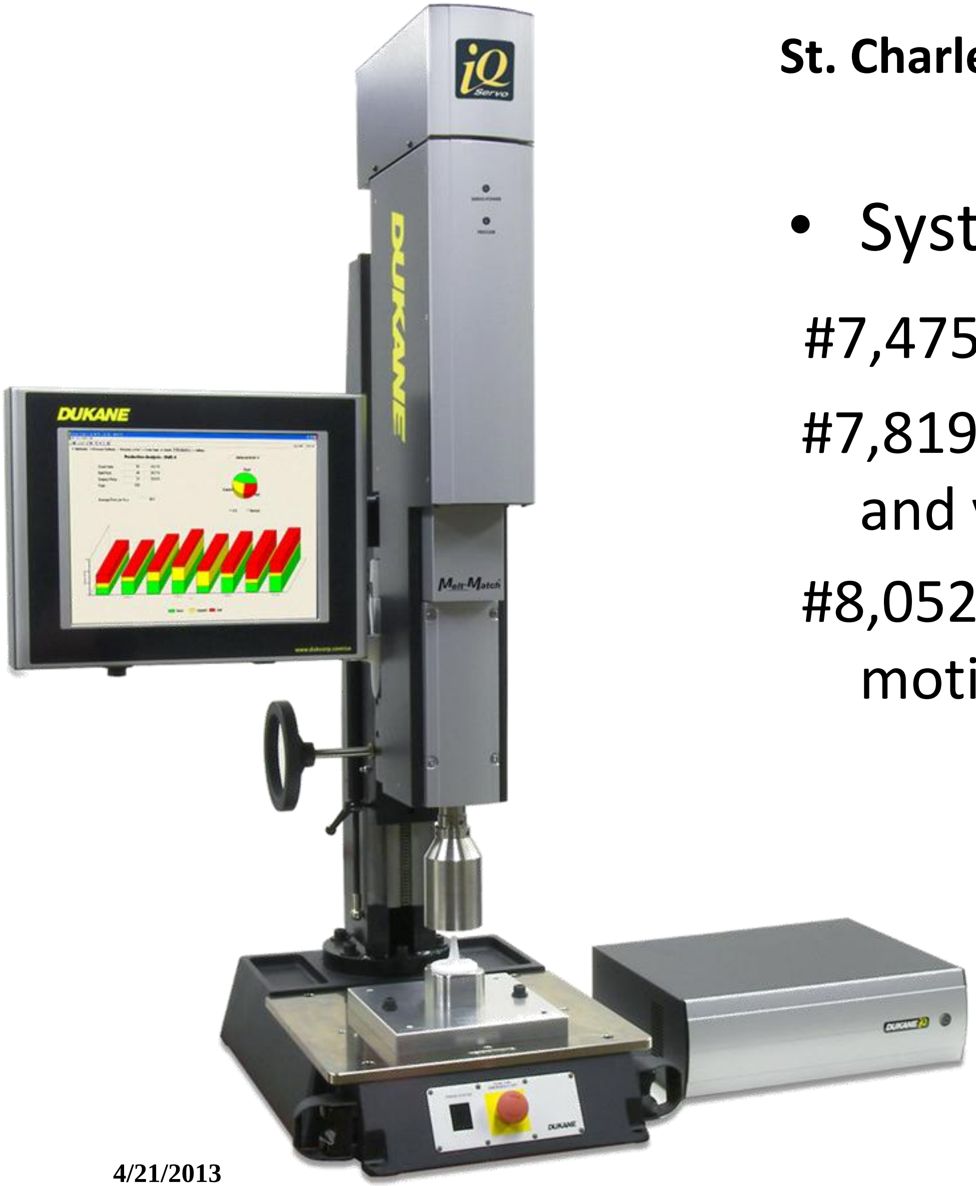
Validation
Calibration

iQ Servo

FDA compliant

- Simplified Validation Servo vs. pneumatic
- No operator controls - eliminates unauthorized machine adjustments
- All mechanical adjustments require tool.

Developed and Manufactured by Dukane



St. Charles, IL

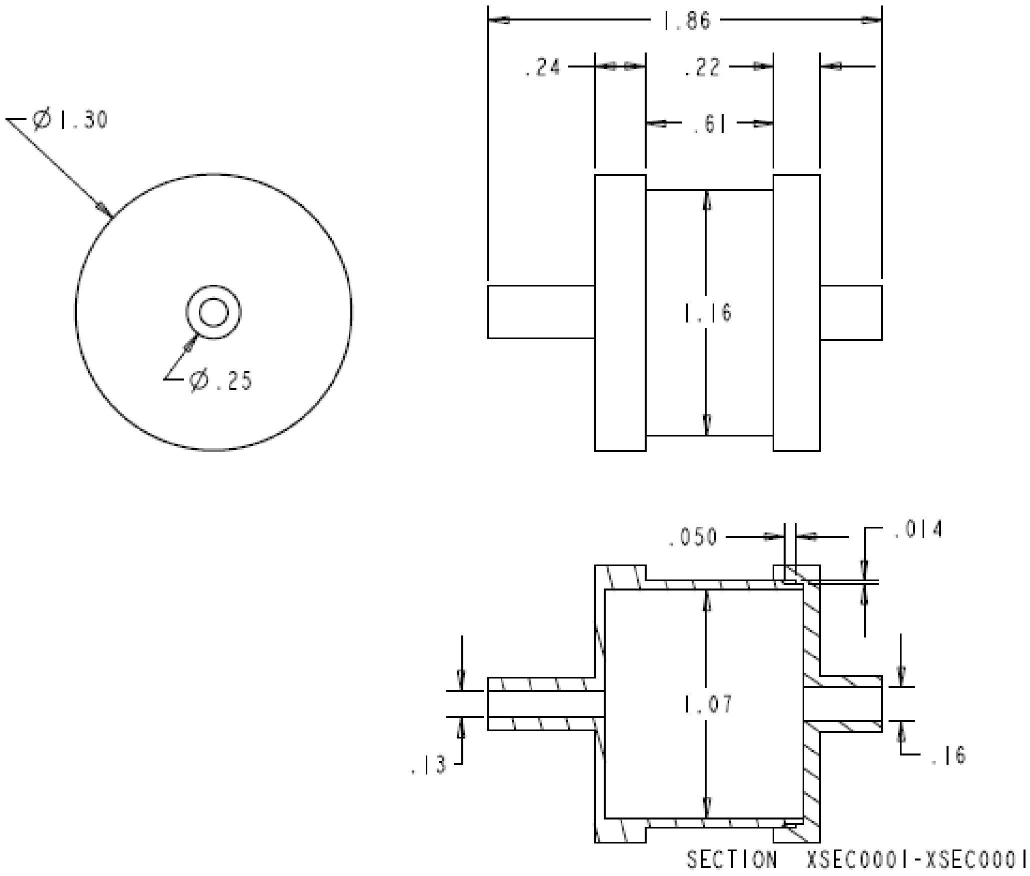
- System Patents

#7,475,801 - iQ Generator

#7,819,158 – Servo packaging and velocity/force profiling

#8,052,816 – Servo with delayed motion

Earlier Experiment



Common ultrasonic shear joint design.

Comparison of Collapse Distance Repeatability For Pneumatic and Servo Welders (round filters Polycarbonate parts)

	Pneumatic	Servo
Average Collapse (in.)	0.0179”	0.0172”
Standard Deviation (in.)	0.0004”	0.0001”

Comparison of Pull Strength Repeatability For Pneumatic and Servo Welders (round filters Polycarbonate parts)

Normalized Data to compensate for uneven Collapse Distance	Pneumatic	Servo
Average Pull Strength per Inch of Weld Depth (Collapse Distance) (lb./in.)	56,730	57,610
Standard Deviation (lb./in.)	8600 (15.2%)	1140 (2.0%)

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3. M. Knights. “Graphical Analysis Helps Find and Fix Ultrasonic Welding Problems” *Plastics Technology. Sept 2005.*
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9. A. Mokhtarzadeh and A. Benatar. "Comparison of Servo and Pneumatic Ultrasonic Welding of HDPE Shear Joints" ANTEC 2011.

10. S. T. Flowers. "Servo-Driven Ultrasonic Welding of Biocomposites" ANTEC 2012.

11. S. Anantharaman and A. Benatar. "Measurement of Residual Stress in Laser Welded Polycarbonate using Photoelasticity" ANTEC 2003.

12. "Specification for Standardized Ultrasonic Welding Test Specimen for Thermoplastics" American Welding Society G1.2M/G1.2:1999.

Questions?