# Fundamentals of the Ultrasonic Plastics Welding

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# Agenda

- Process Theory
- Systems & Components
- Tooling- Fixture & Horn Technology
- Materials & Design
- Ultrasonic Techniques
- Machine Set-up considerations
- Process Control and monitoring
- Applications
- Troubleshooting

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# Plastics Assembly/Processing

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Hotplate

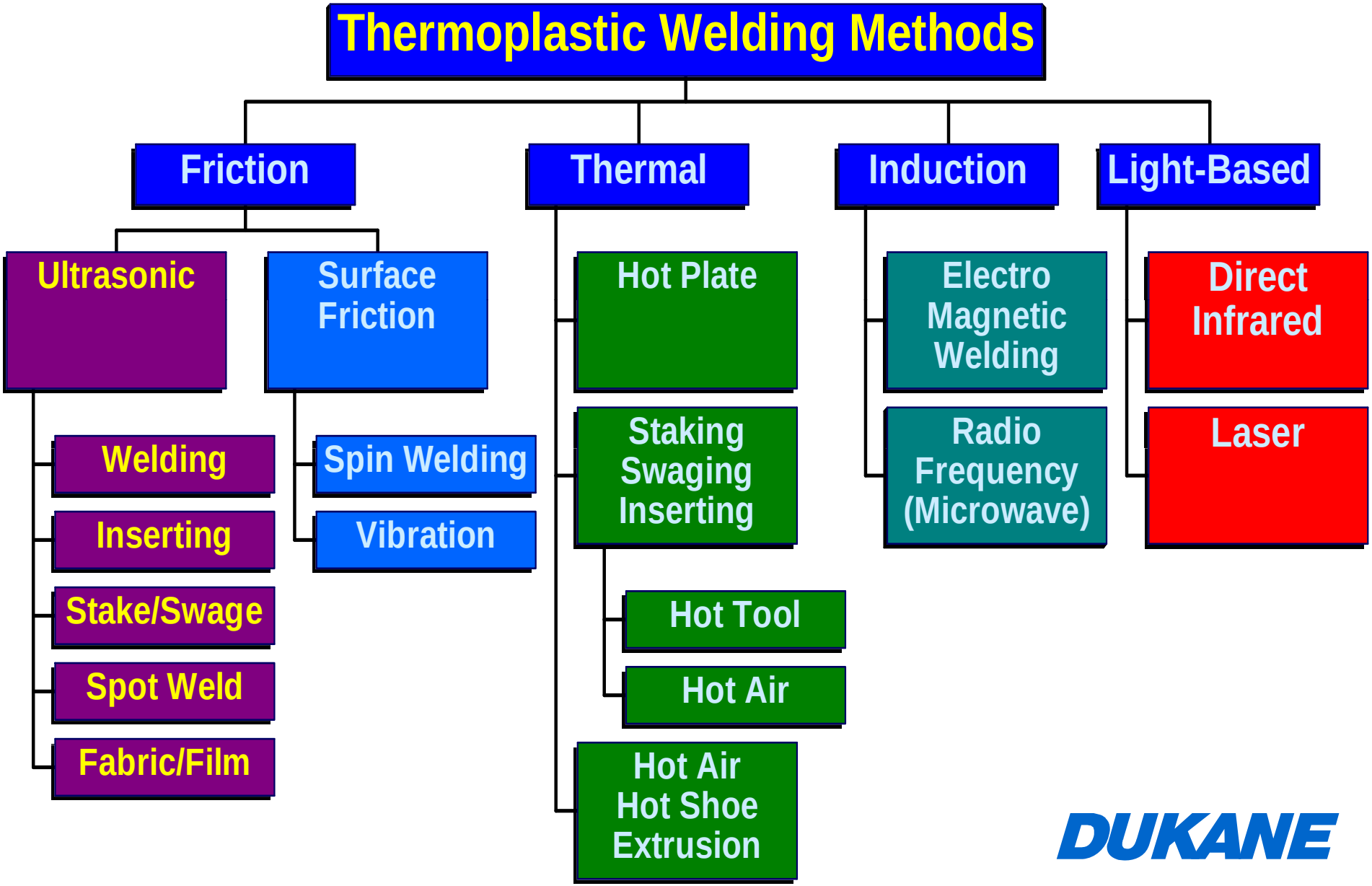

Ultrasonic


Vibration

Laser

Thermal


Spin


Thermoplastic Welding Methods
Friction
Thermal
Induction
Light-Based
Ultrasonic
Surface Friction
Hot Plate
Electro Magnetic Welding
Direct Infrared
Welding
Inserting
Stake/Swage
Spot Weld
Fabric/Film
Spin Welding
Vibration
Staking
Swaging
Inserting
Hot Tool
Hot Air
Hot Air
Hot Shoe
Extrusion
Radio Frequency (Microwave)
Laser
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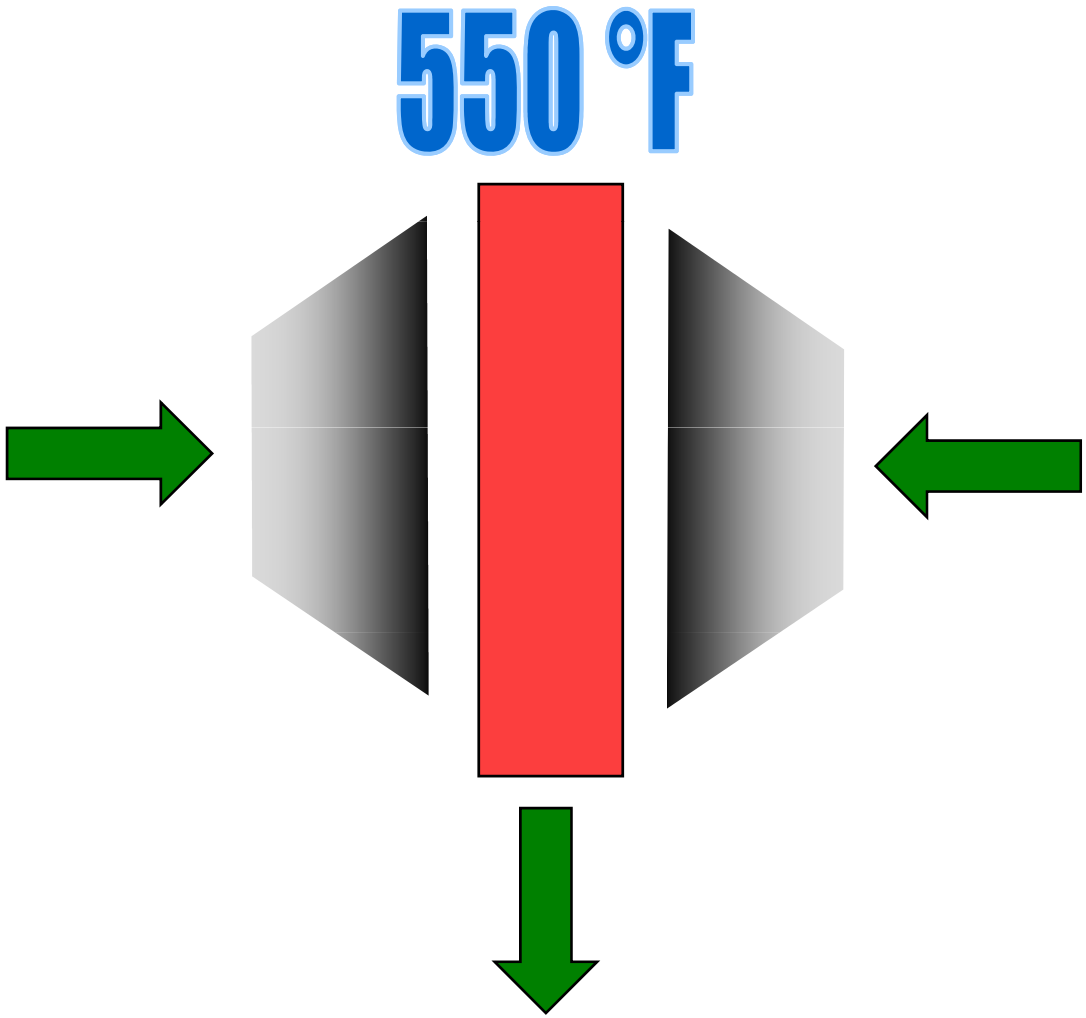
# Hot Plate Welding





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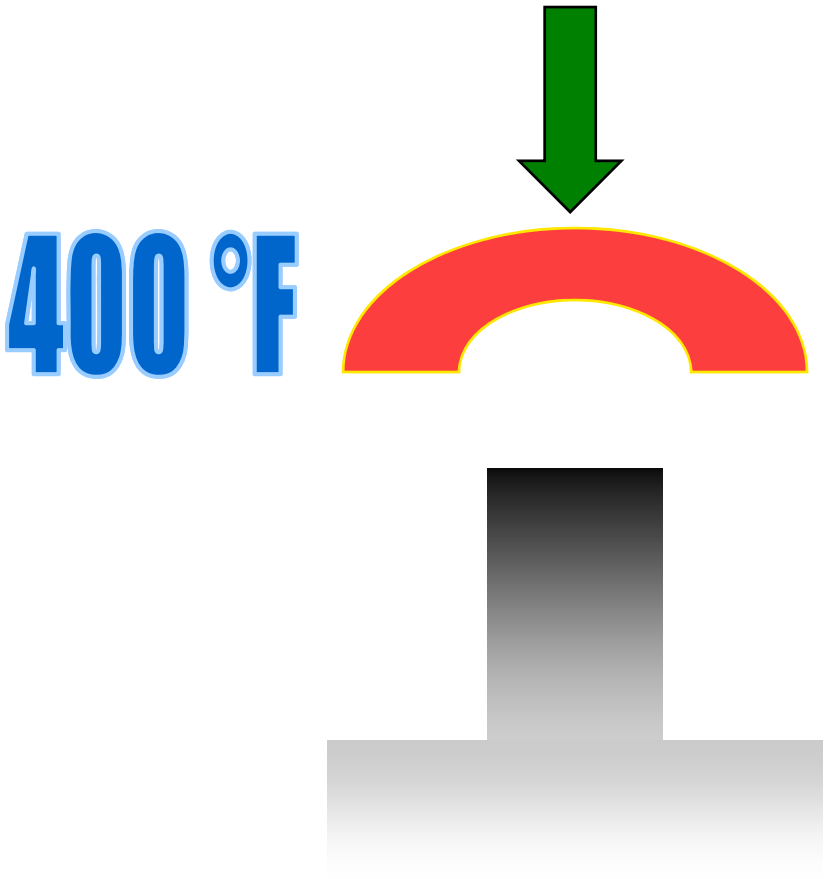
# Thermal Staking

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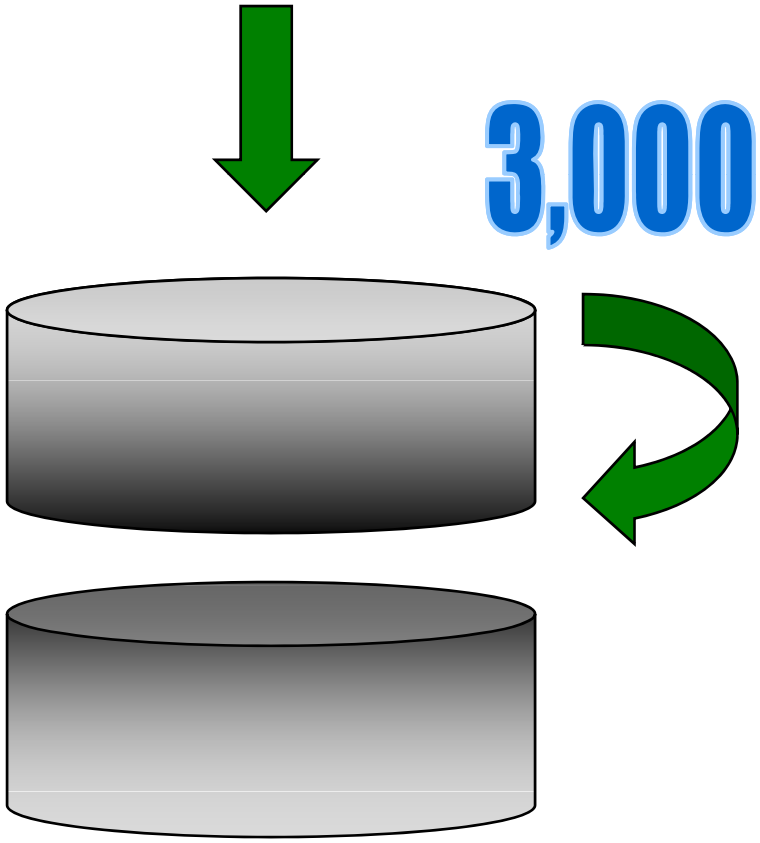
# Spin Welding



3,000 rpm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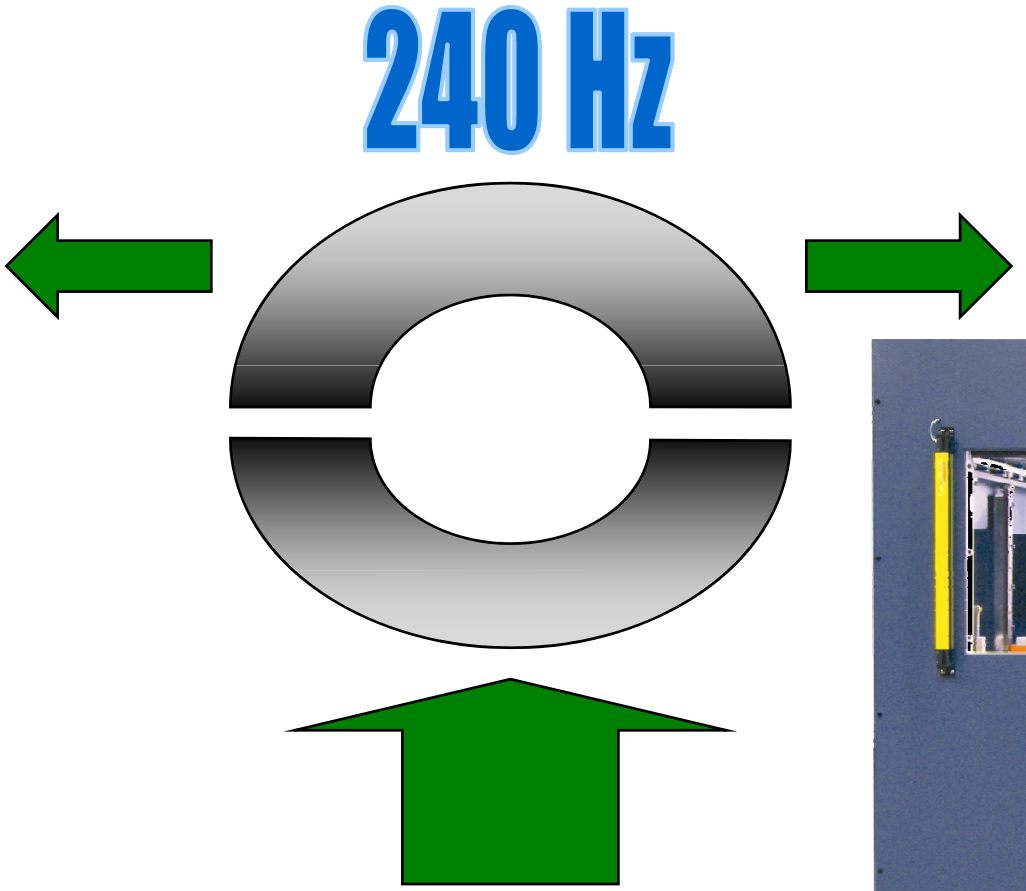
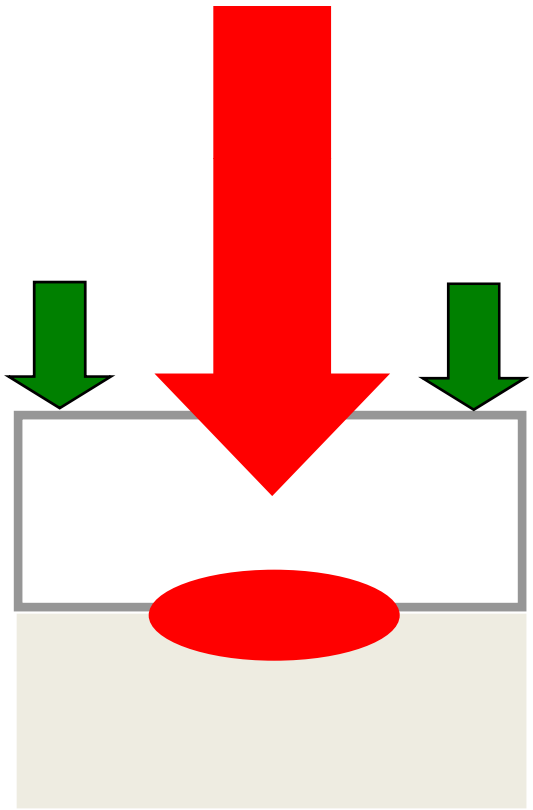
# Vibration Welding




# Laser Welding



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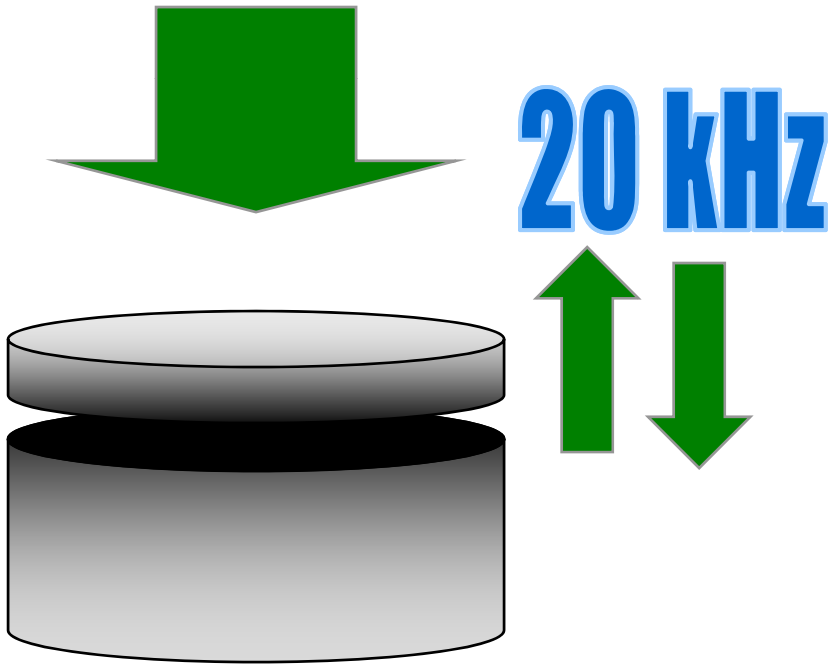
# Ultrasonic Welding





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Ultrasonics - vibratory mechanical motion in frequencies typically above the range of human hearing

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# System Components

- Generator/Controller/Power Supply
- Press
- Transducer
- Booster
- Horn
- Fixture

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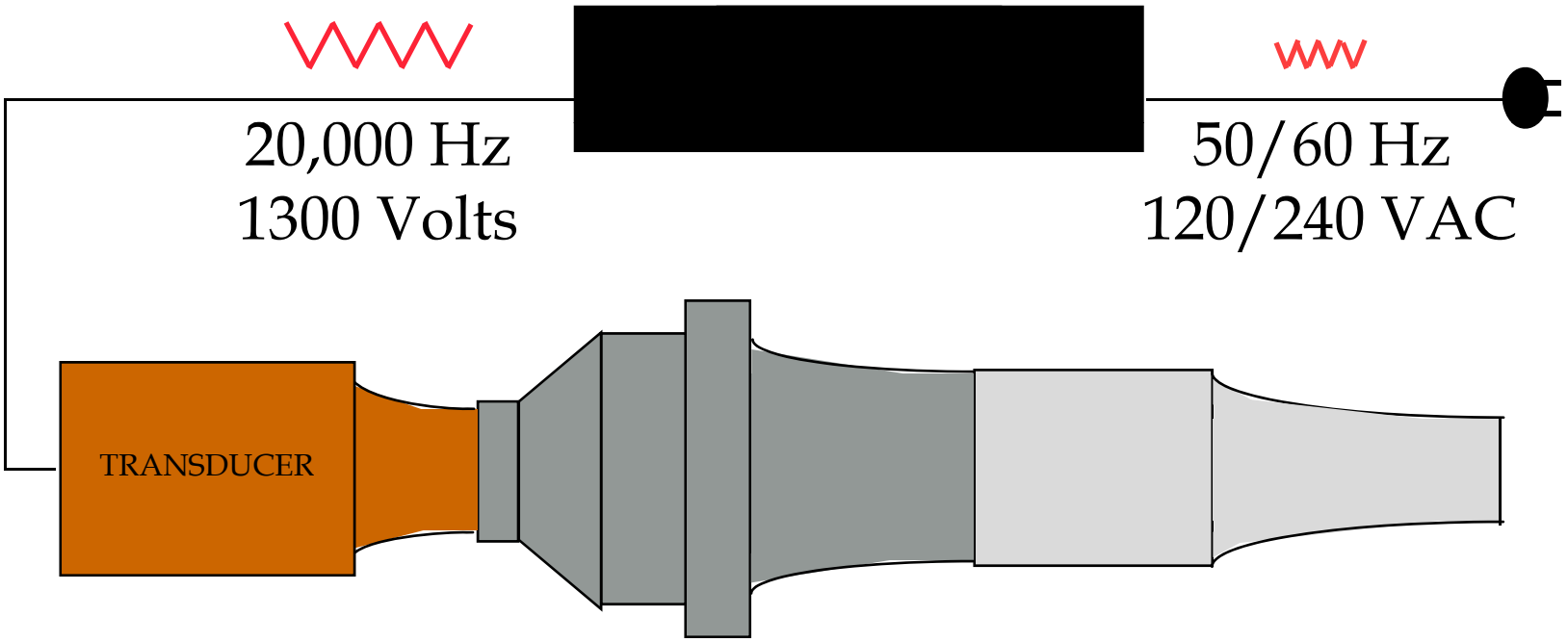
# Conversion of Electrical Energy to Mechanical Motion




0.0008” (20 µm) @ 20 kHz **X** Booster Gain **X** Horn Gain = Amplitude

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# Transducer Driver

# Transducer/ Converter

# Hand Probe

# Generator/Process Controller


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# Booster

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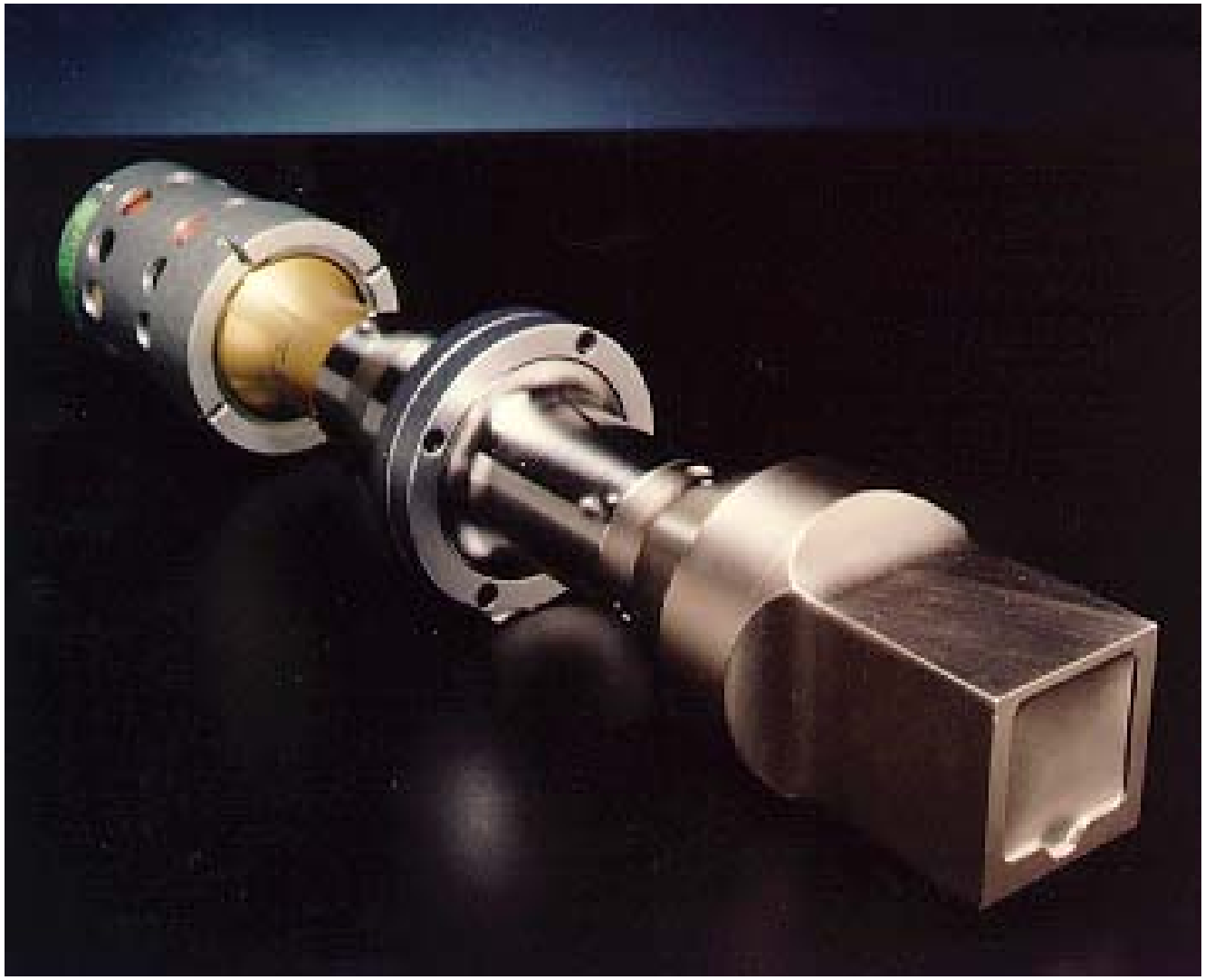
# Stack Assembly



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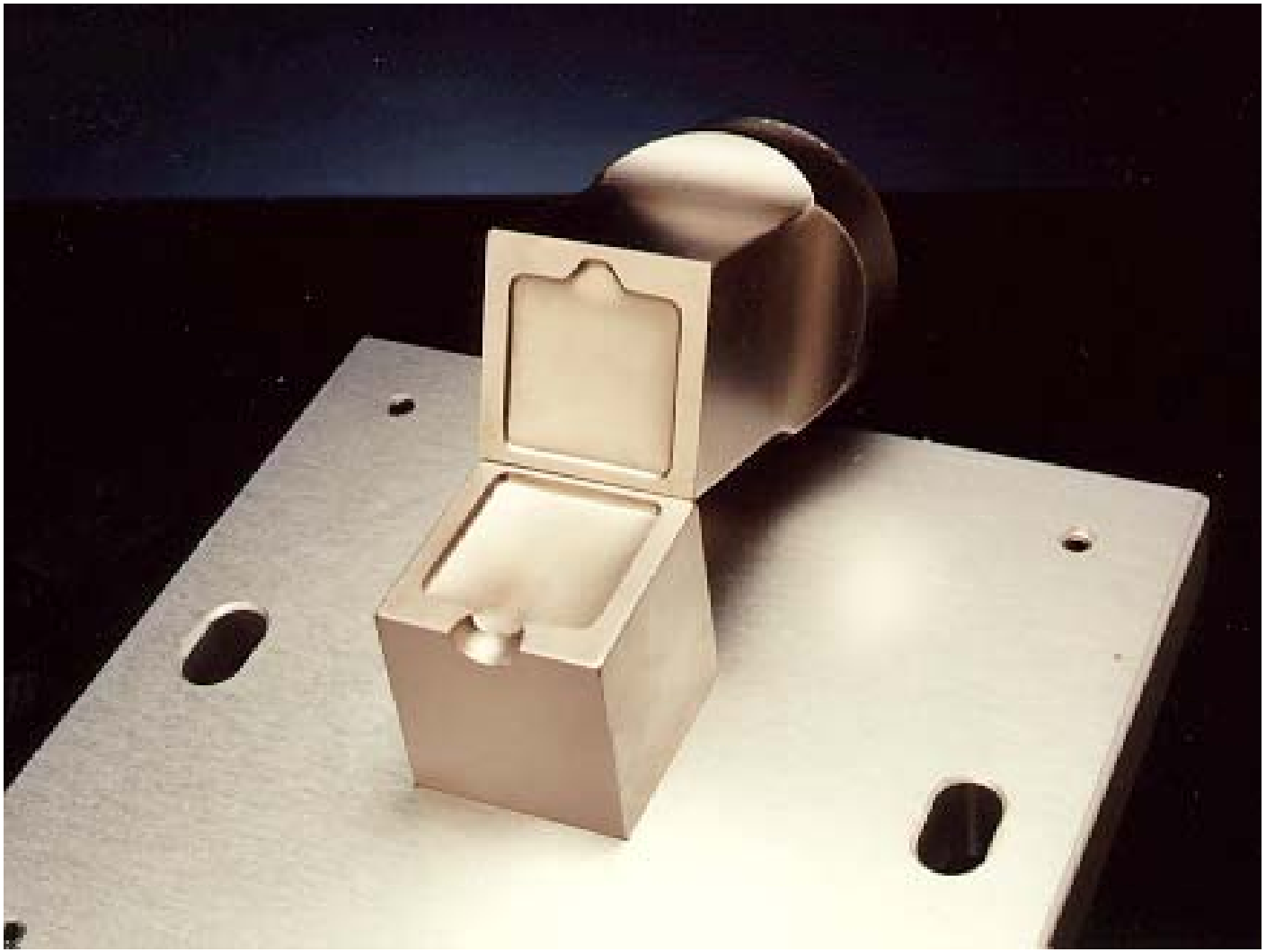
# Horn & Fixture



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# Ultrasonic Welding

- Vibration
- Friction
- Heat
- Melt
- Weld
- U/S Off and Hold Cycle

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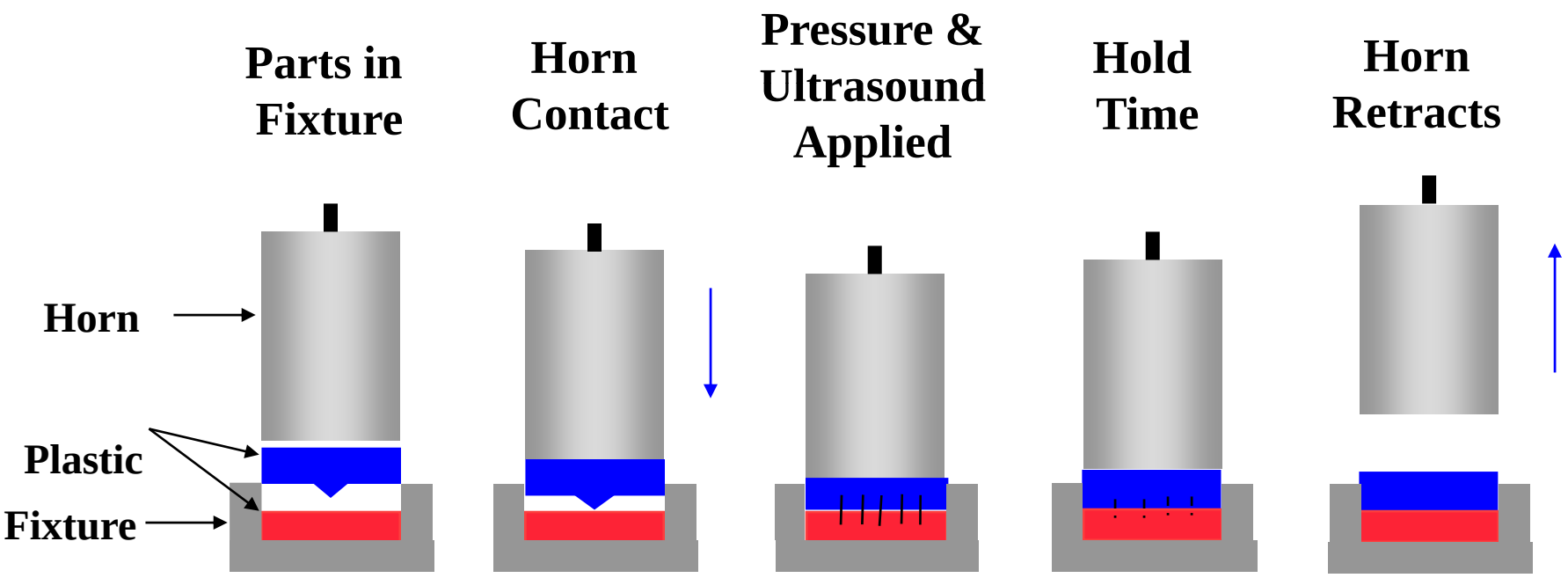
# How a Weld is achieved

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# Why use Ultrasonics in Plastic Welding?

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# Advantages

- No consumables
- Fast cycle Times
- Very accurate
- Highly repeatable
- Versatile equipment
- Parts are easily recycled
- Environmentally safe
- No foreign materials added

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# Industries that use Ultrasonics Plastic Welding

- Medical
- Automotive
- Electronics
- Consumer Products
- Toys
- Packaging
- Appliance

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U.S. MAIL
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Ultrasonics
PAMPRYL
Lactantia
Lait 1%
Partiellement écrémé
Lactantia
Lait 2%
Partiellement écrémé
BASKETBALL
Premium Plus

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# Systems Available

- Hand Held
- Probe
- Press/Thruster
- Rotary/Automated




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# Operating Frequencies
# 15, 20, 30, 40, 50 kHz

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# Advantages of Higher Frequencies

- Higher frequency - lower amplitude
- Gentle welding provides maximum control on small delicate parts
- Lower mechanical and thermal stress to small parts
- Low noise

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# Horns or Sonotrodes

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# “Amplitude”

- The peak-to peak excursion, or travel distance, of the vibration of a booster or horn at its work face.

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# “Gain”

- The ratio of output amplitude to input amplitude of a booster or horn
- GBW - Gain-Bandwidth relationship

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# How to Determine the Booster Ratio to Use

**20 kHz**

**Transducer Amplitude X Booster Gain X Horn Gain = STACK AMPLITUDE**

**Stack Amplitude ≥ Resin Amplitude Requirement**

- Transducer Amplitude ..... 0.0008 inches
- Resin amplitude requirement.... (i.e. Polycarbonate) 0.004 inches
- Horn gain factor..... (.5” diameter exponential) 4:1

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*Plug in the numbers to do the math and solve for* ***BOOSTER GAIN:***

- .0008” *(Transducer Amp.)* x 4 *(Horn Gain)* = .0032”
- .004” *(Polycarb)* /.0032” =
- Booster gain 1.25 :1

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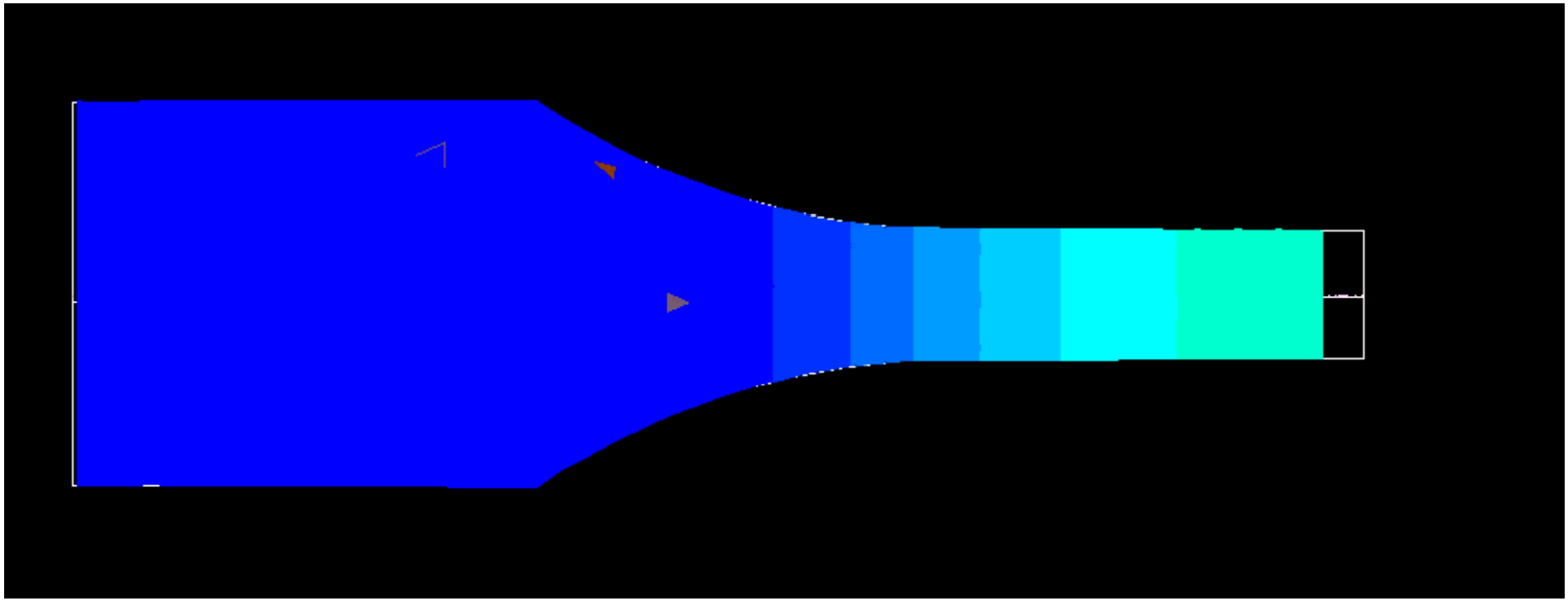
# Amplitude Demonstration



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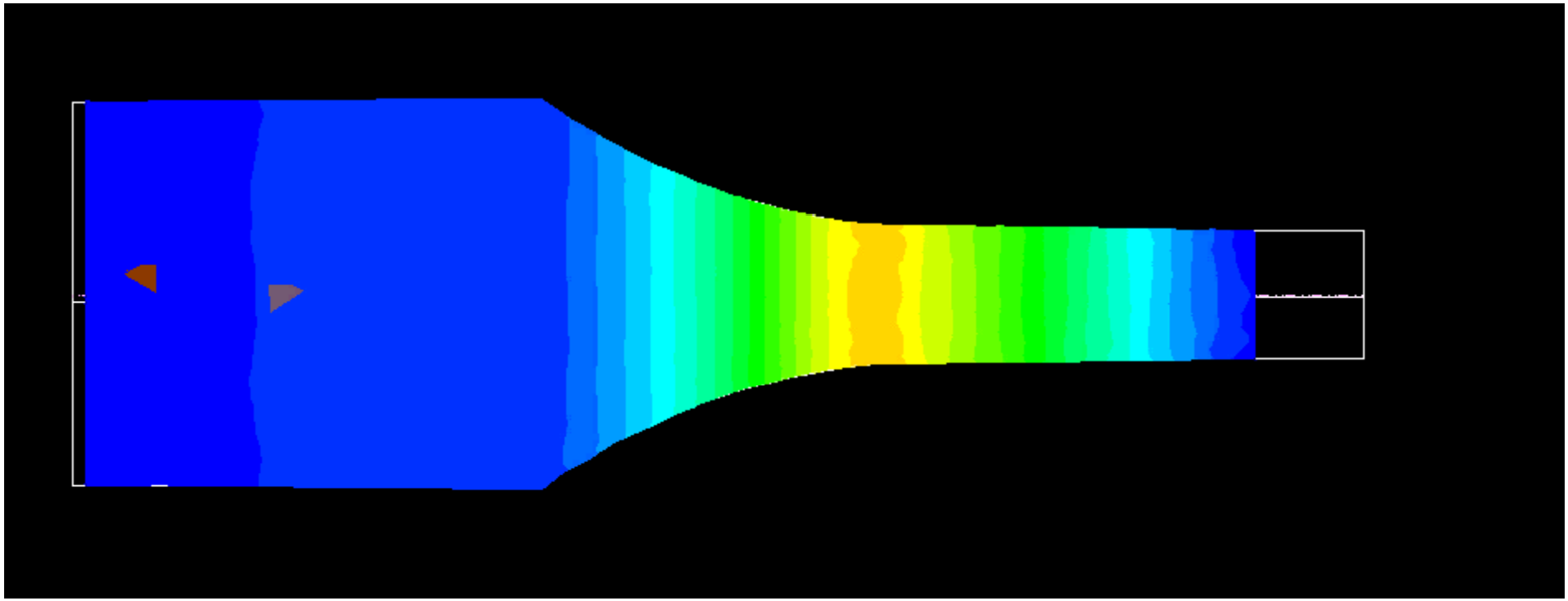
# Stress Demonstration



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# Various types of horns

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# Horn Materials

- Titanium
- Aluminum
- Hardened Steel or Steel Alloys

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# Horn Tuning Ranges

- **20 kHz**
  - 19,950 Hz -------- 20,050 Hz
- **40 kHz**
  - 39,900 Hz -------- 40,100 Hz

***Tuned to frequency, not length.***

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# Horn Tuning Ranges

- **30 kHz**
  - 29,925 Hz -------- 30,075 Hz
- **15 kHz**
  - 14,965 Hz -------- 15,035 Hz

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# Types of Plating

- Chrome
- Nickel
- Teflon/Nickel
- Carbide
  - Brazed Slug
  - Carbide Coating

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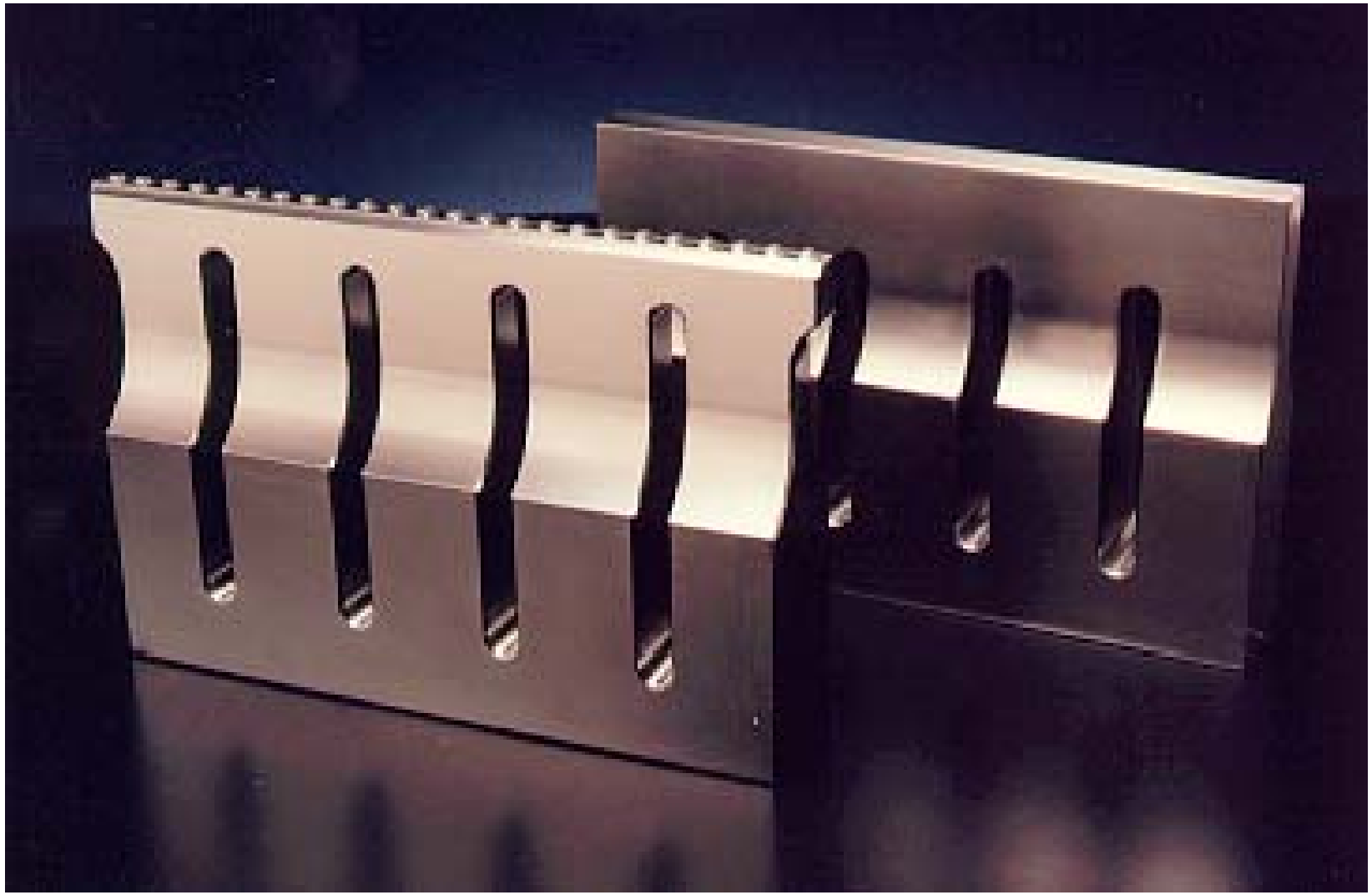
# Slotted Horns



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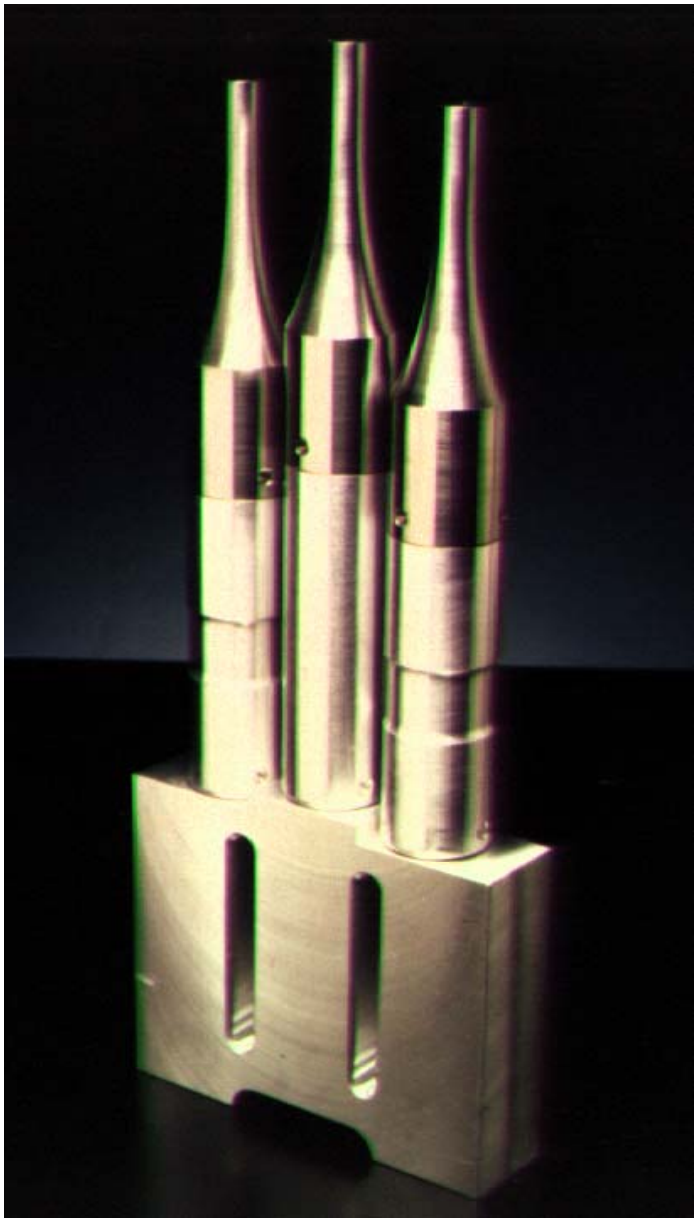
# Composite Horns



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# Composite Horns

# Half & Full Wave Horn

# Replaceable Tip Horns

# Nodal Mounted Plunger Horn

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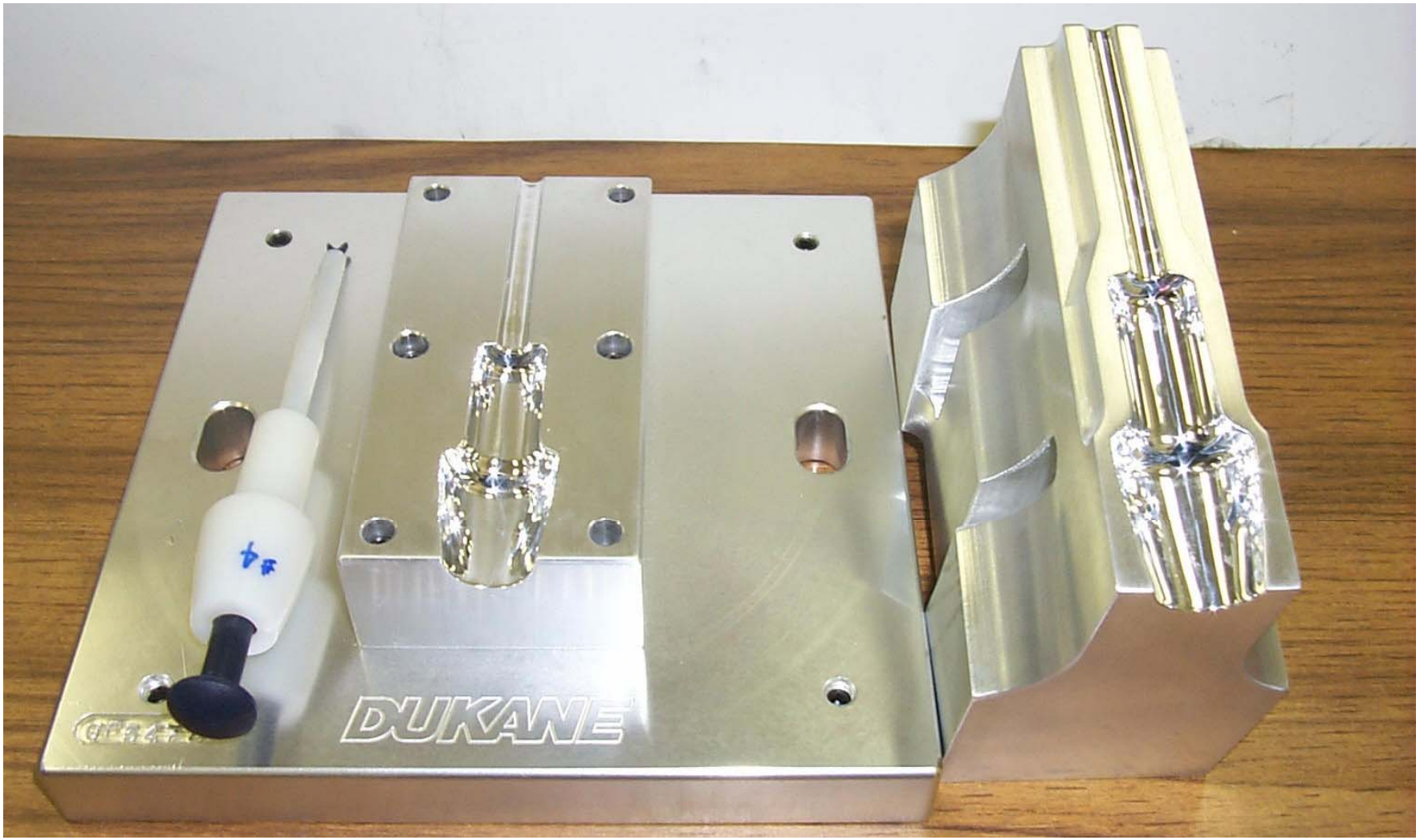
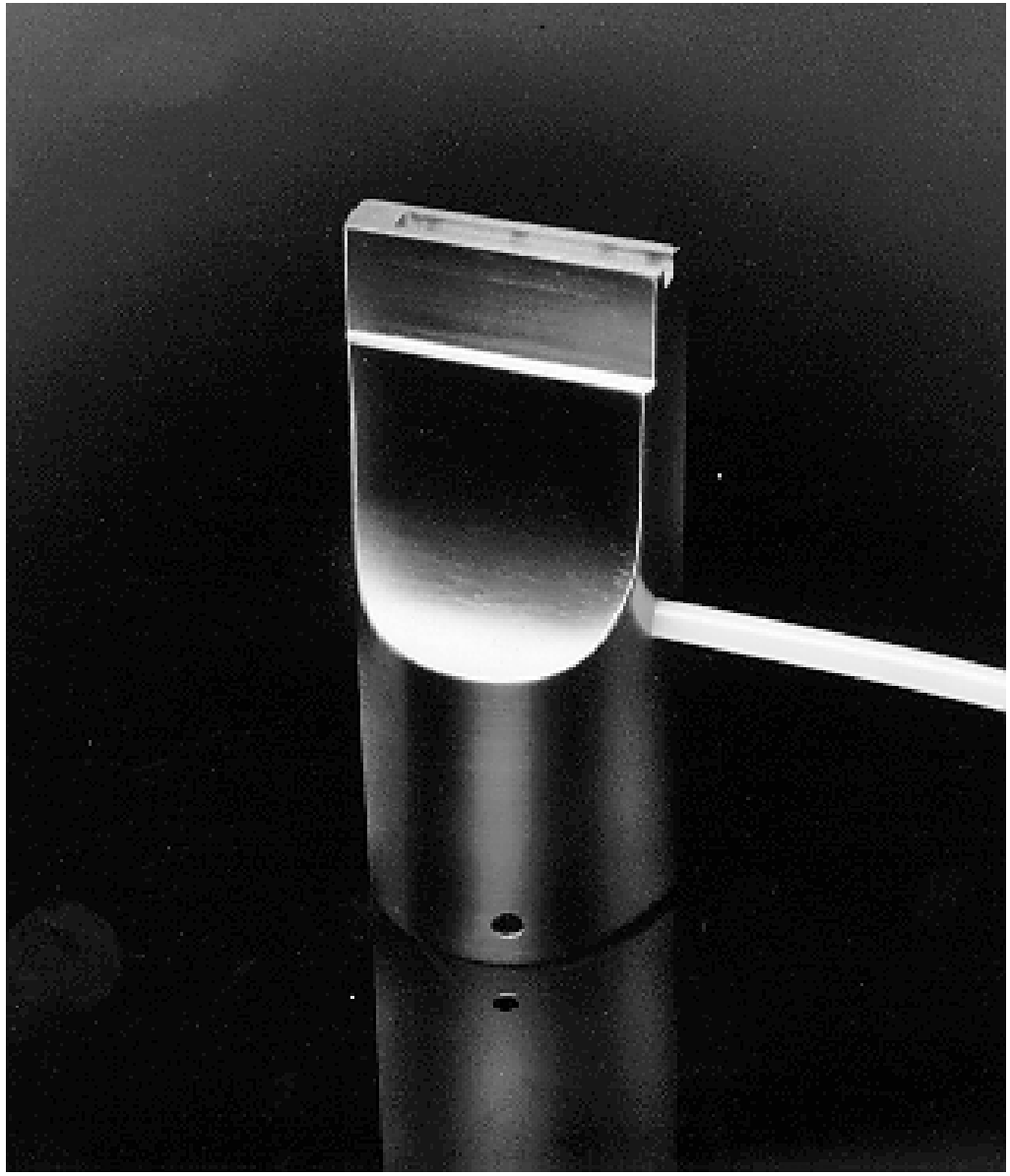
# Trace Milled Horns

# Trace Milled Horns



# Vacuum Horns



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# F.E.A. Modeling of Acoustical Tools (Horns)

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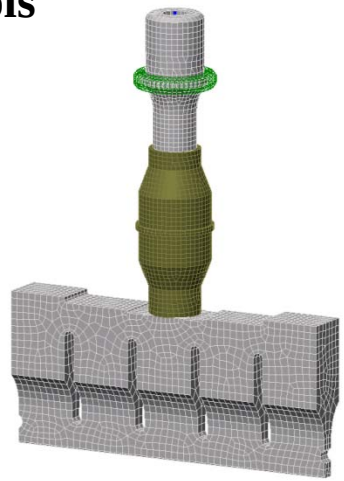
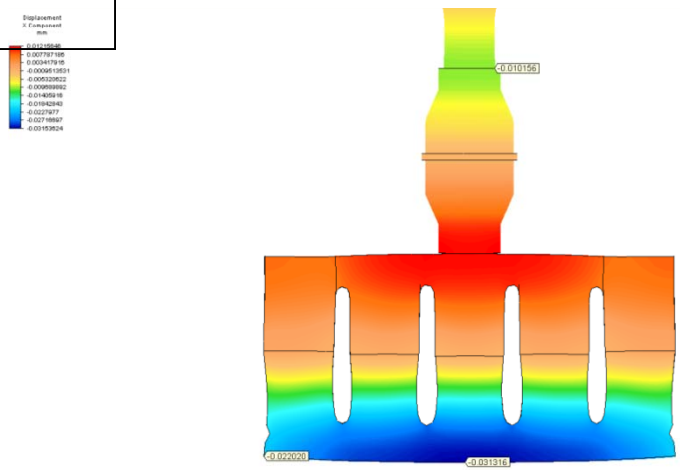
**Case #1 - 12.000” X 0.500” Horn**

**Amplitude Variation reduced from 18.6 um to 8.0 um**

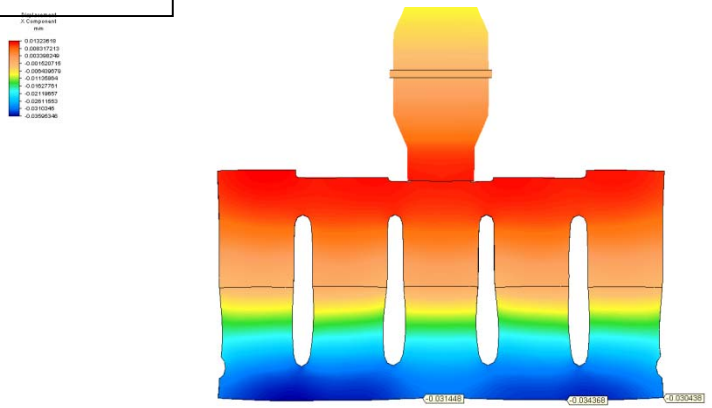
**F.E.A. Modeling of Acoustical Tools**



**Initial Design**



**Optimized Design**



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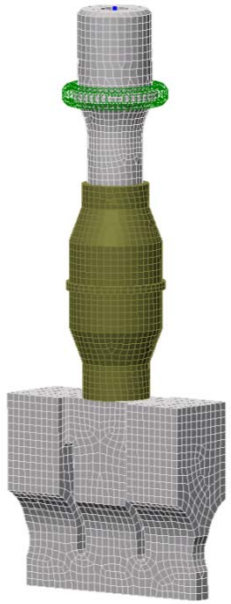
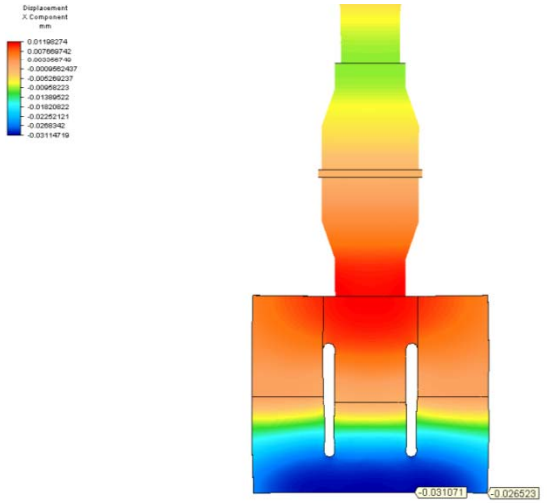
**Case #2 - 0.500” X 6.000” 20khz Horn**

**Amplitude variation reduced from 9.0 um to 2.6 um**

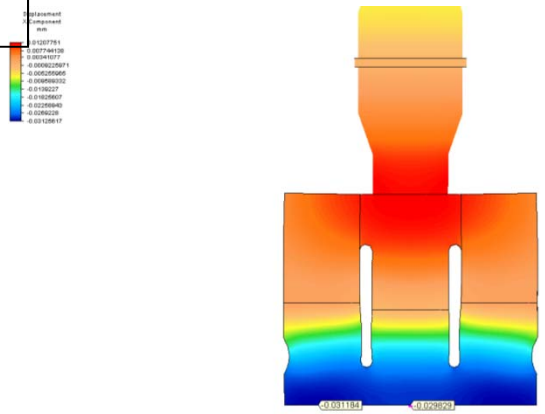
## F.E.A. Modeling of Acoustical Tools



## Initial Design




## Optimized Design



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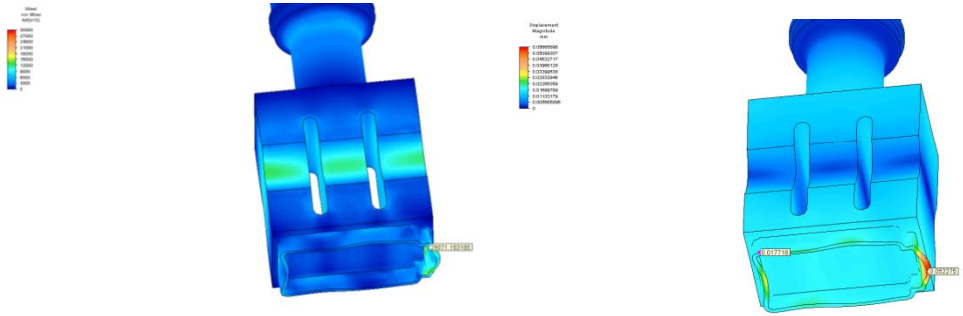
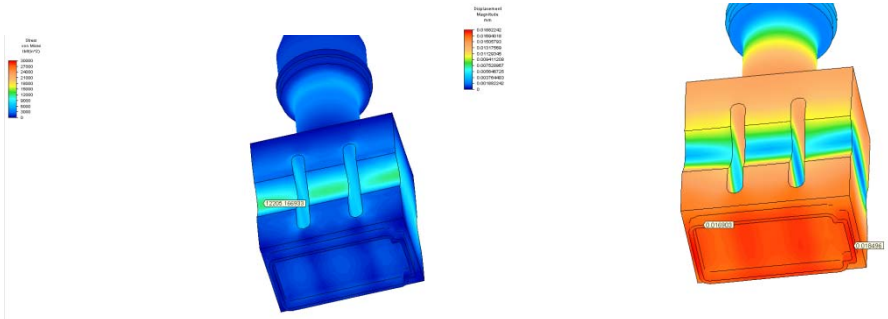
**Case #3 – 4.000” X 2.500” 20khz Block Horn with a tall and narrow weld pad.**

- **Stress reduced from 29,000 psi to 12,200 psi**
- **A very large sideways motion eliminated**
- **Amplitude variation of only 3.2 um**

## Initial Design



## Optimized Design



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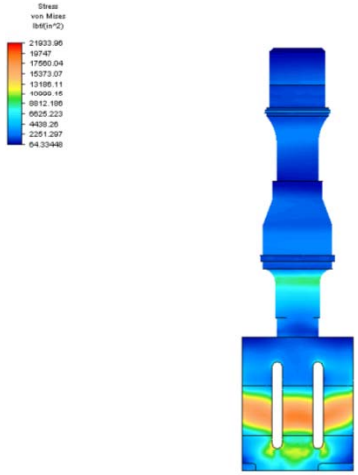
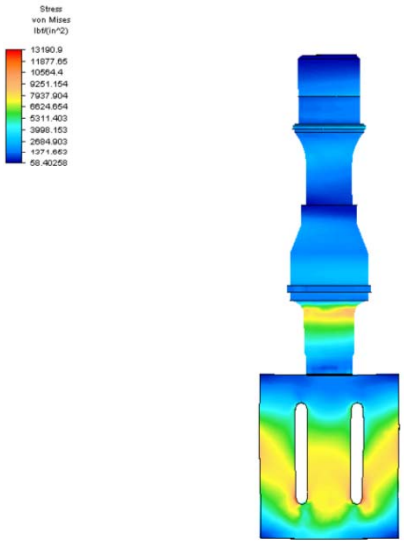
**Case #4 – 4.000” X 2.750” 20khz Block Horn with a contoured face.**

**• Stress reduced from 21,900 psi to 13,200 psi**

## Initial Design




## Optimized Design

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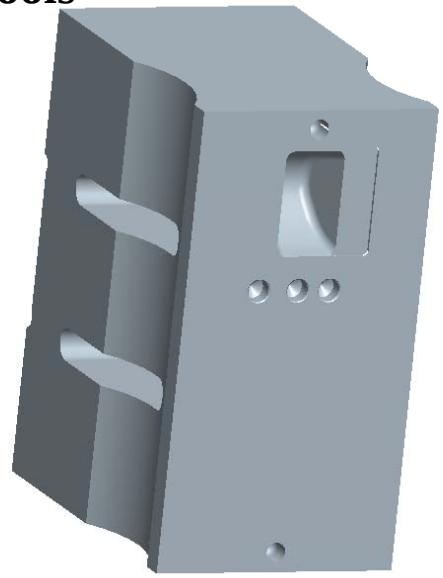
**Case #5 – 6.000” X 3.200” 20khz Block Horn with a non-symmetric face**

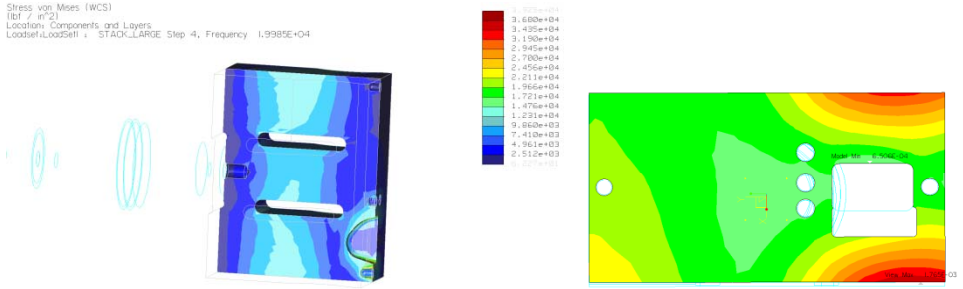
- **Stress reduced from 39,300 psi to 19,600 psi**

- **Amplitude variation reduced from 56um to 13um**

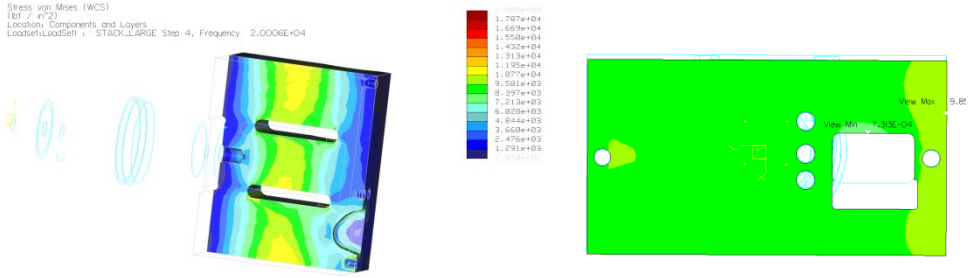
# F.E.A. Modeling of Acoustical Tools



## Initial Design




## Optimized Design

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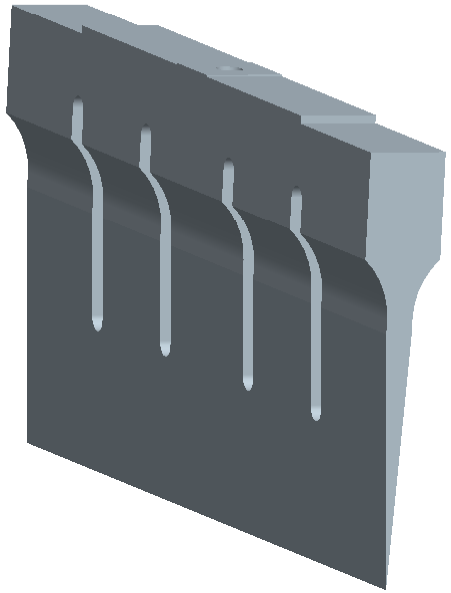
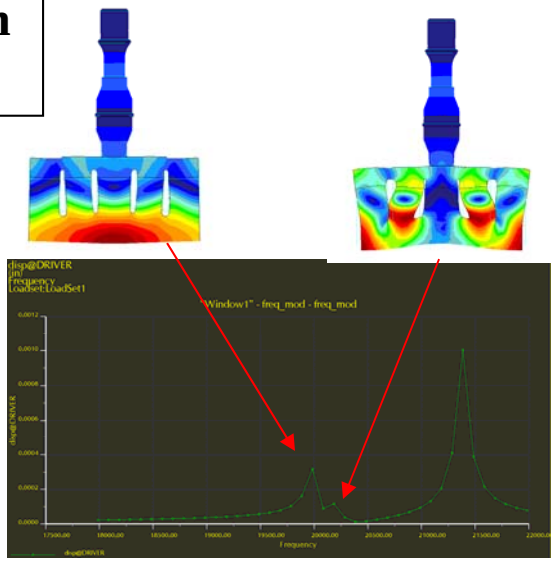
**Case #6 - 12.000” 20khz Cutting blade**

**Elimination of secondary frequency that occurred too close to 20 kHz**

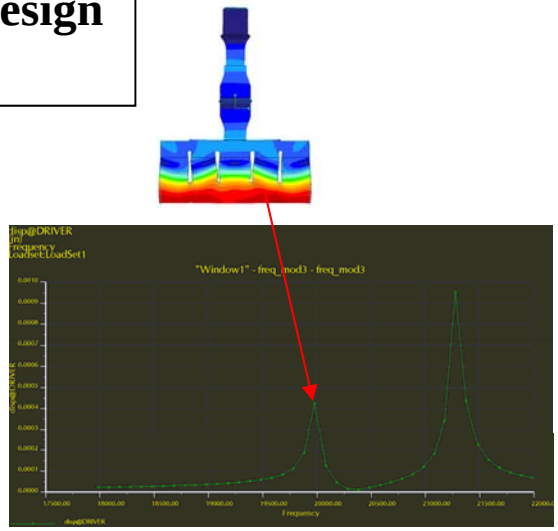
# F.E.A. Modeling of Acoustical Tools



## Initial Design




## Optimized Design

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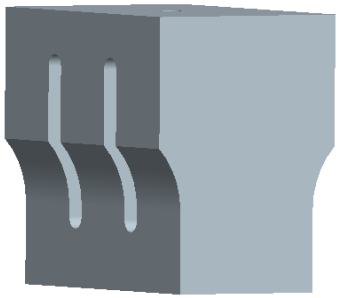
**Case #7 - 6.800” X 3.400” 15khz Horn**

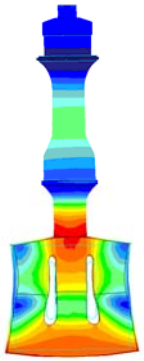
- **Secondary frequency moved away from primary frequency**

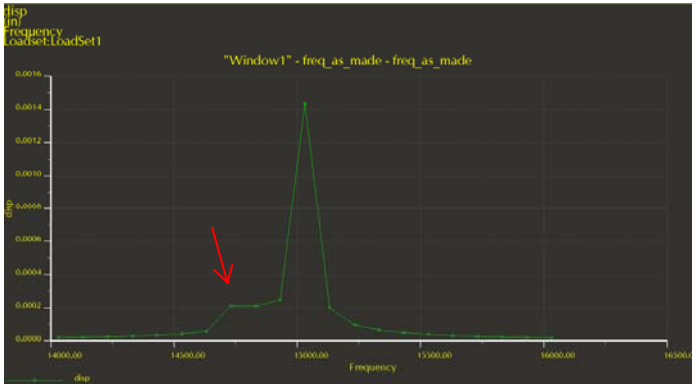
- **Maximum stress reduced from 17,000 psi to 10,000 psi**

# F.E.A. Modeling of Acoustical Tools

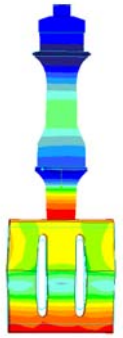


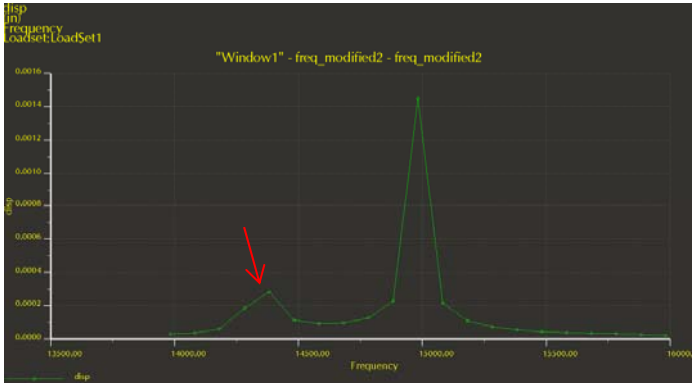
## Initial Design






## Optimized Design



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# Fixtures

- Alignment
- Support
- Means of Leveling

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# Types of Fixtures

- Rigid
  - Stainless Steel
  - Aluminum
  - Teflon / Delrin
- Resilient- reduces marking on soft materials
  - Polyurethane

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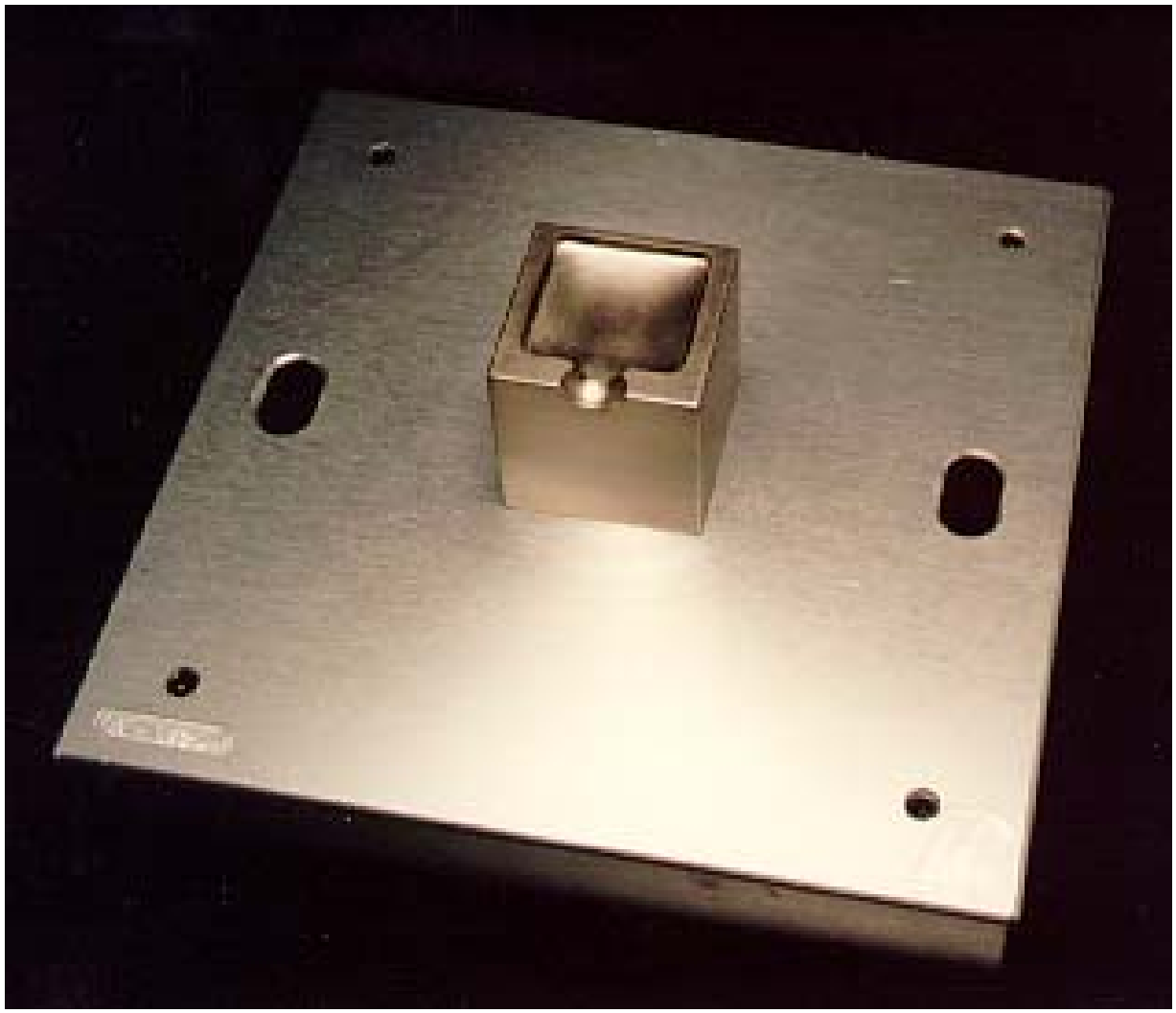
# Rigid Fixture - Stainless Steel



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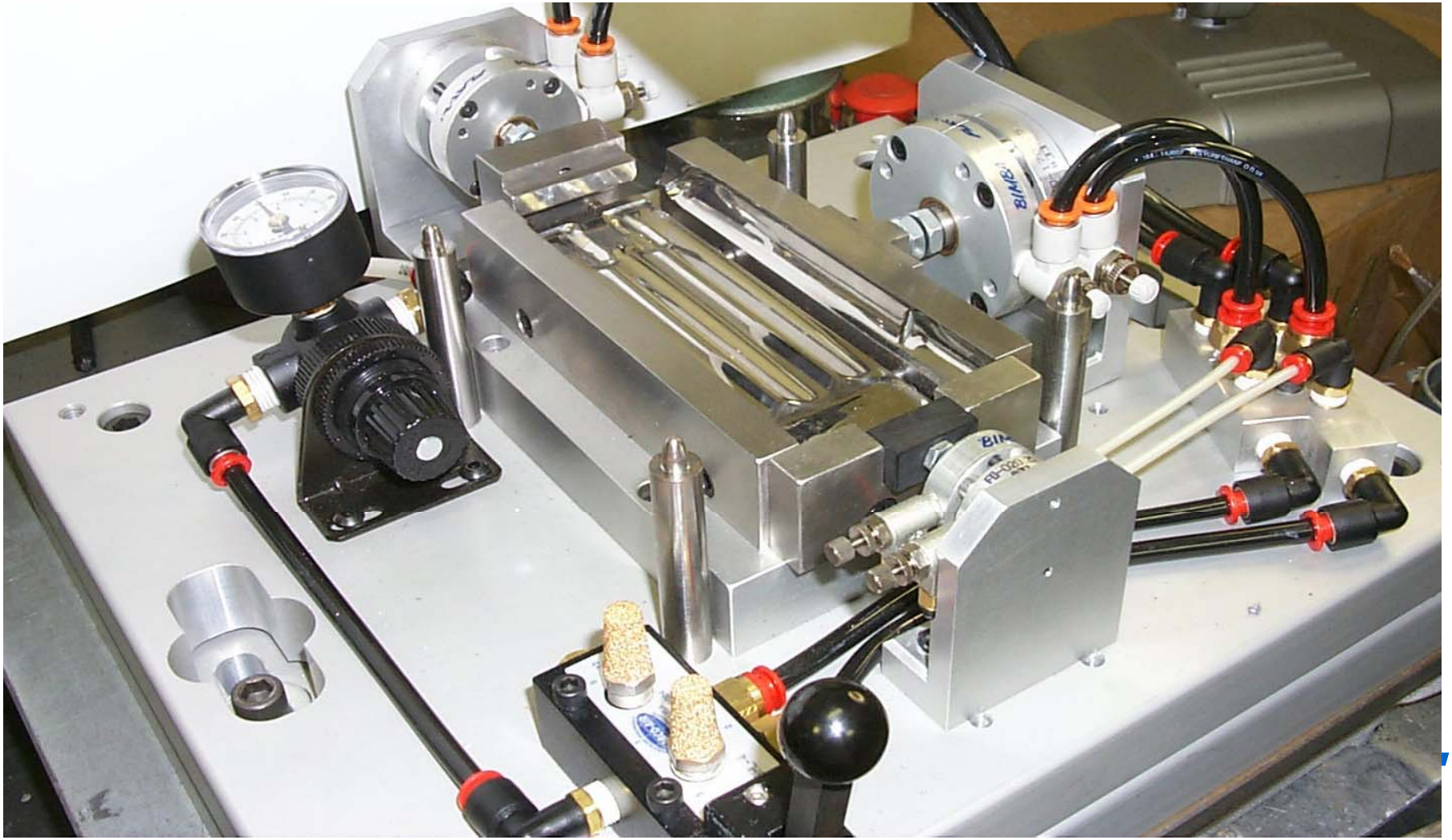
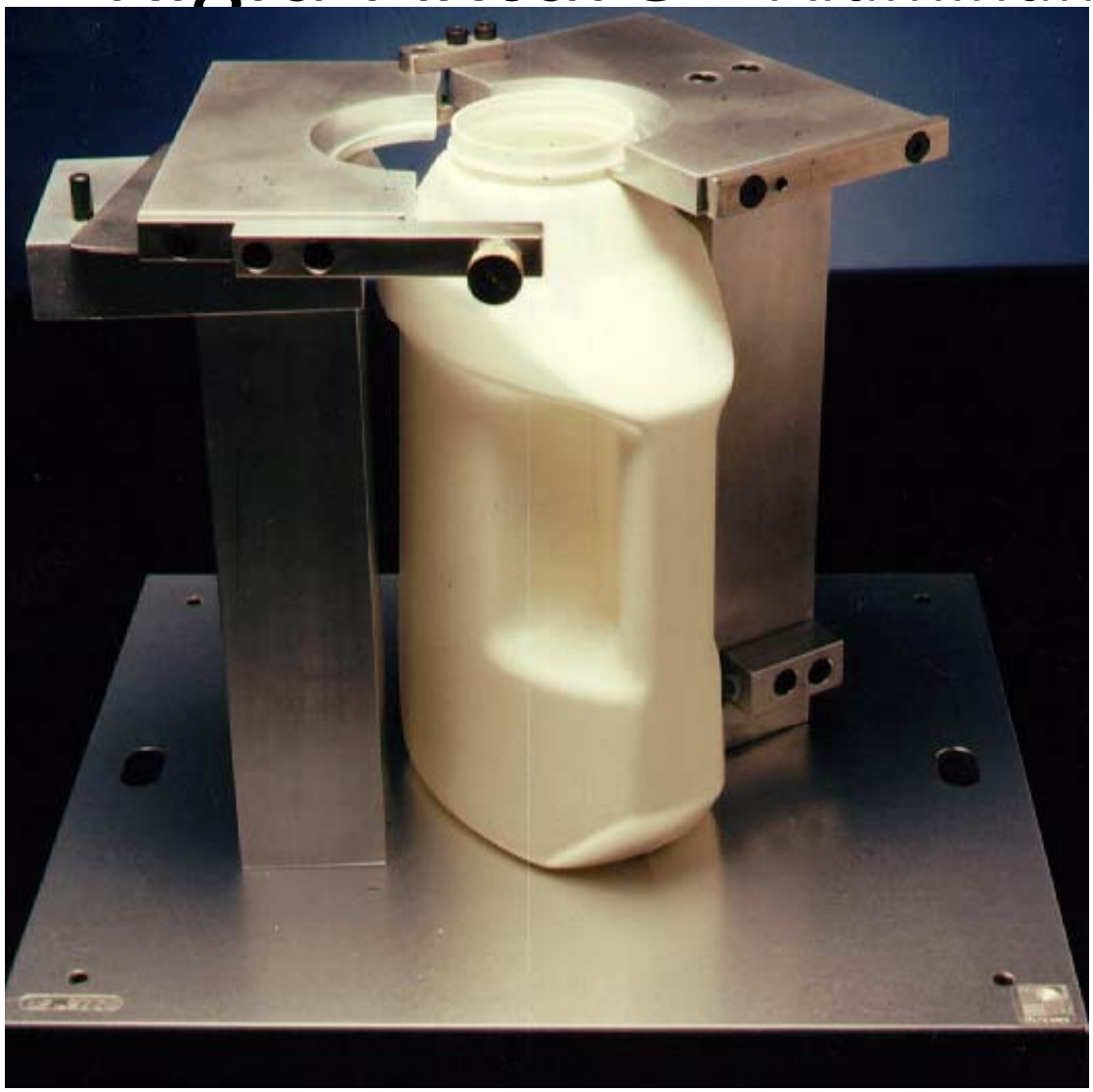
# Rigid Fixture - Contoured, Stainless Steel With Pneumatic Clamping on Three Sides



# Rigid Fixture - Aluminum



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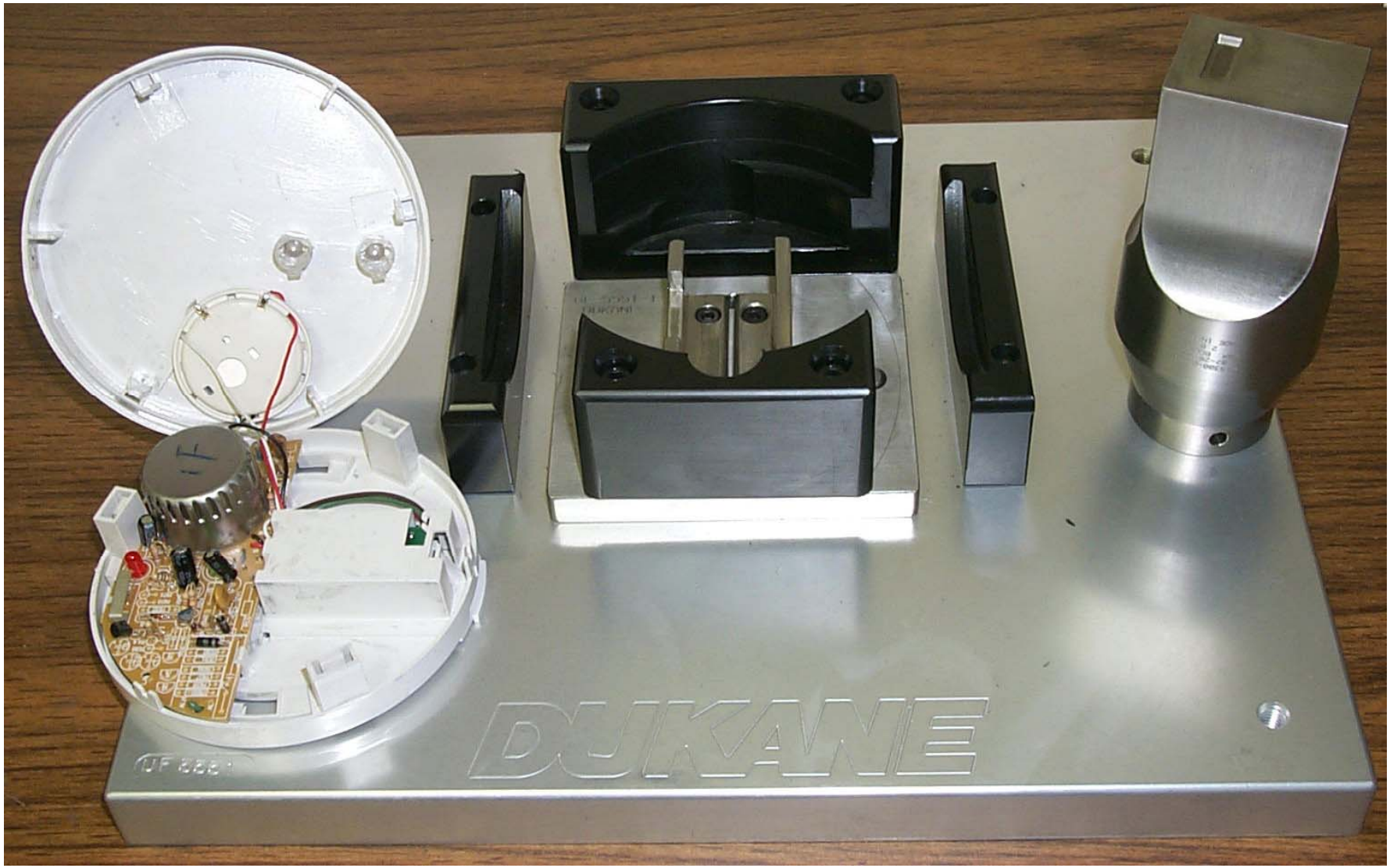
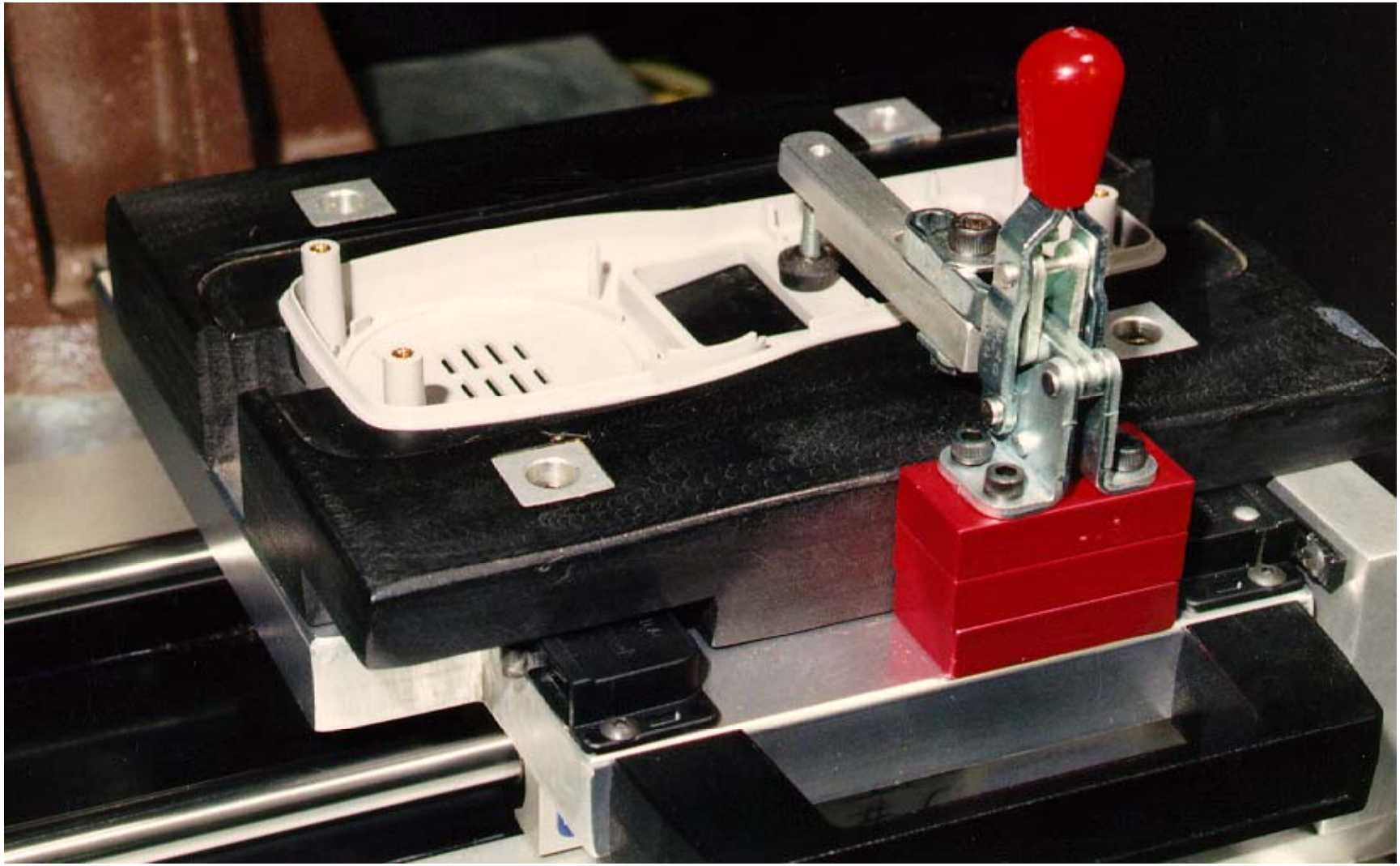
# Stainless/Delrin Fixture



# Two Position Slide Fixture



# Resilient Fixture - Polyurethane

# Plastic Parts

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# Polymers

- Thermoset- not weldable
- Thermoplastic
  - Amorphous
  - Semi-crystalline

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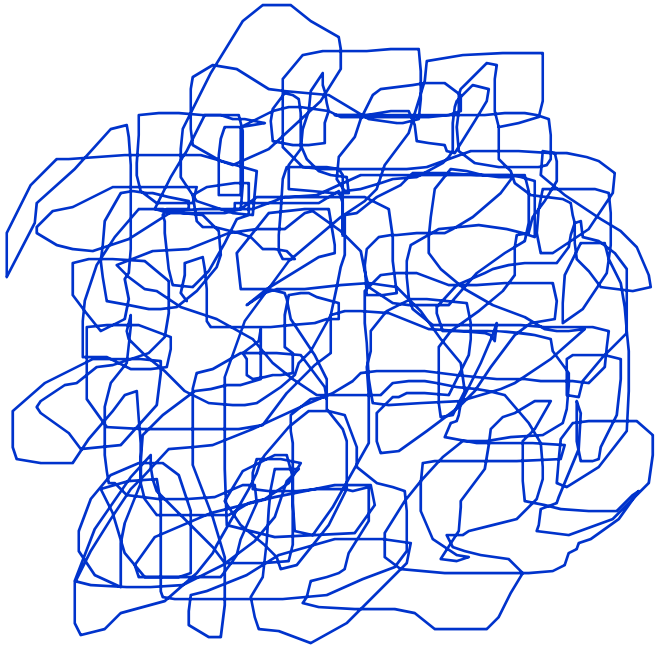
# Physical Structure

**Amorphous**



**Semi-crystalline**

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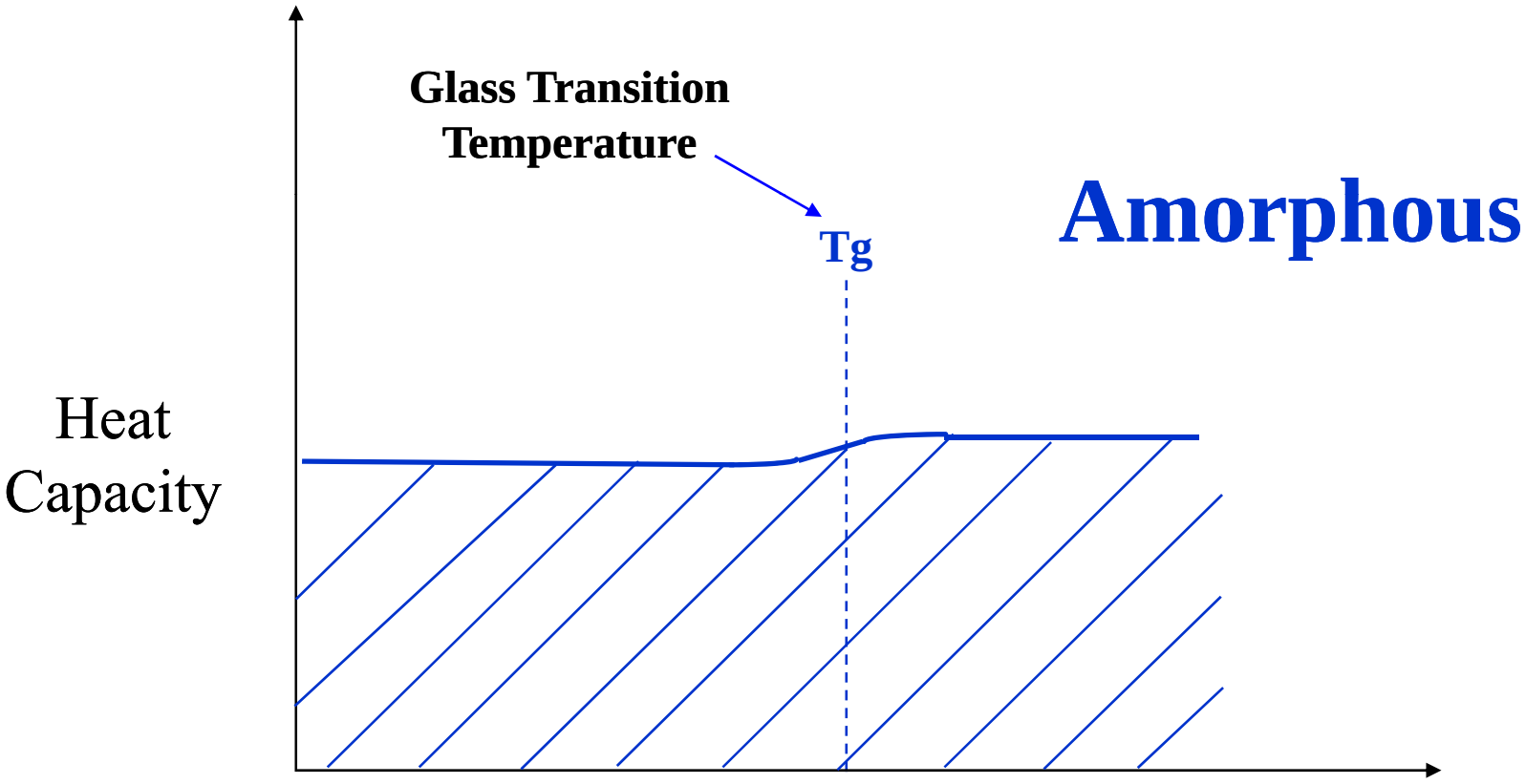
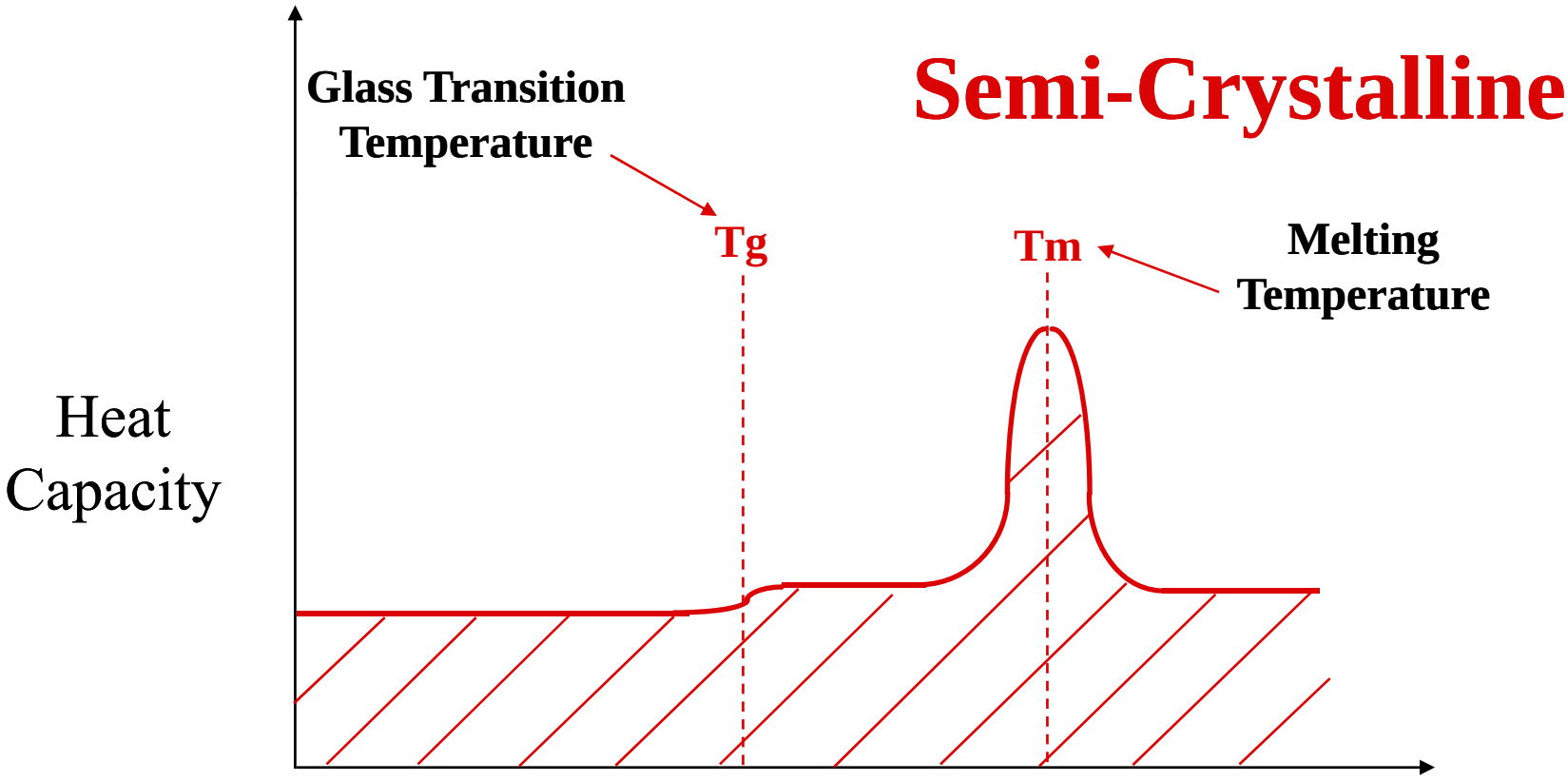
# Melt Characteristics




GE Plastics
DUKANE

# Melt Characteristics

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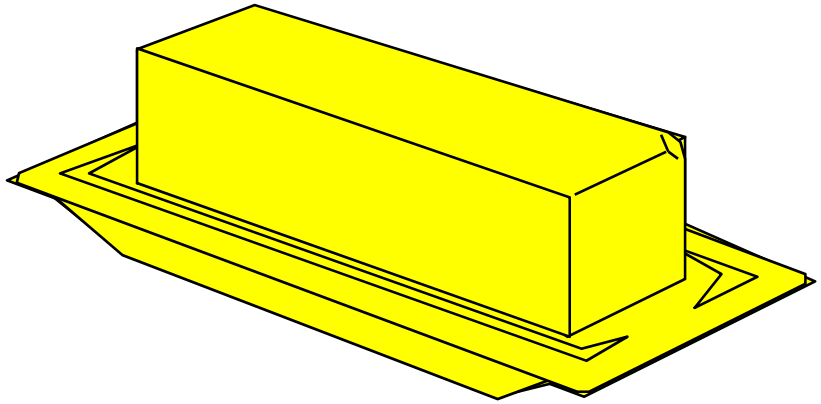
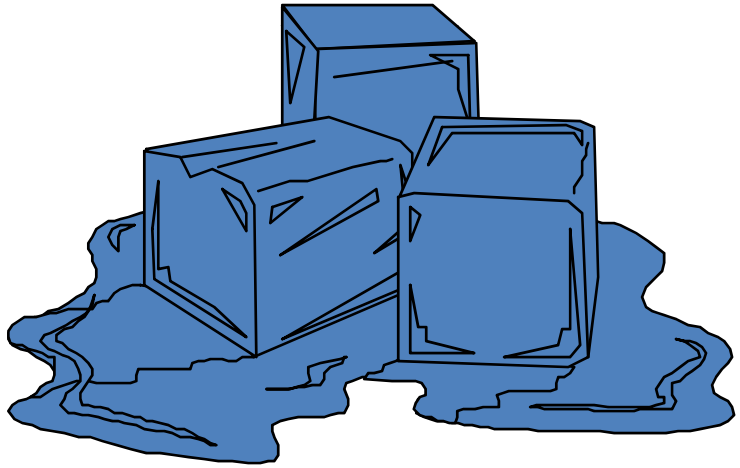
# Melt Characteristics

**Amorphous**



***Broad Softening Range***

**Crystalline**



***Sharp Melting Point***

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# Material Compatibility

- Similar molecular structure
  - Polystyrene/ABS/Acrylic
- Melting point/range within 40 degrees F
- Similar melt flow index

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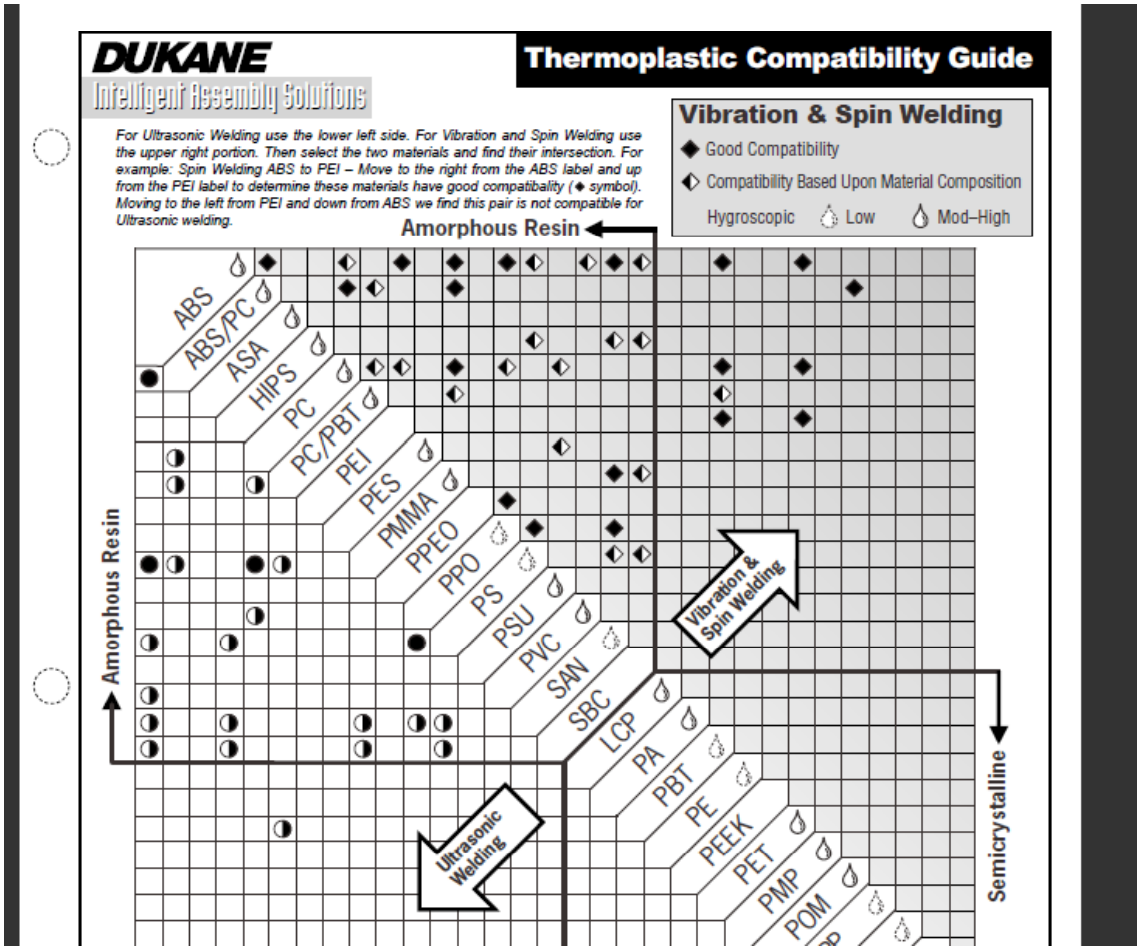
# Thermoplastic Compatibility Guide

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# Factors That Affect Weldability

- Lubricants
- Impact Modifiers
- Foaming Agents
- Colorants
- Resin Grade
- Resin age
- Engineered resins

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# Factors That Affect Weldability

- Regrind
  - Keep to a minimum if possible
  - Keep percentage consistent
- Hygroscopicity **(hy·gro·scop·ic·i·ty)**
  - Nylon, Acetal, Polycarbonate, Polysulfone
- Fillers
  - Glass, Carbon, Mineral, Talc
- Mold Release Agents
  - Paintable, Printable

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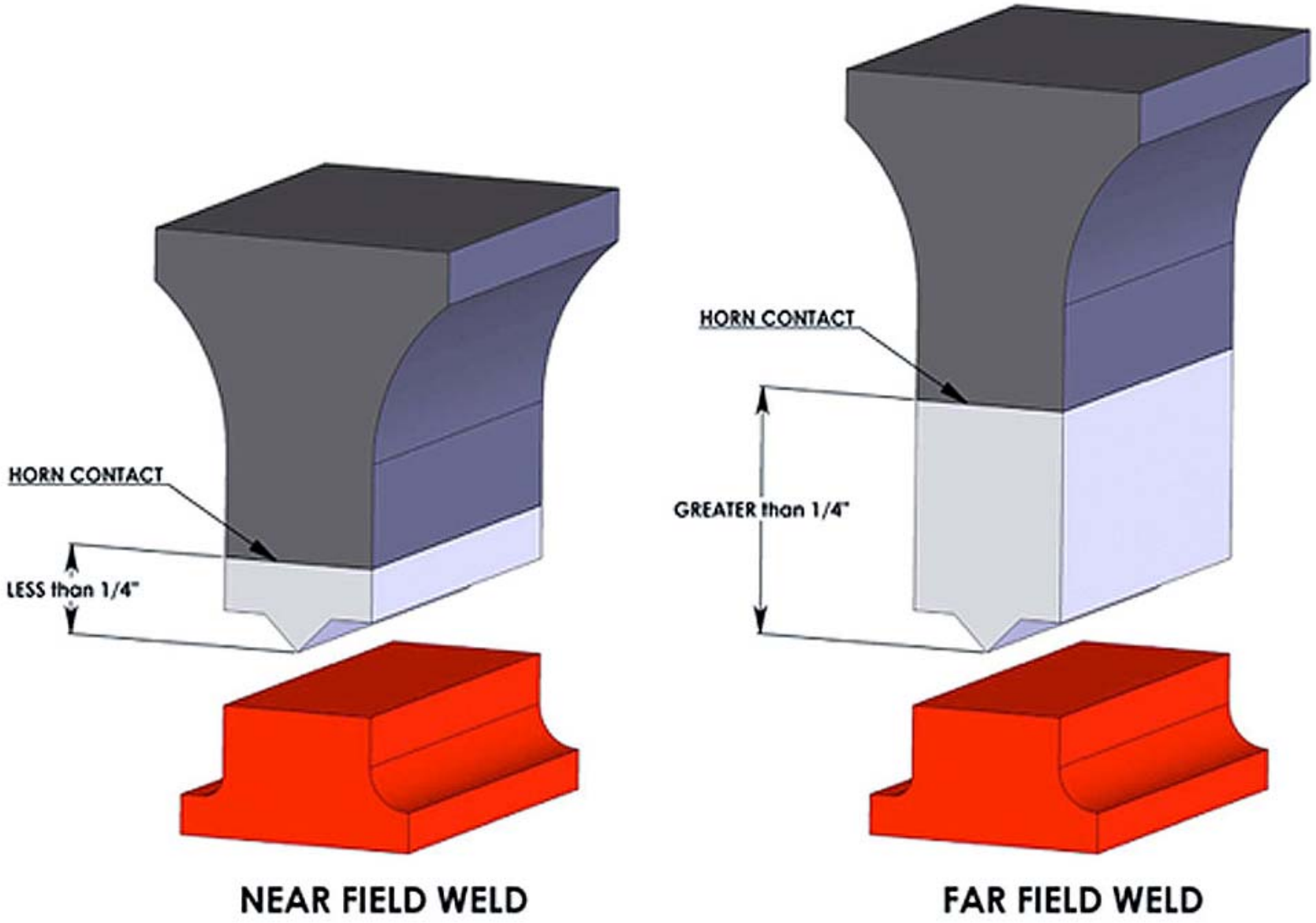
# Near Field Vs. Far Field Welding Joints



# Purpose of Ultrasonic Joint Design

- Small Initial Contact Area
- Uniform Contact
- Means of Alignment

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# Types of Ultrasonic Joints

- Energy Director
- Shear Joint

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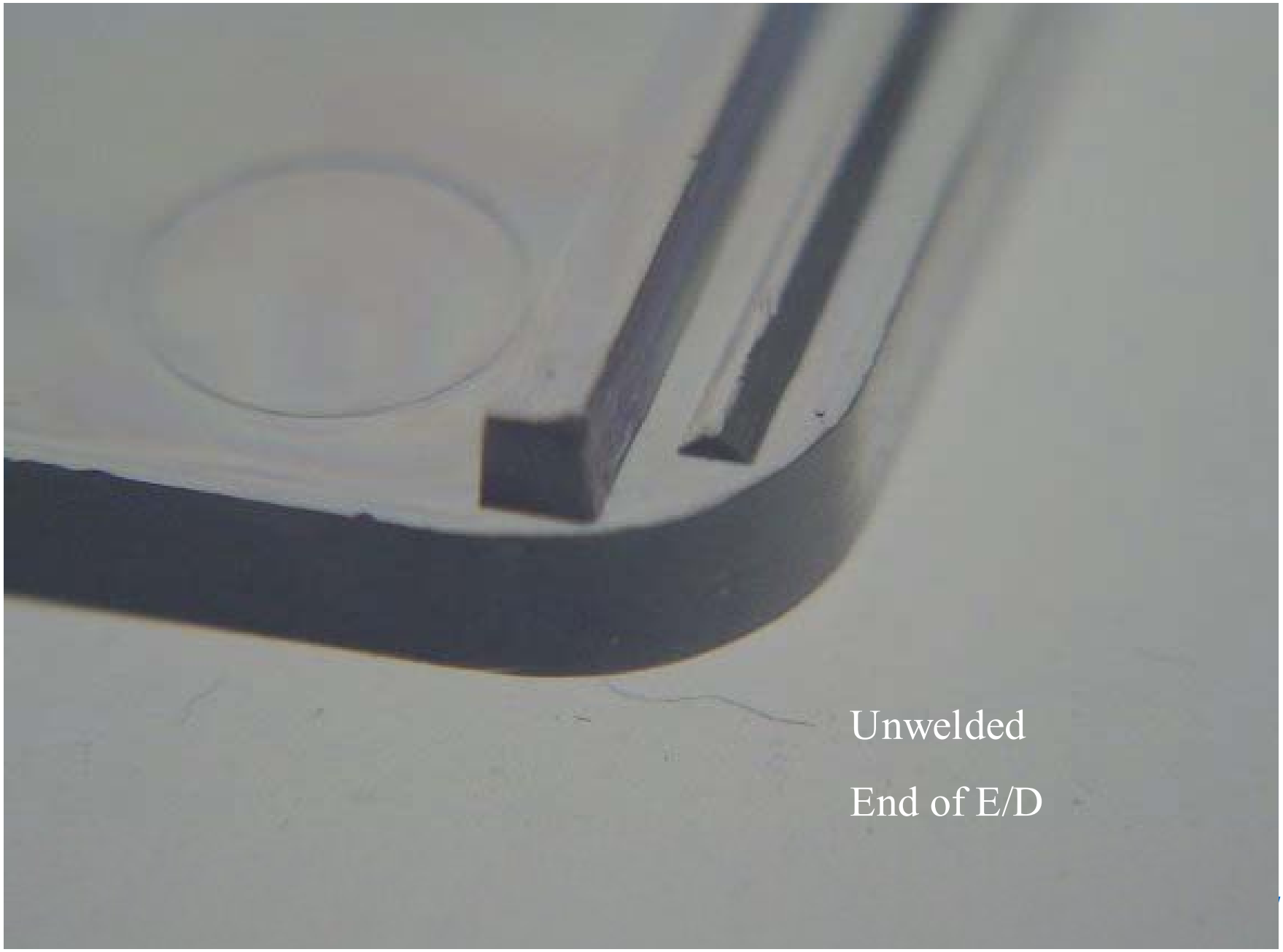
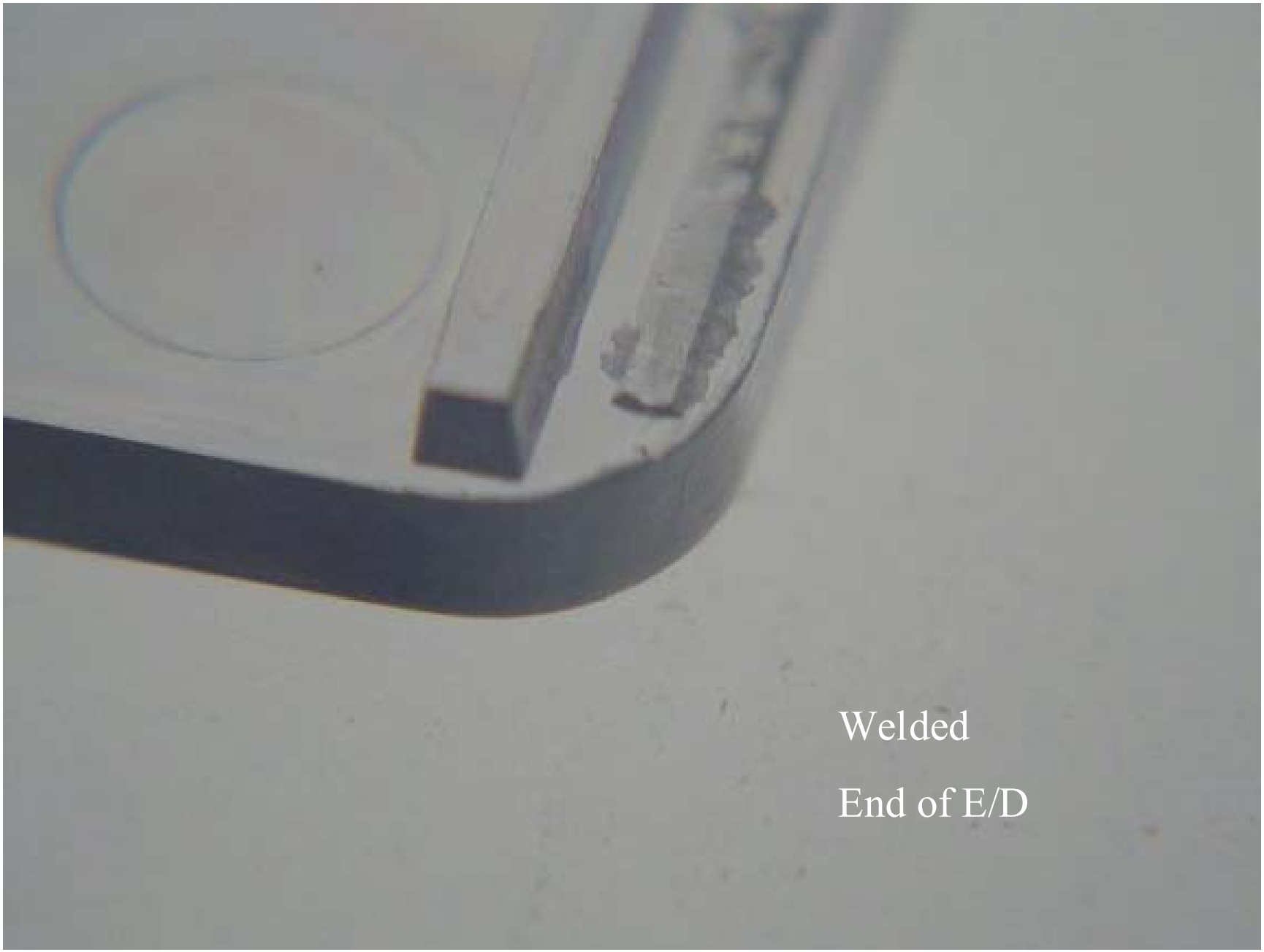
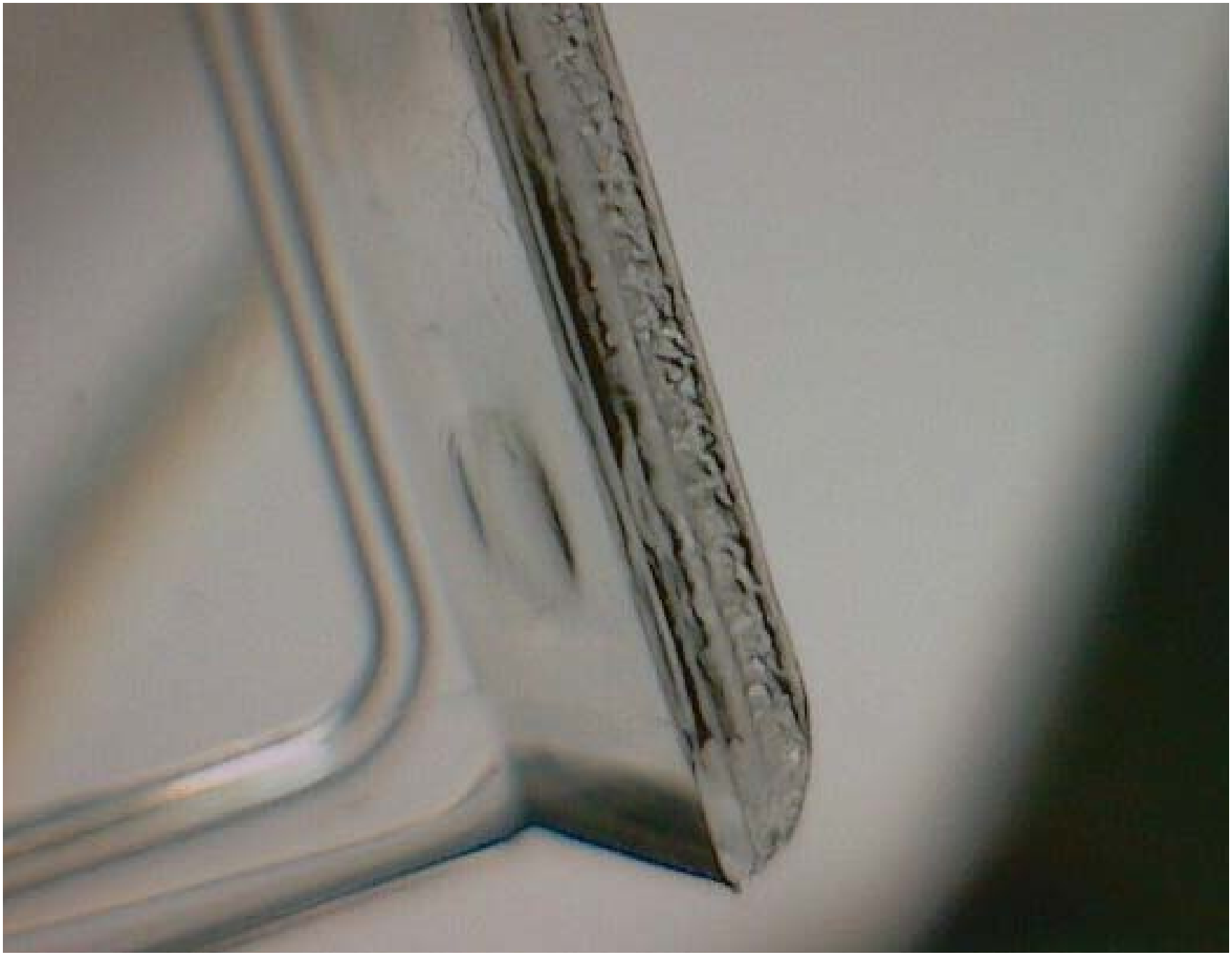
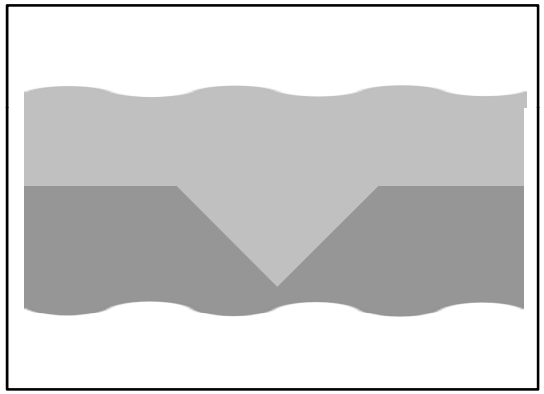

Unwelded
End of E/D

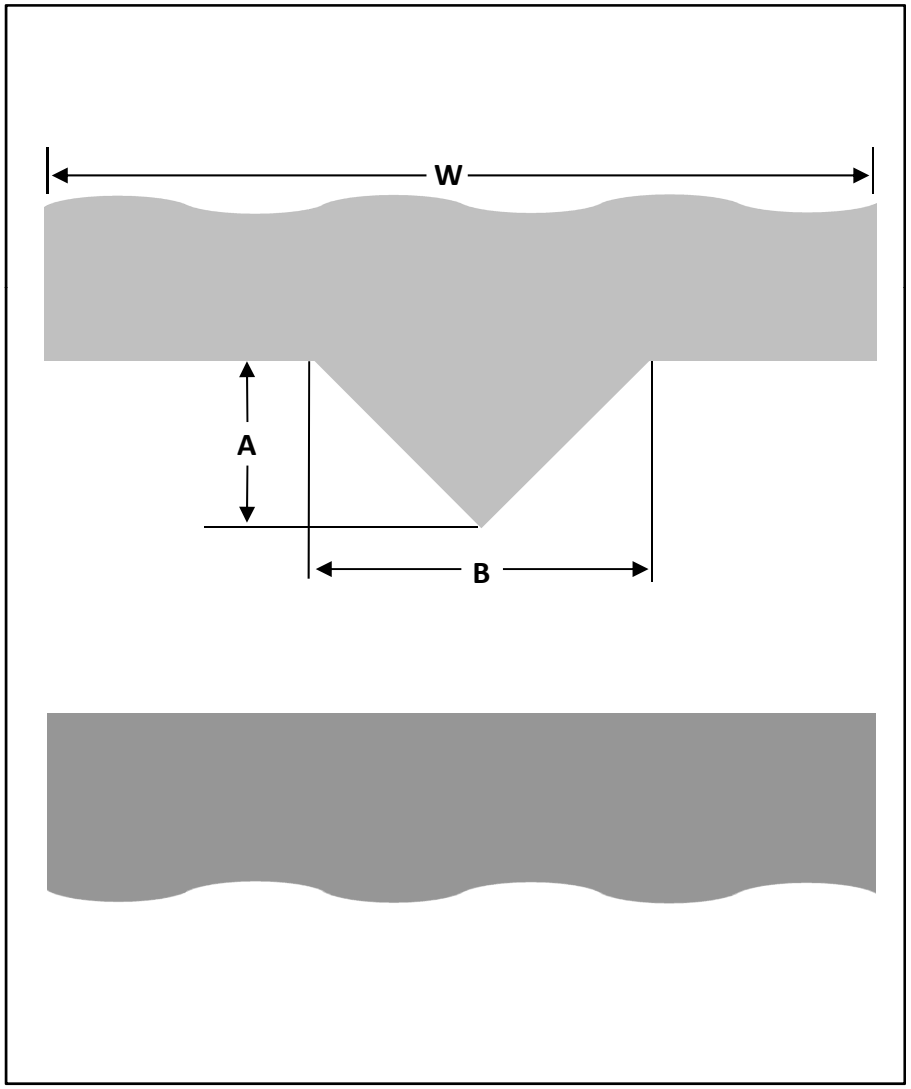

Welded
End of E/D



# 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° |

# Step Joint

- Provides part location
- Allows for control of flash travel.

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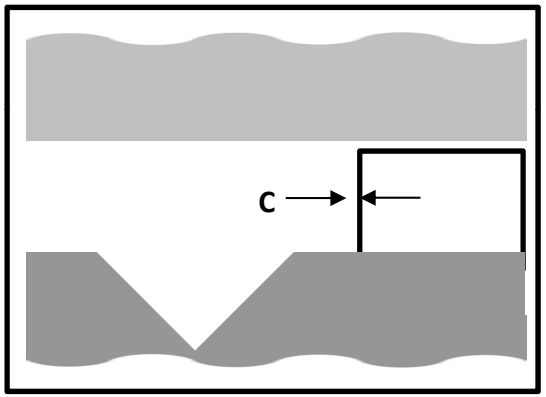
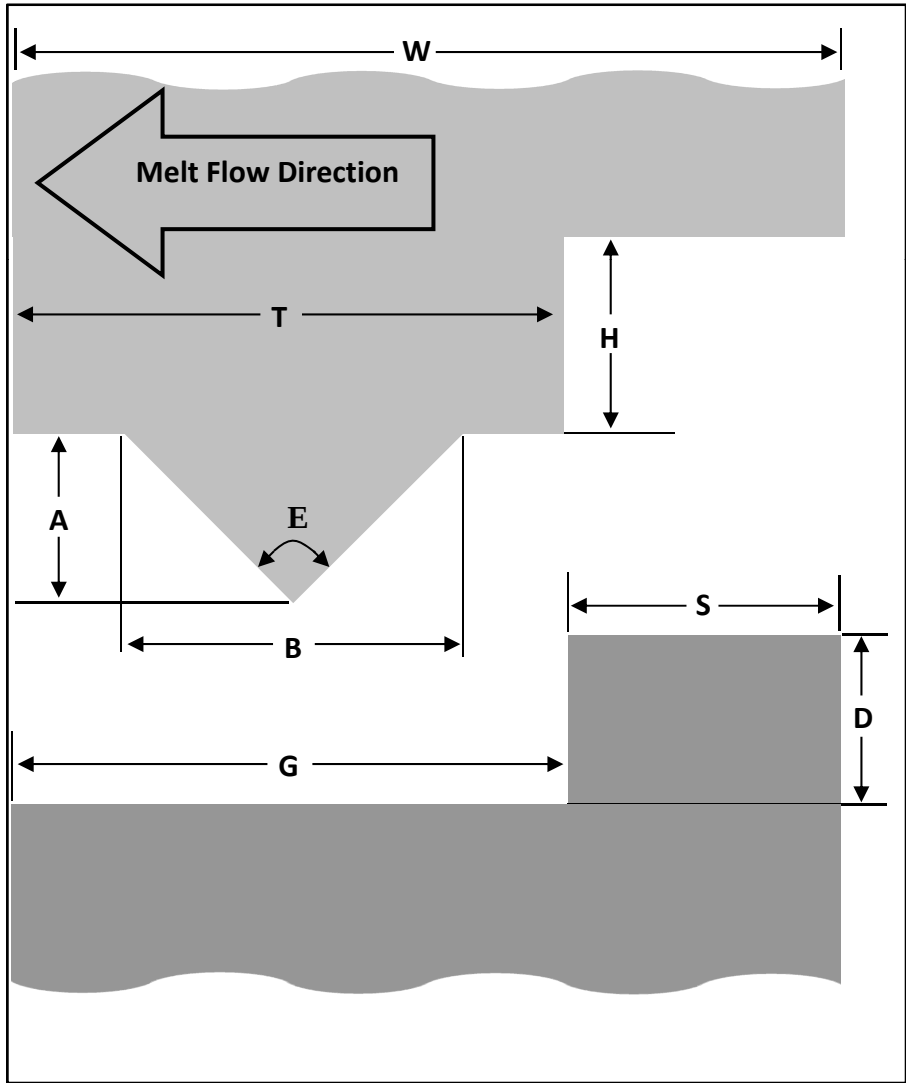
# Ultrasonic Welding Joints

## Step Energy Director

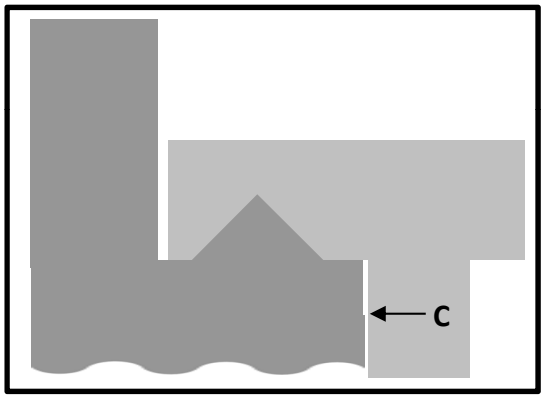


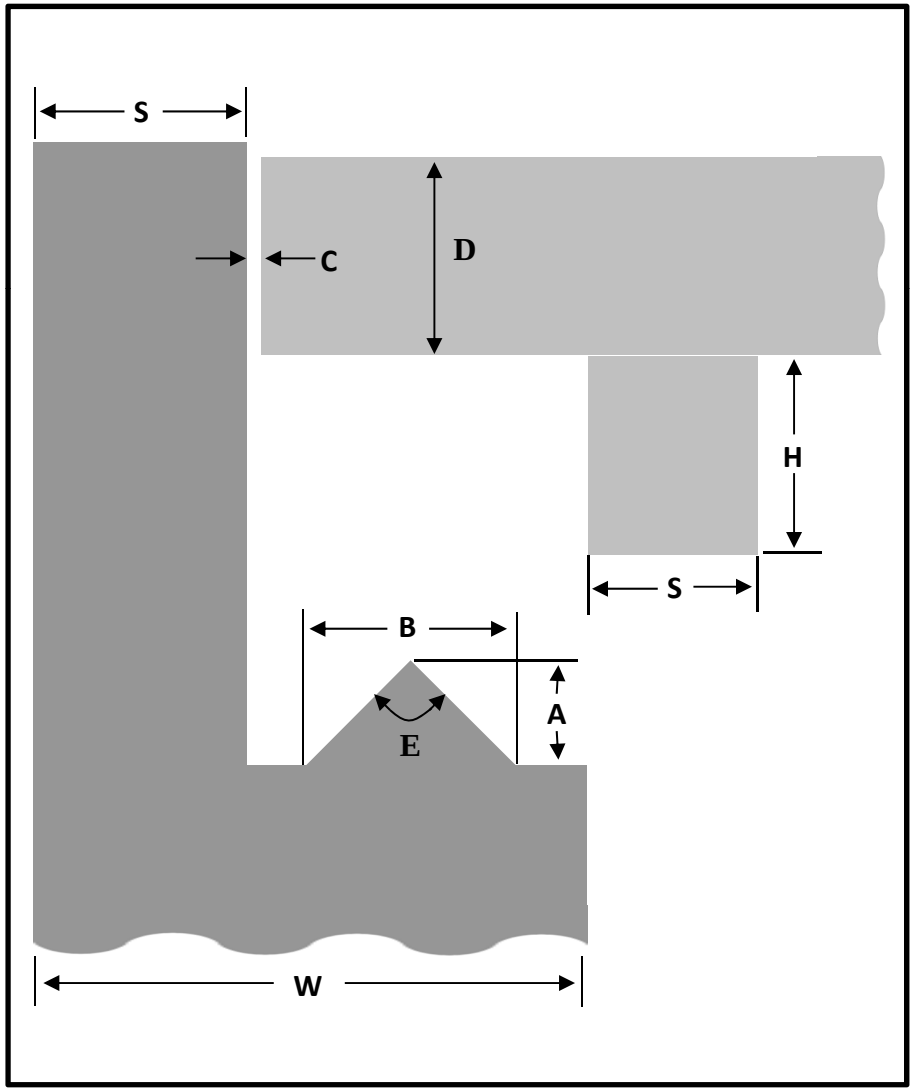

| | Dimension | General Guidelines |
|---|---|---|
| W | Wall Thickness | Minimum 0.060" |
| B | Energy Director Base Width | W/4 to W/5 |
| A | Energy Director Height | B/2 or 0.866B |
| T | Energy Director Wall Width | 2/3 W |
| H | Energy Director Wall Height | 2/3 W |
| G | Step Width | T + 0.002" to 0.004" |
| D | Step Depth | H + 0.001" |
| S | Step Side Wall Width | Minimum 0.020" |
| C | Clearance | 0.002" to 0.004" |
| E | Energy Director Angle | 60° or 90° |

# Ultrasonic Welding Joints

## Step Energy Director Variation




| | Dimension | General Guidelines |
|---|---|---|
| W | Wall Thickness | Minimum 0.060" |
| B | Energy Director Base Width | W/4 to W/5 |
| A | Energy Director Height | B/2 or 0.866B |
| T | Tongue Width | 2/3 W |
| H | Tongue Height | 2/3 W |
| C | Clearance | 0.002" to 0.004" |
| S | Side Wall Width | Minimum 0.025" |
| D | Wall Thickness | Minimum 2B |
| E | Energy Director Angle | 60° or 90° |



# Tongue and Groove Joint

- Provides improved part location
- Allows for containment of flash
- Excellent Design for Leak Free Seals

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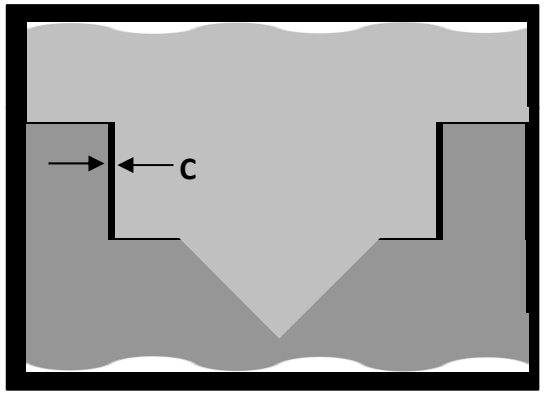
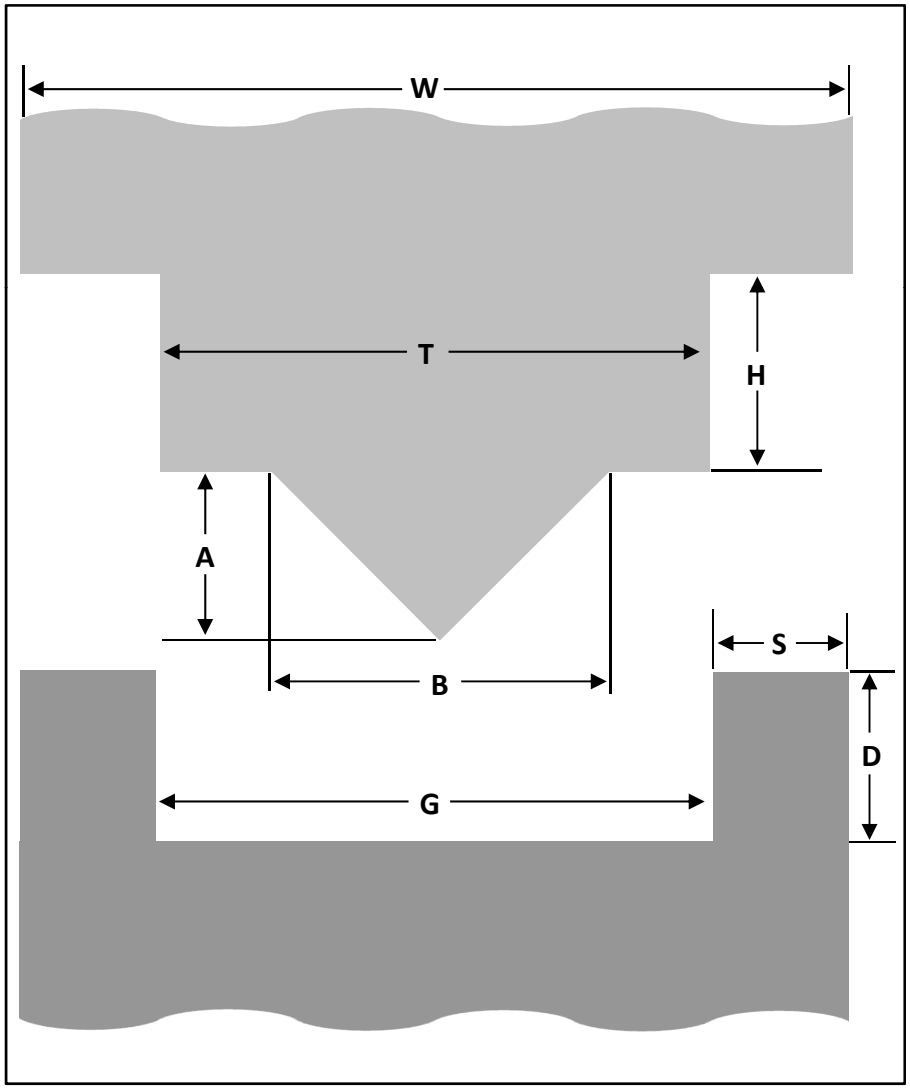
# Ultrasonic Welding Joints

## Tongue and Groove with 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 |
| T | Tongue Width | W/3 |
| H | Tongue Height | W/3 |
| G | Groove Width | T + 0.004" to 0.008" |
| D | Groove Depth | H + 0.001" |
| S | Groove Side Wall Width | Minimum 0.025" |
| C | Clearance | 0.002" to 0.004" |
| E | Energy Director Angle | 60° or 90° |



# Energy Director Magnified

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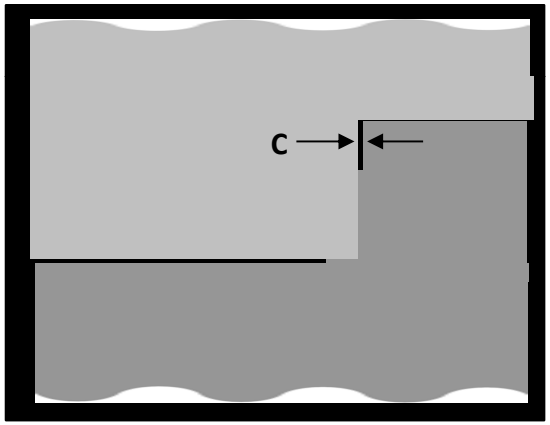
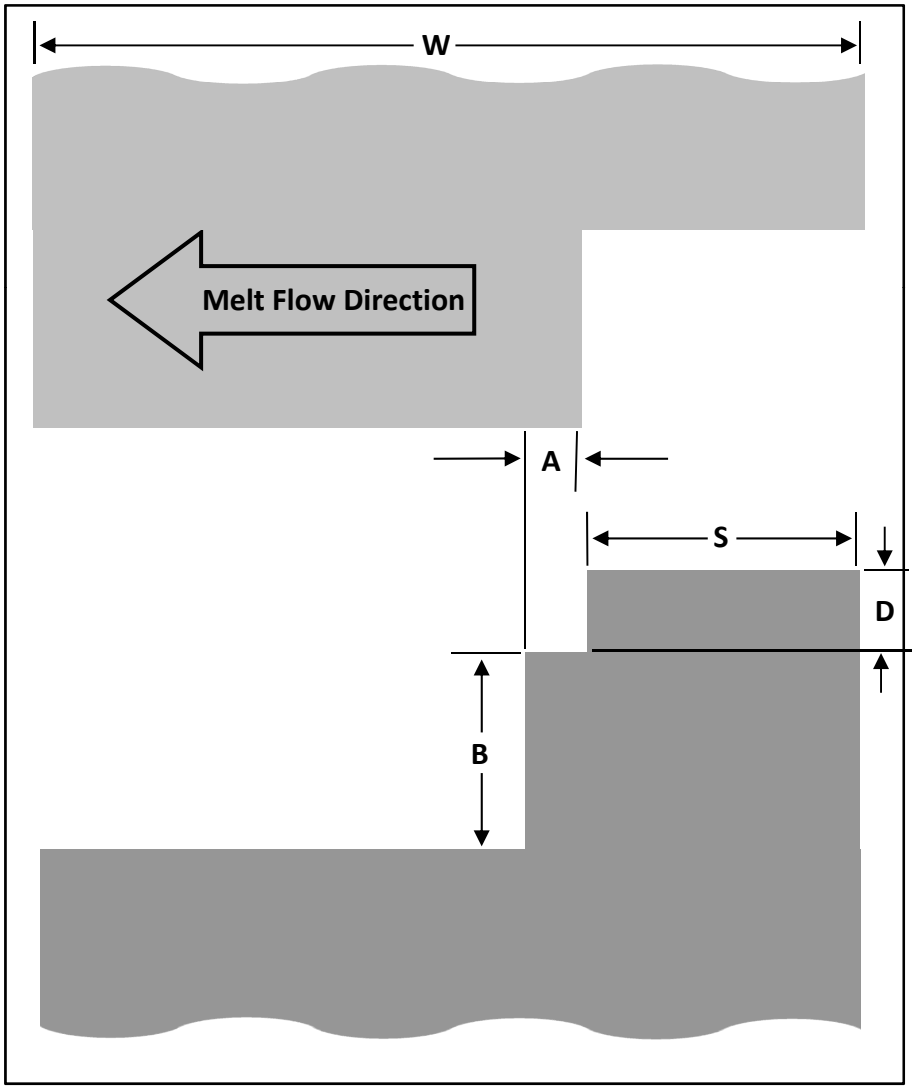
# Ultrasonic Welding Joints

## Shear

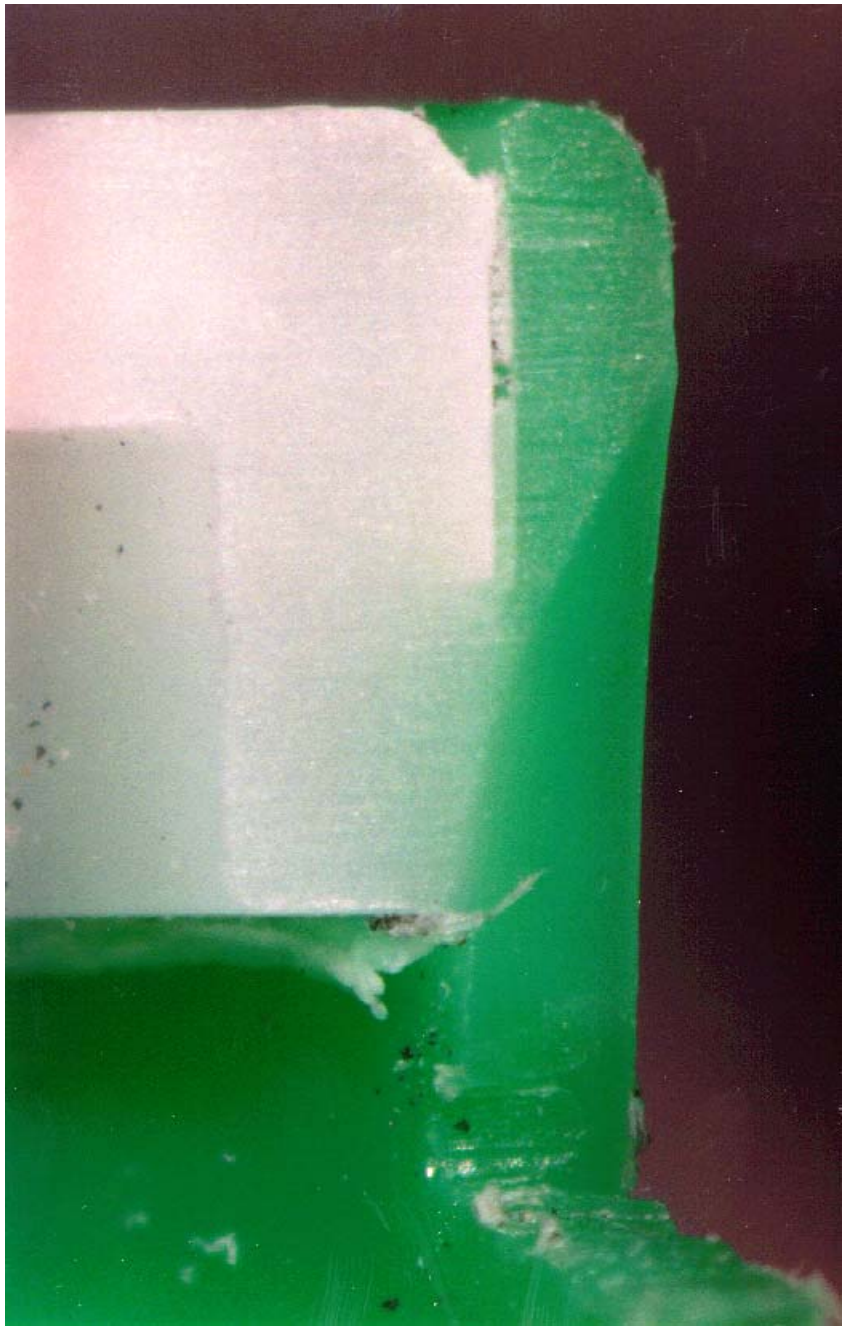



| | Dimension | General Guidelines |
|---|---|---|
| W | Wall Thickness | Minimum 0.060" |
| B | Shear Length | Approximately 0.030” |
| A | Shear Width | 0.008” – 0.020” |
| D | Lead-in | 0.020” – 0.050” |
| S | Side Wall Width | Minimum 0.020" |
| C | Clearance | 0.003" to 0.005" |



# Shear Joint

1. **Ideal for leak free seals in relatively smaller parts**
2. **Can be problematic with changing molding conditions**
3. **Relies on consistent dimensions of shear amount and depth.**



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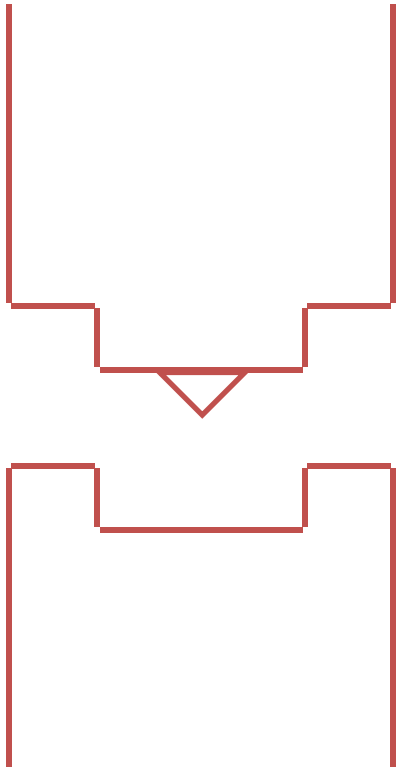
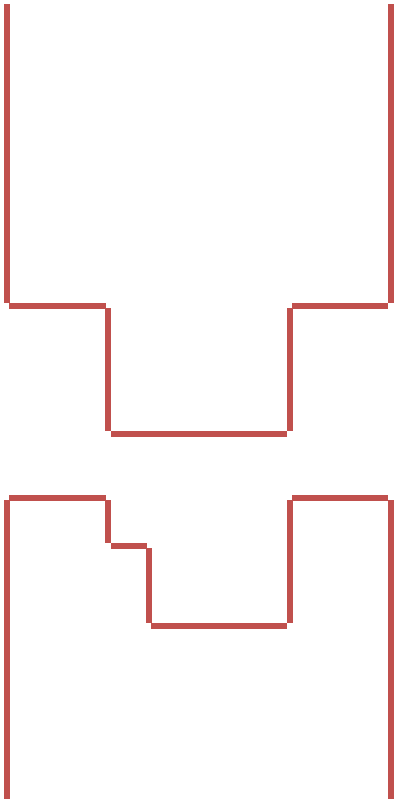
# Tongue and Groove Joints



Energy Director



Shear

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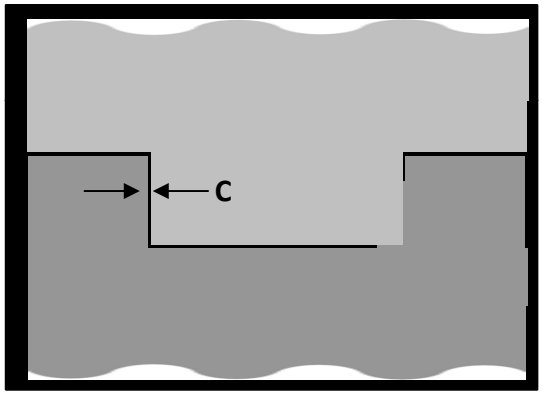
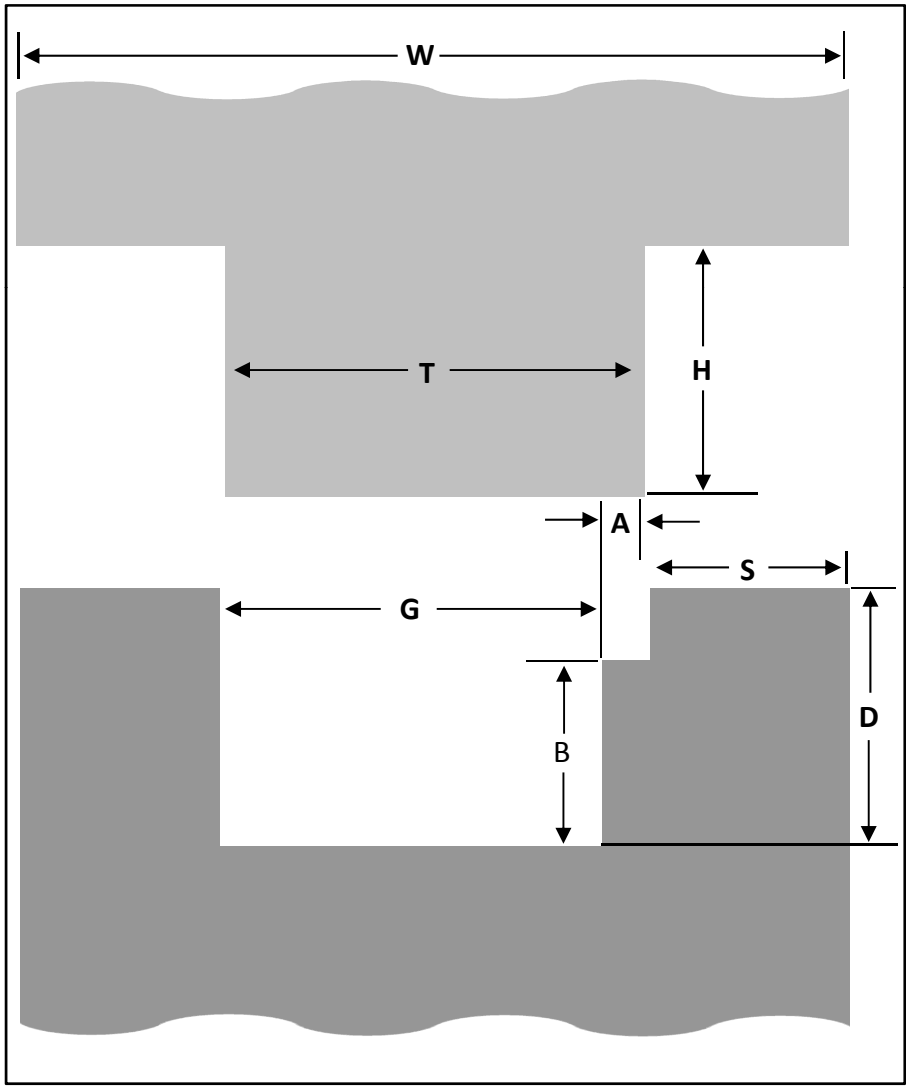
# Ultrasonic Welding Joints

## Tongue and Groove Shear - Single

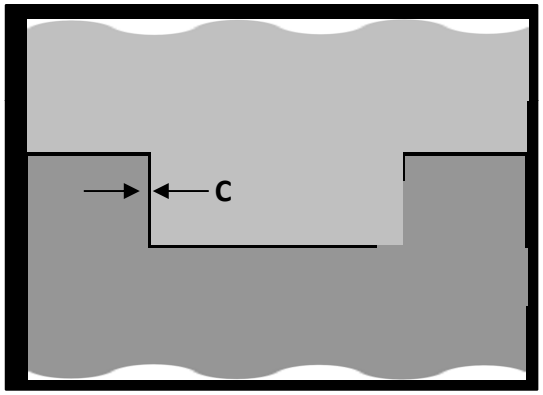


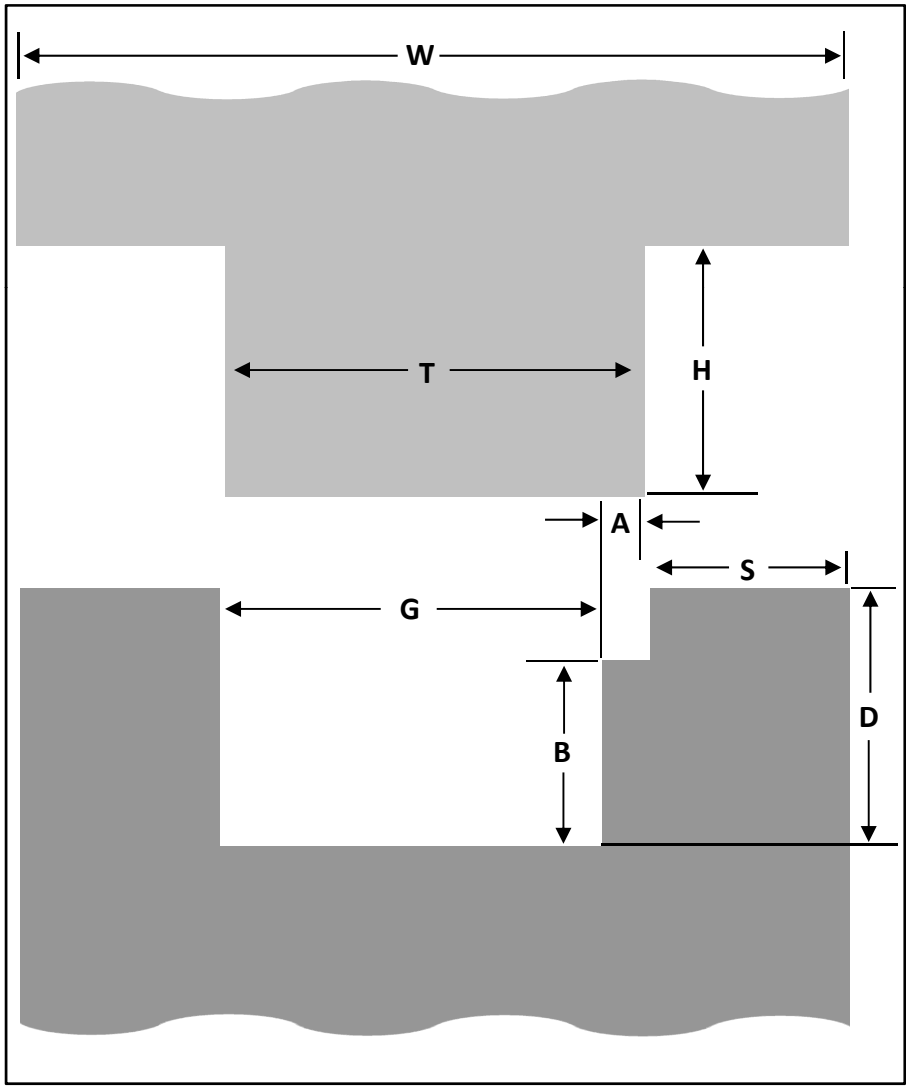




| | Dimension | General Guidelines |
|---|---|---|
| W | Wall Thickness | Minimum 0.090" |
| B | Shear Length | Approximately 0.030” |
| A | Shear Width | 0.008” – 0.020” |
| T | Tongue Width | W/3 |
| H | Tongue Height | W/3 |
| G | Groove Width | T - (A+2·C) |
| D | Groove Depth | H + 0.015" |
| S | Groove Side Wall Width | Minimum 0.025" |
| C | Clearance | 0.002" to 0.004" |

# Ultrasonic Welding Joints

## Tongue and Groove Shear - Single

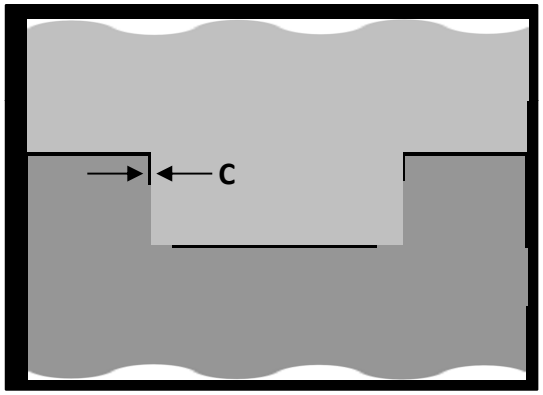


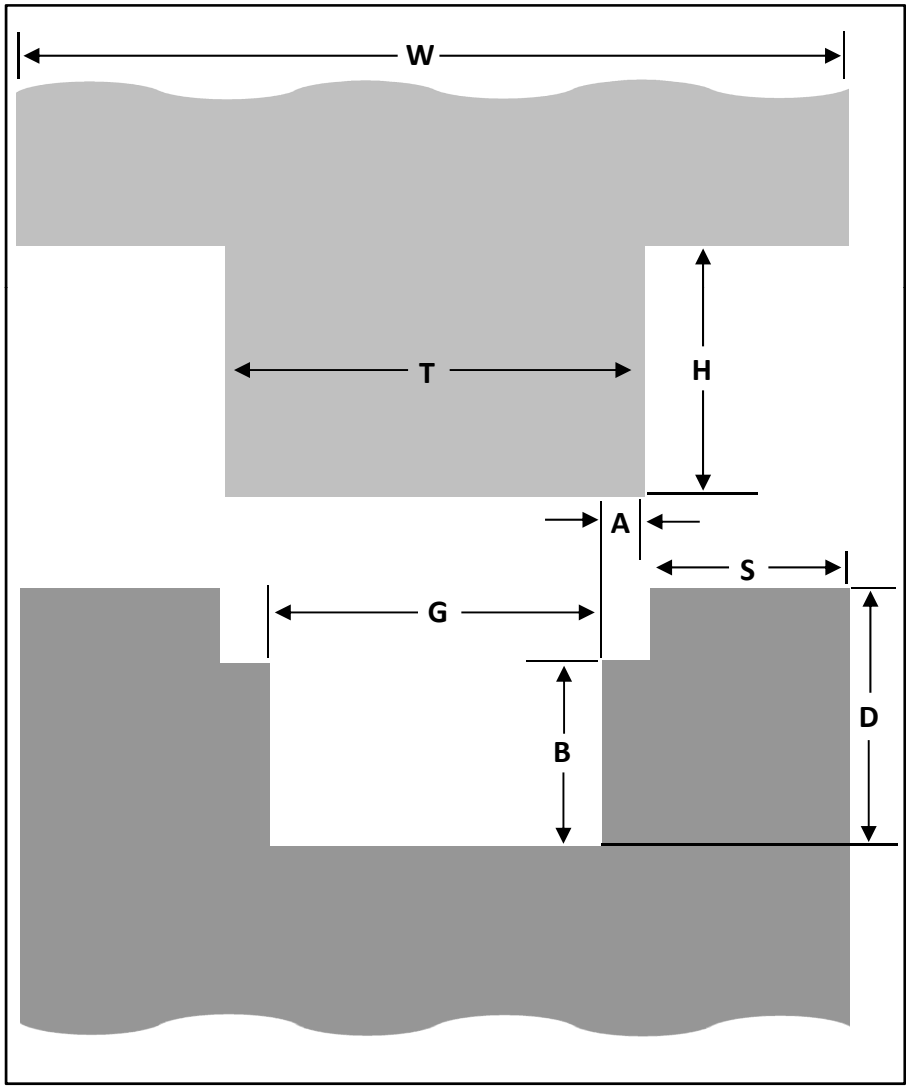

| | Dimension | General Guidelines |
|---|---|---|
| W | Wall Thickness | Minimum 0.090" |
| B | Shear Length | Approximately 0.030” |
| A | Shear Width | 0.008” – 0.020” |
| T | Tongue Width | W/3 |
| H | Tongue Height | W/3 |
| G | Groove Width | T - (A+2·C) |
| D | Groove Depth | H + 0.015" |
| S | Groove Side Wall Width | Minimum 0.025" |
| C | Clearance | 0.002" to 0.004" |

# Ultrasonic Welding Joints

## Tongue and Groove Shear - Double

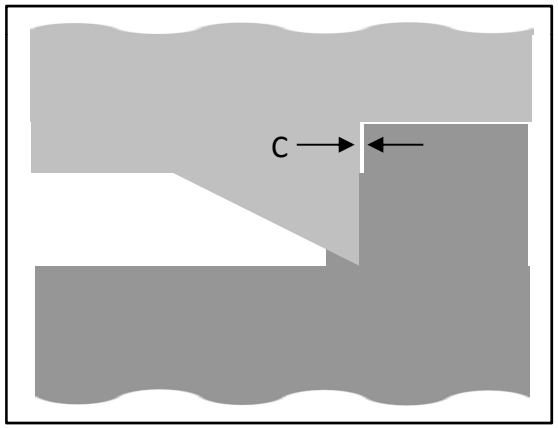


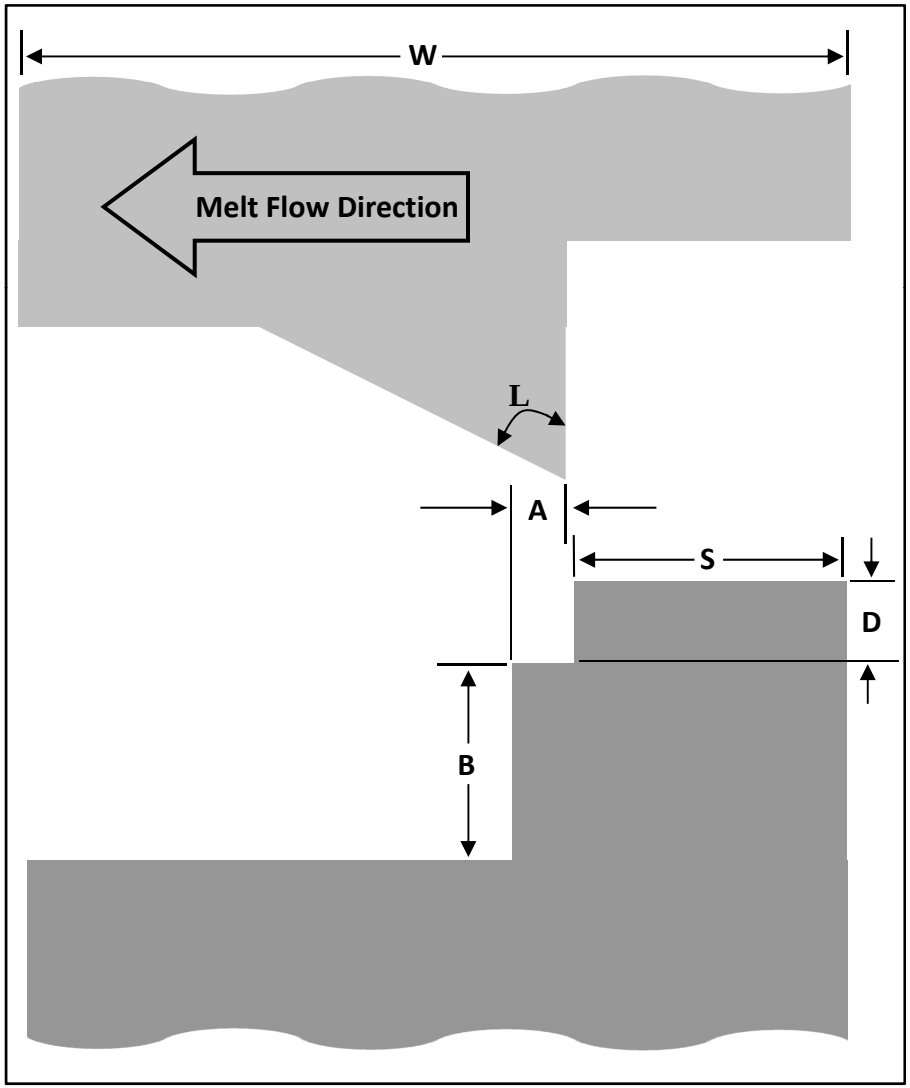

| | Dimension | General Guidelines |
|---|---|---|
| W | Wall Thickness | Minimum 0.090" |
| B | Shear Length | Approximately 0.030” |
| A | Shear Width | 0.008” – 0.020” |
| T | Tongue Width | W/3 |
| H | Tongue Height | W/3 |
| G | Groove Width | T - (2·A+2·C) |
| D | Groove Depth | H + 0.015" |
| S | Groove Side Wall Width | Minimum 0.025" |
| C | Clearance | 0.002" to 0.004" |



# Ultrasonic Welding Joints

## Shear Variation




| | Dimension | General Guidelines |
|---|---|---|
| W | Wall Thickness | Minimum 0.060" |
| B | Shear Length | Approximately 0.030” |
| A | Shear Width | 0.008” – 0.020” |
| D | Lead-in | 0.020” – 0.050” |
| S | Side Wall Width | Minimum 0.020" |
| C | Clearance | 0.003" to 0.005" |
| L | Shear Lead-in Angle | 60° |

# Ultrasonic Welding Techniques

- Welding
- Staking
- Swaging
- Inserting
- Spot Welding

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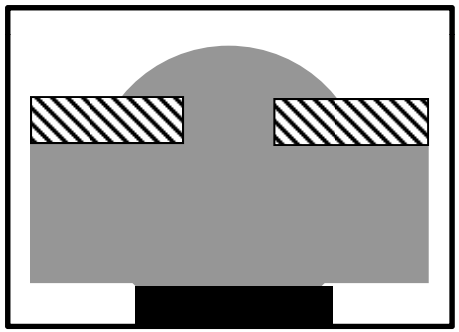
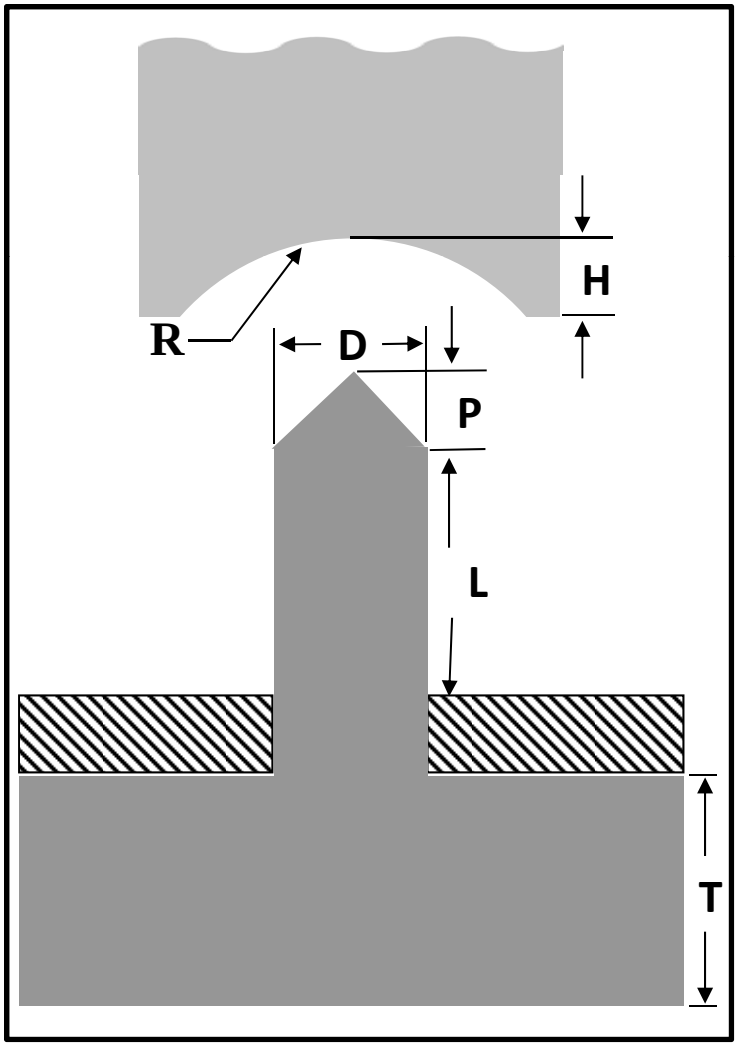
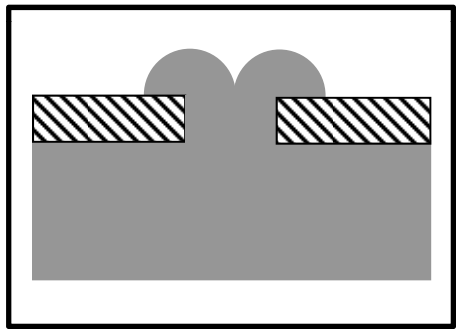
# DOME

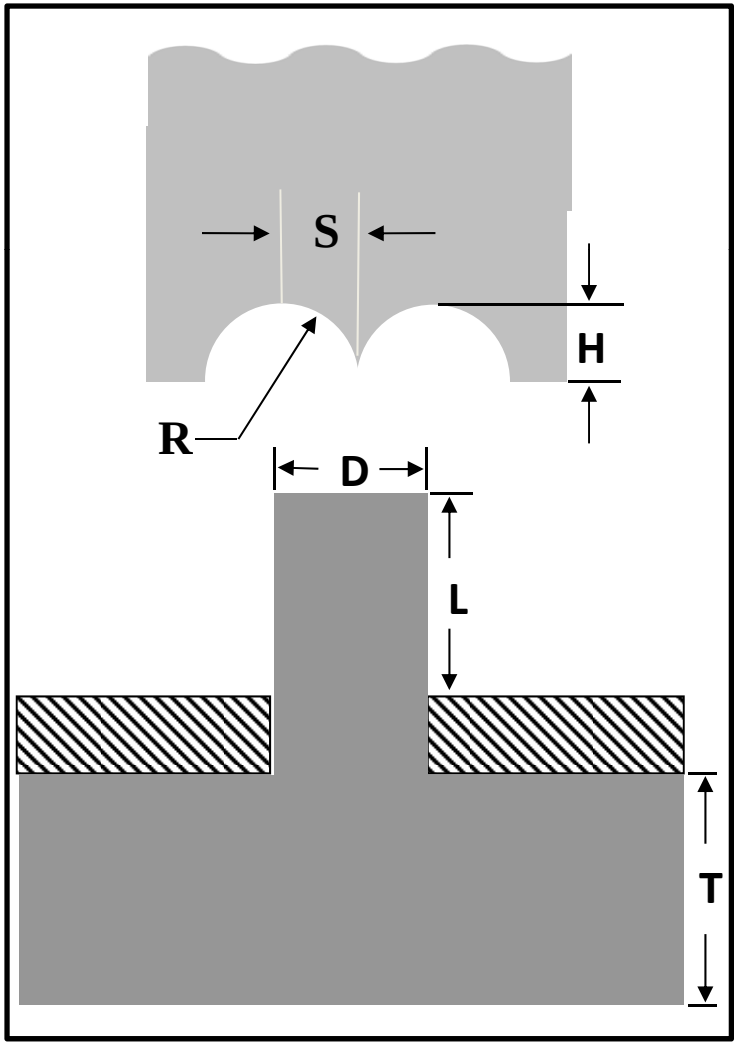





| | Dimension | General Guidelines |
|---|---|---|
| D | Post Diameter | < 0.125” |
| L | Post Length | (7/6)D |
| T | Wall Thickness | Minimum 2D |
| R | Dome Detail Radius | 1.5D |
| H | Dome Detail Height | 0.5D |

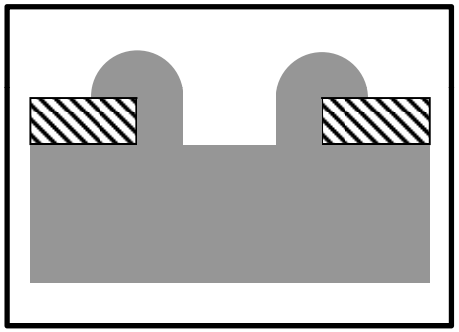
# ROSETTE

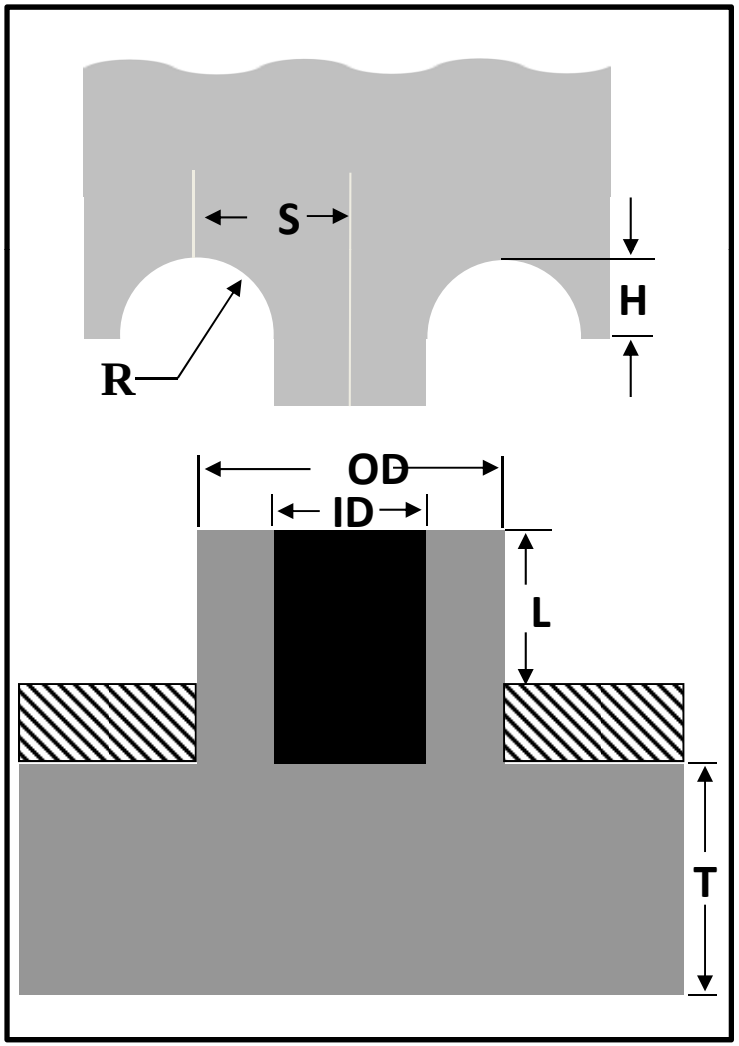





| | Dimension | General Guidelines |
|---|---|---|
| D | Post Diameter | 0.063” – 0.156” |
| L | Post Length | 0.5πD |
| T | Wall Thickness | Minimum 2D |
| R | Dome Detail Radius | 0.5D |
| H | Dome Detail Height | 0.5D |

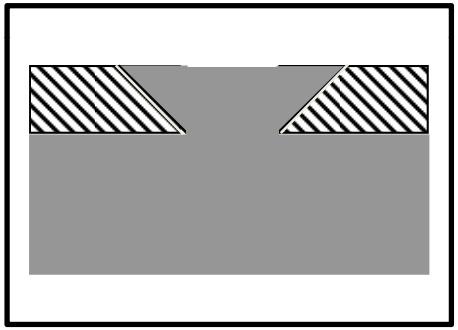
# HOLLOW BOSS

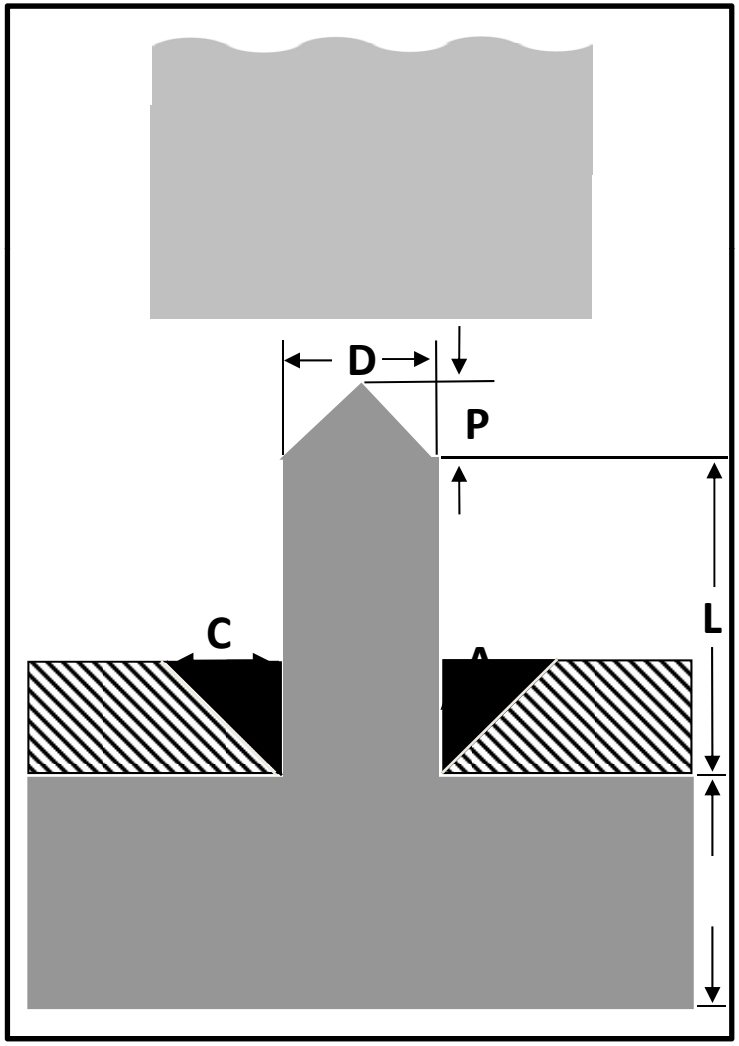





| | Dimension | General Guidelines |
|---|---|---|
| OD | Post Outer Diameter | > 0.156” |
| ID | Post Inner Diameter | ~0.5OD |
| L | Post Length | π([R(ID + 2R)] / [2(ID + R)]) |
| T | Wall Thickness | < 2 OD |
| R | Dome Detail Radius | (OD – ID)/2 |
| H | Dome Detail Height | R |

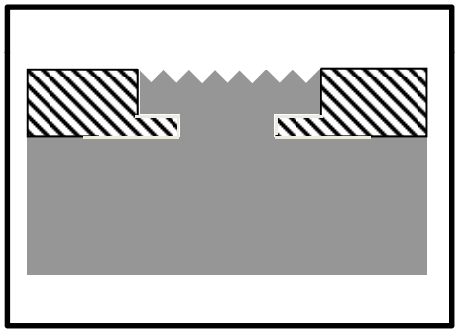
# FLAT

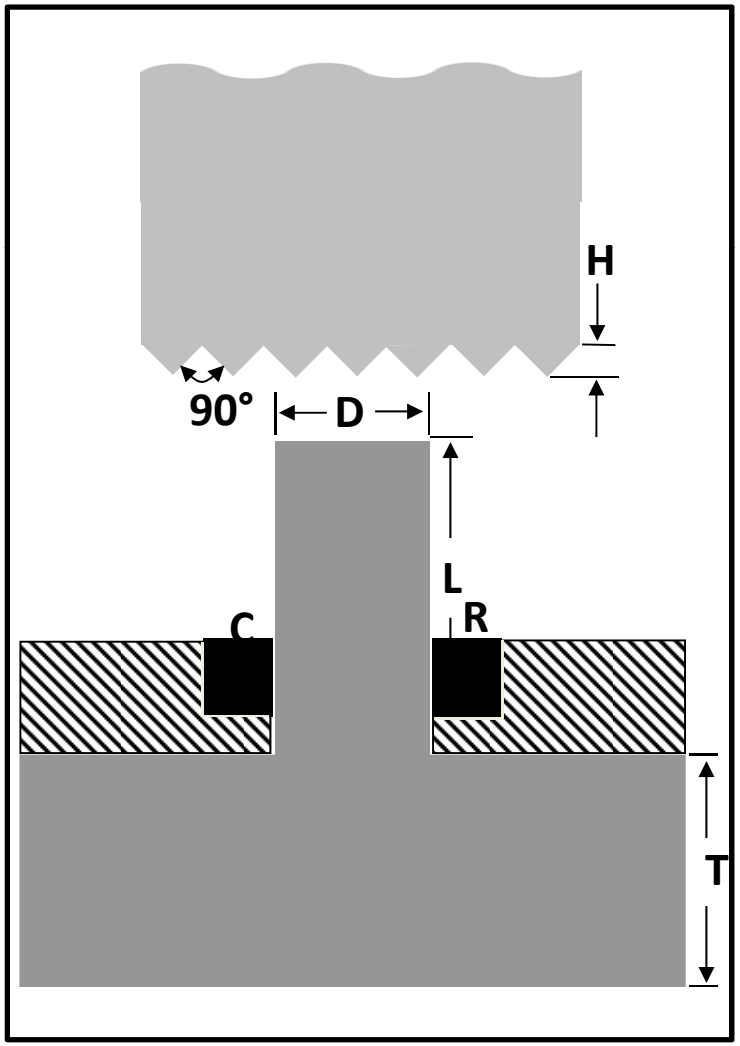





| | Dimension | General Guidelines |
|---|---|---|
| D | Post Diameter | < 0.125” |
| L | Post Length | $(C/3D^2)*(3D^2 + 6C*D + 4C^2) – D/6$ |
| T | Wall Thickness | < 2 OD |
| C | Countersink Hole Width | ~ 0.75D |
| A | Countersink Hole Angle | 45° |

# KNURLED

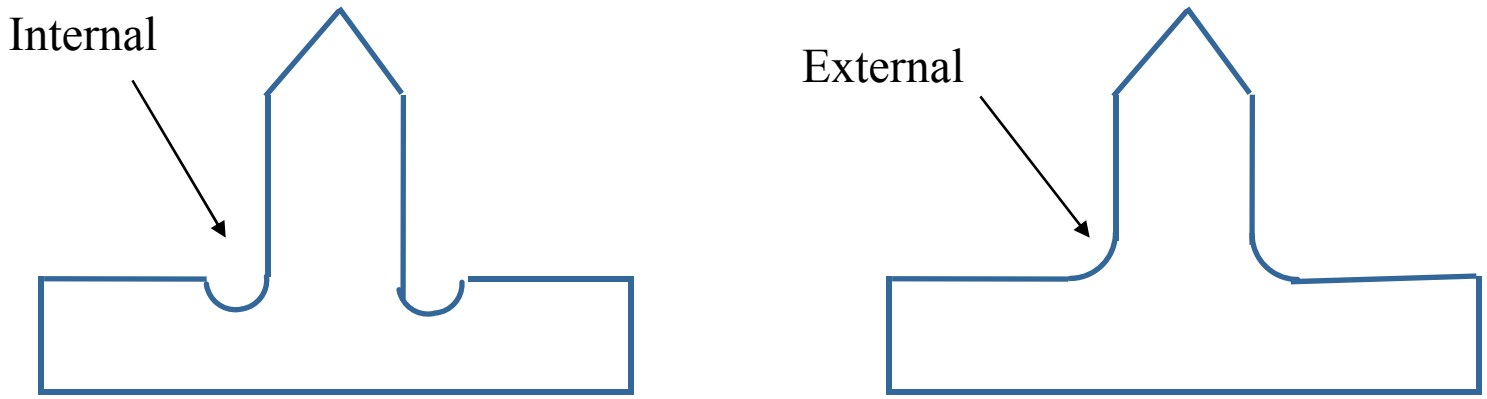





| | Dimension | General Guidelines |
|---|---|---|
| D | Post Diameter | < 0.250” |
| L | Post Length | 2D |
| T | Wall Thickness | Minimum 2D |
| R | Relief Depth | D |
| C | Relief Width | 0.5D |

# Staking

Radius Designs for Stress Relief

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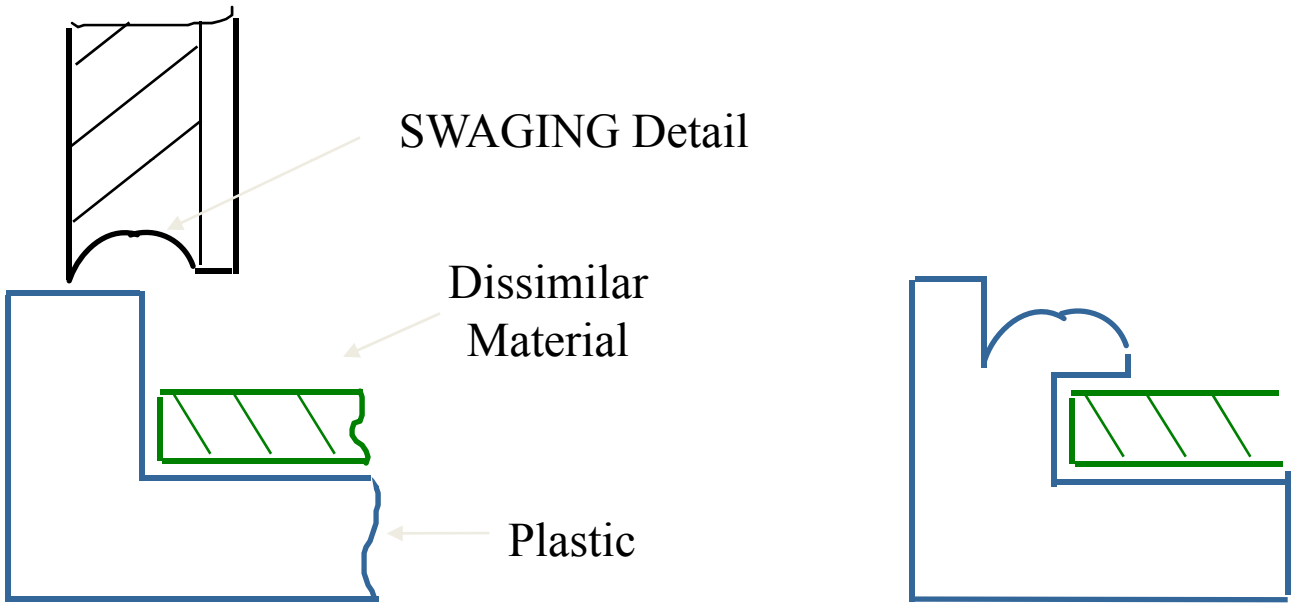
# Swaging

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# Brass Inserts

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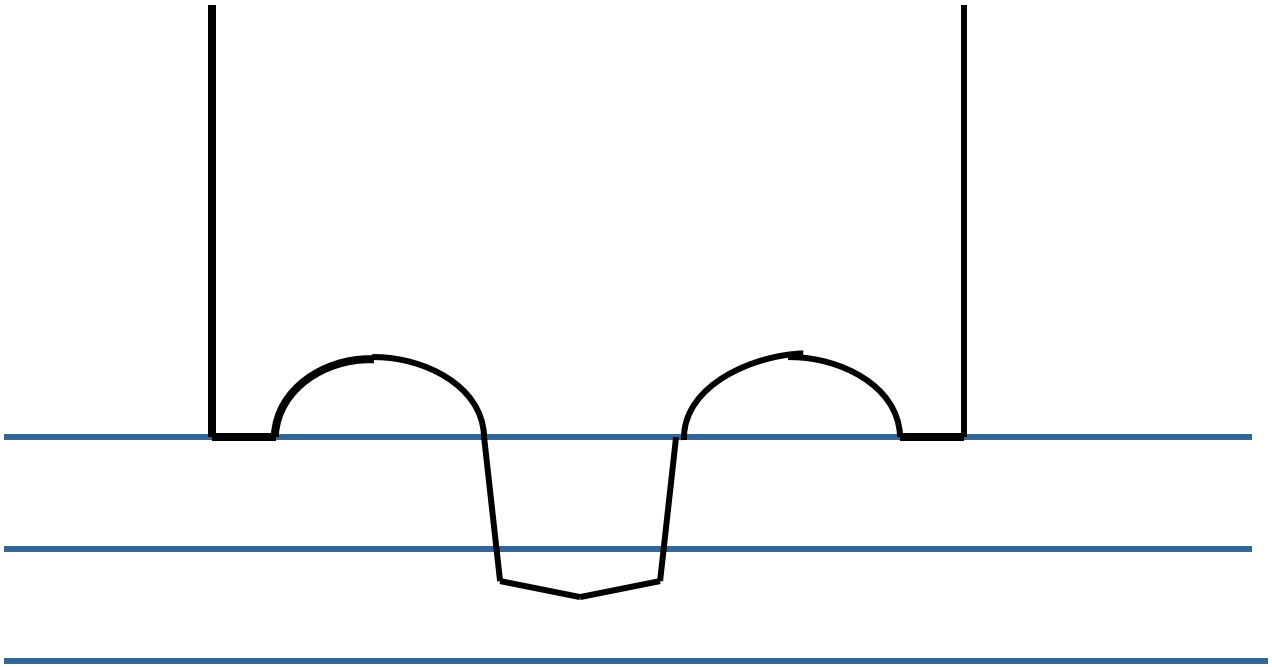
# Spot Welding



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# Spot Welding

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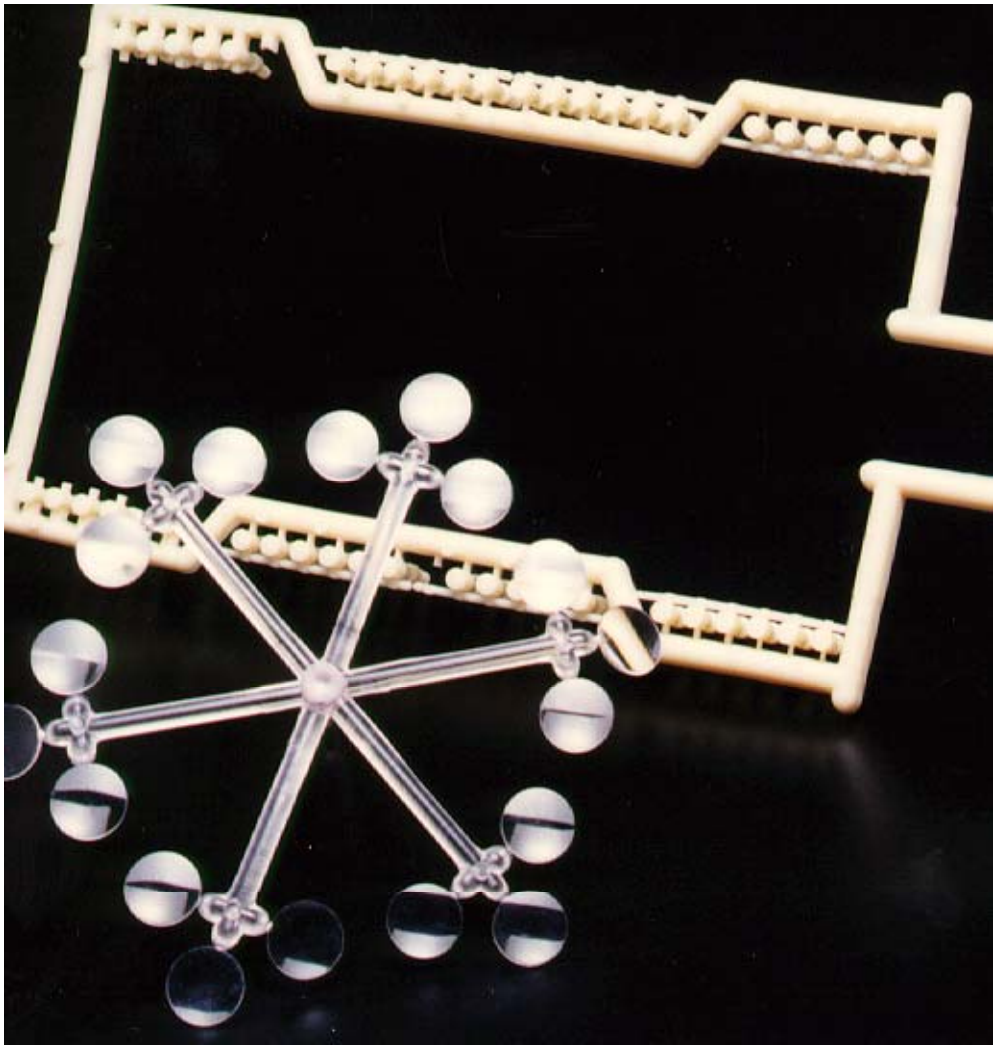
# Degating



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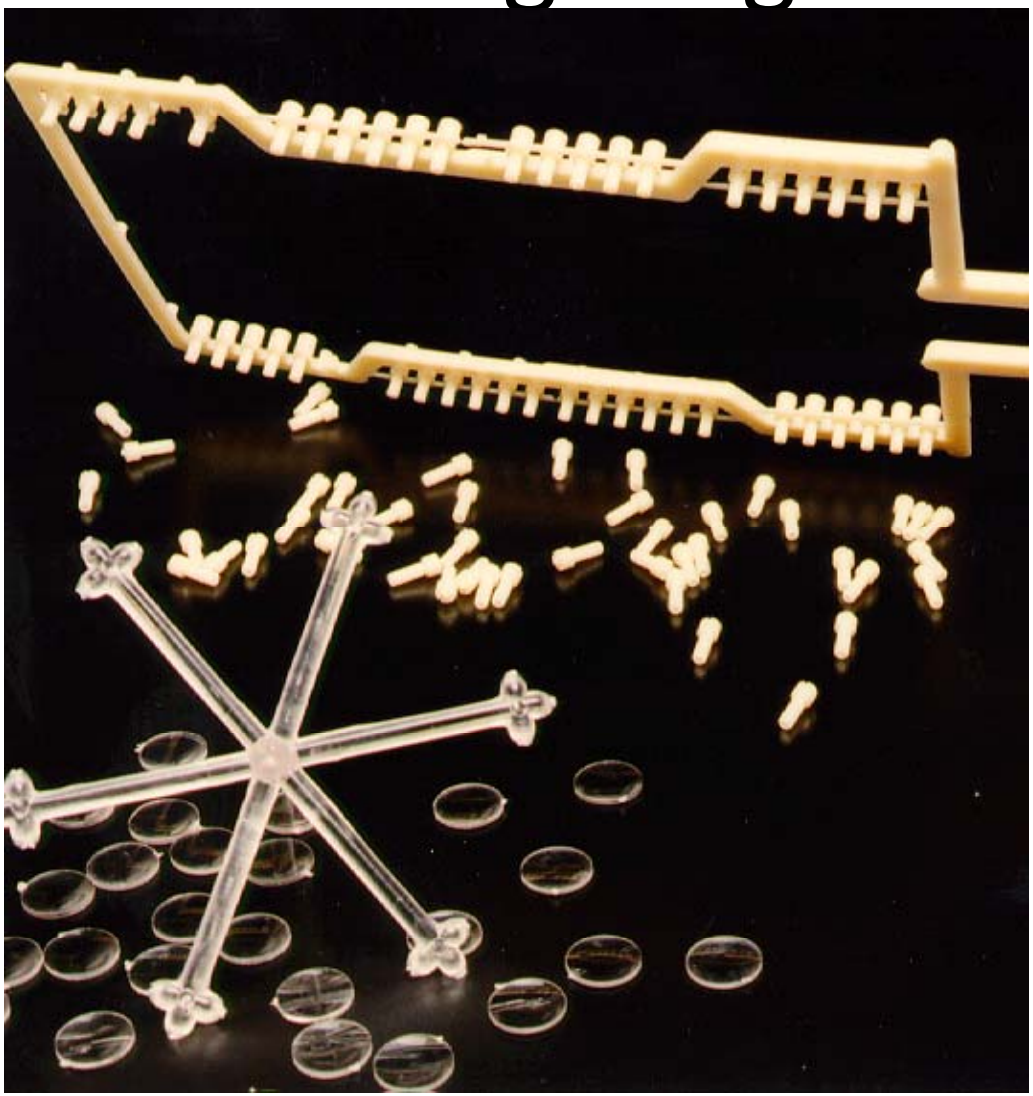
# Degating



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# Fundamentals of the Process Control

Putting the power of ultrasound to work

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# What is Process Control?

**Process Control** is a method of evaluating and improving product and process quality on a continuous basis

It is a closed-loop process involving four steps

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# Four Step Process

1. Operate a process with at least one requirement.

**Requirement** is an expected condition that must be met to successfully complete a process

2. Measure at least one variable against its requirement during the process.
3. Compare the measured result against the requirement.
4. Take corrective action, if necessary.

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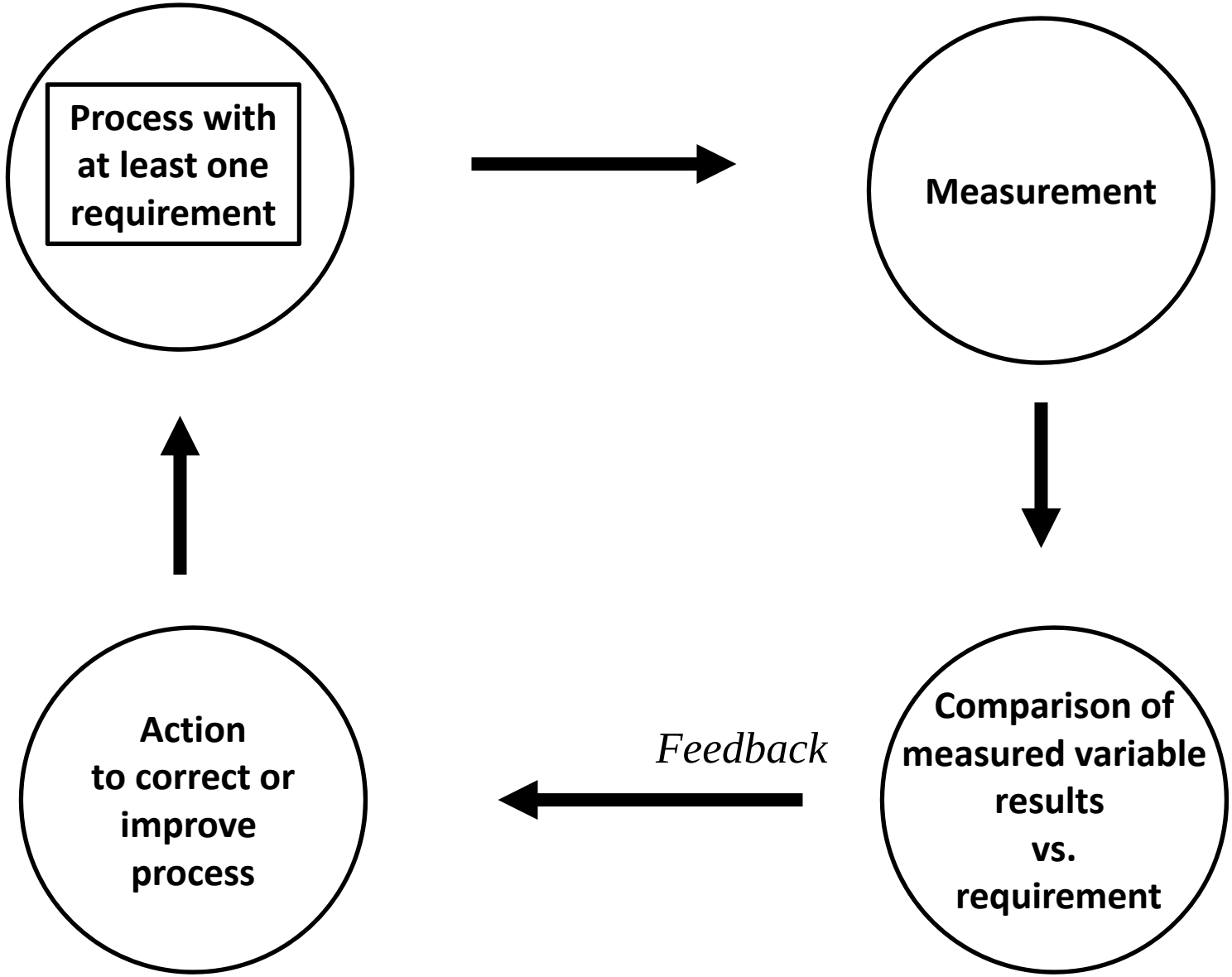
Process with at least one requirement
Measurement
Comparison of measured variable results vs. requirement
Feedback
Action to correct or improve process

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# Review of all primary weld methods available

- Weld by Time *(open loop process)*

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# Review of all primary weld methods available

- Weld by Time *(open loop process)*
- Weld by Energy - *watts over time (joules)*

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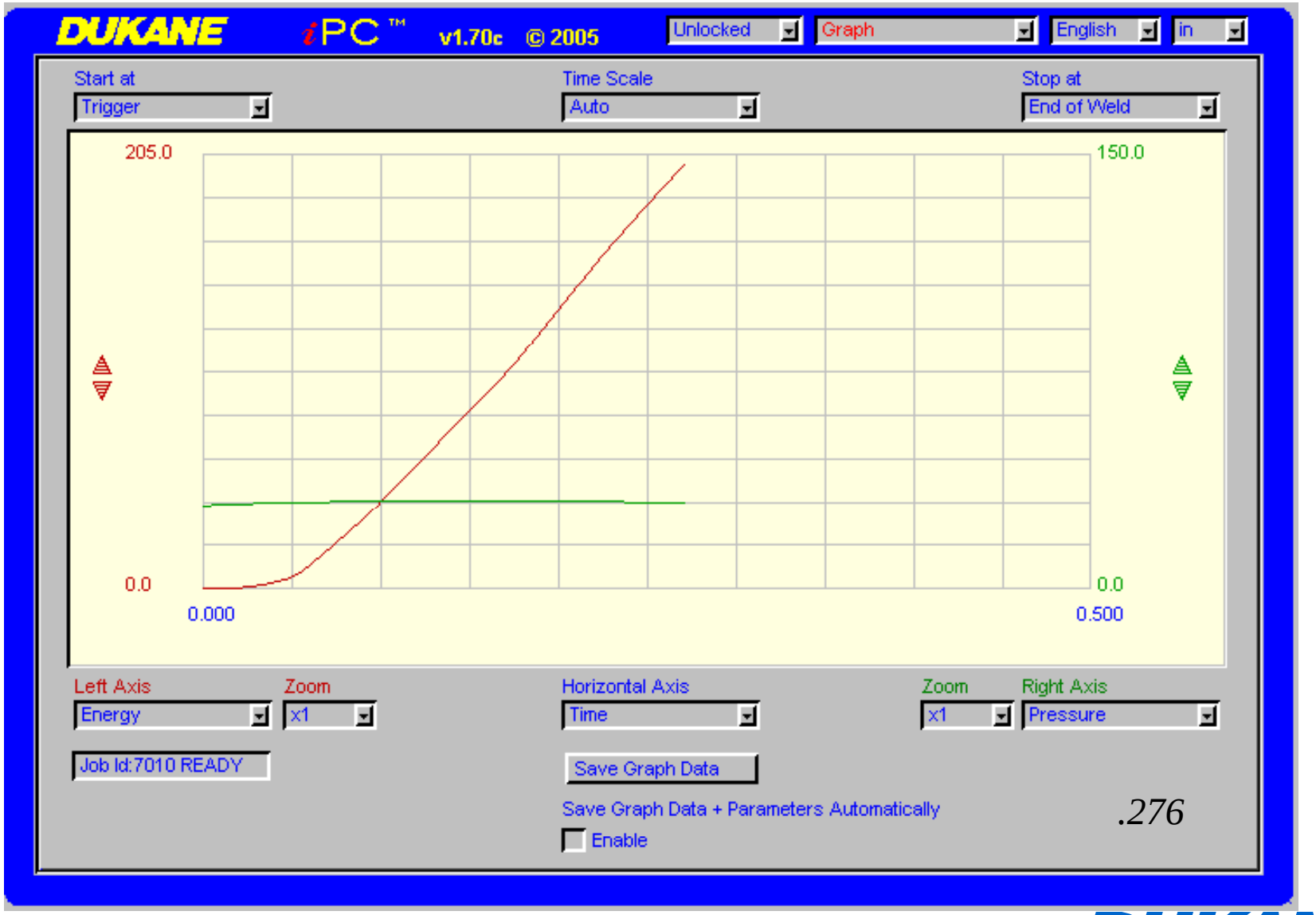
# Weld by Energy (30 psi weld force)

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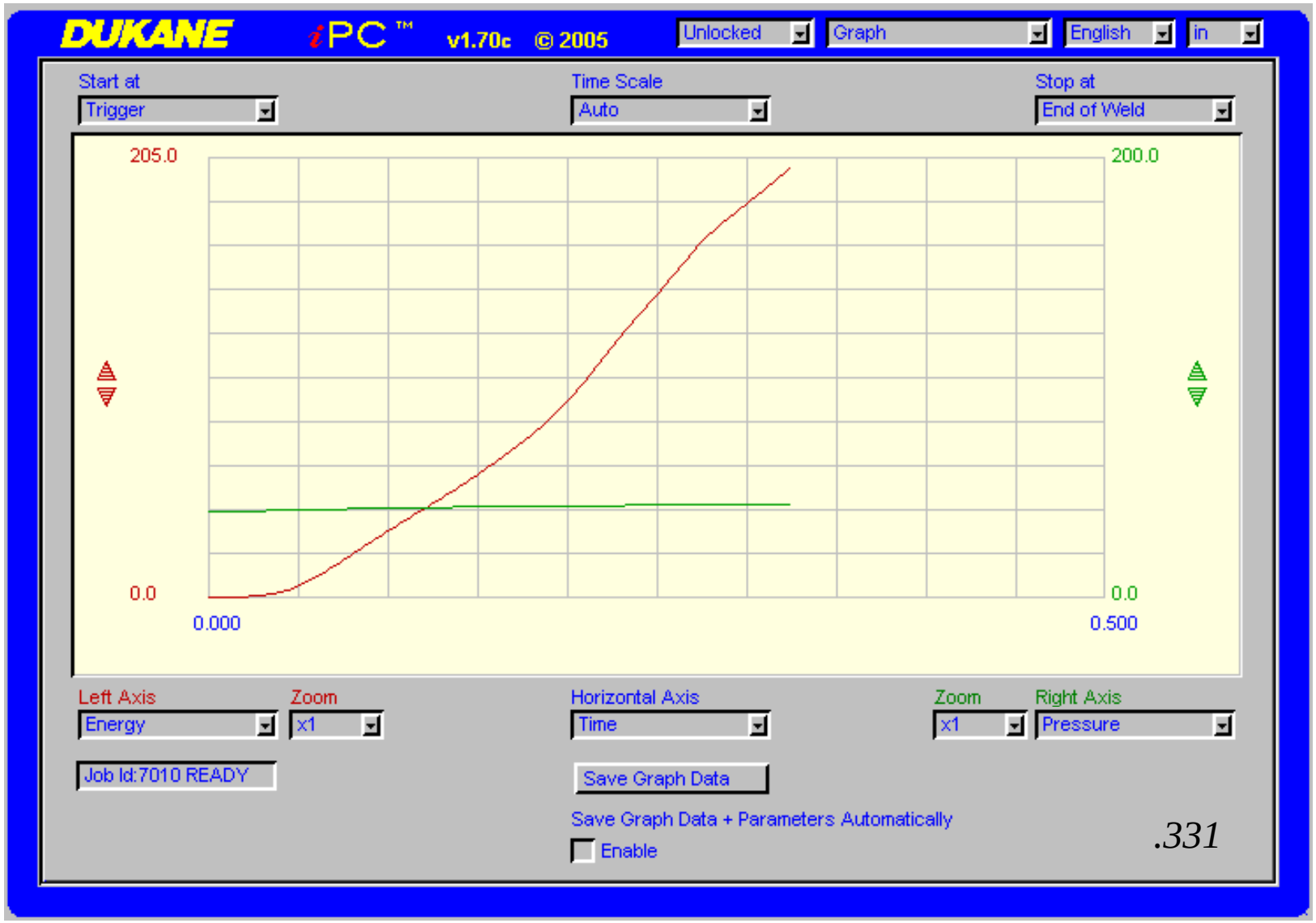
# Weld by Energy (25 psi weld force)

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# Review of all primary weld methods available

- Weld by Time
- Weld by Energy
- Weld by Peak Power - *highest peak watts*

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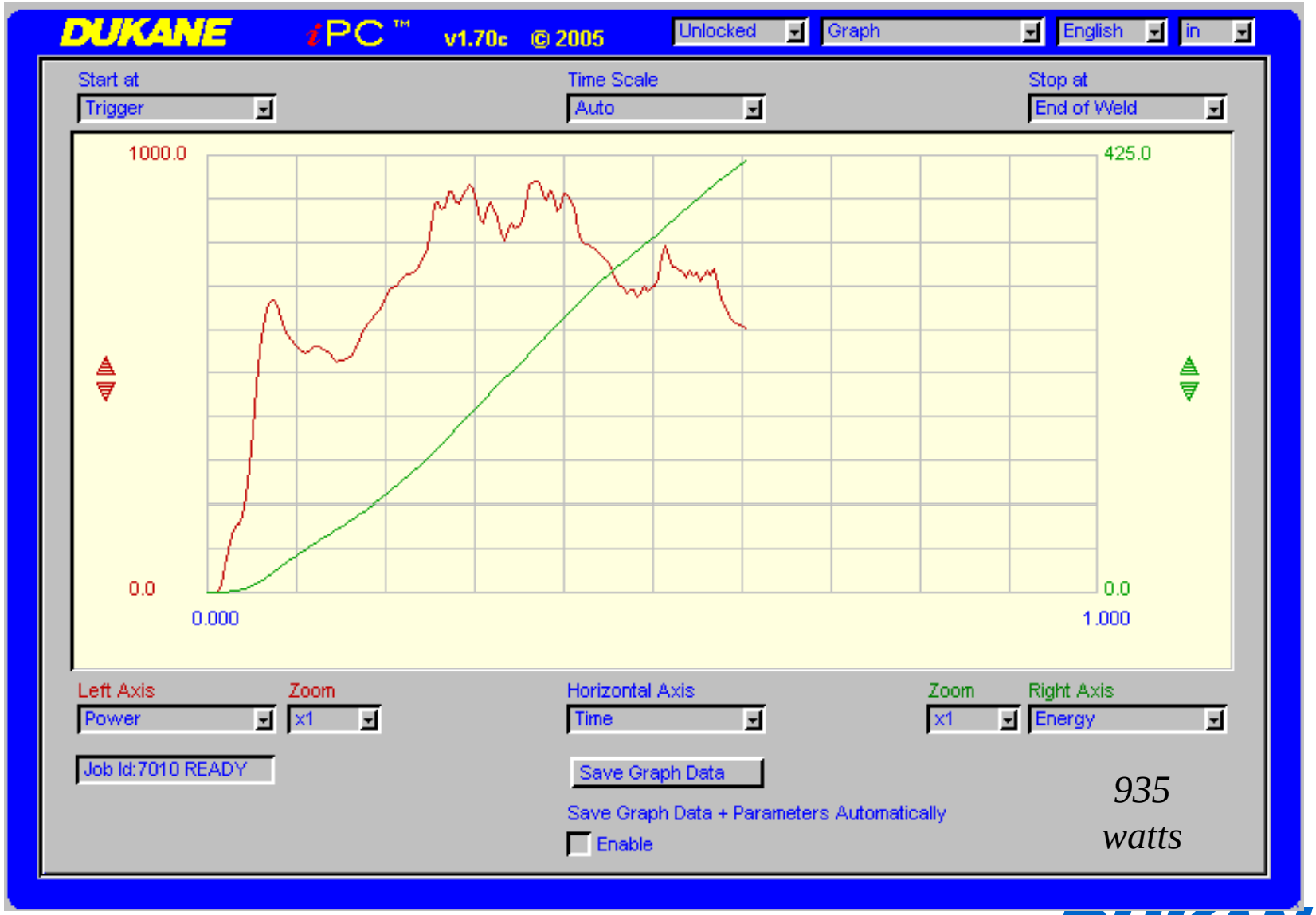
# Weld by Peak Power

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# Review of all primary weld methods available

- Weld by Time
- Weld by Energy
- Weld by Peak Power
- Weld by (Collapse) Distance

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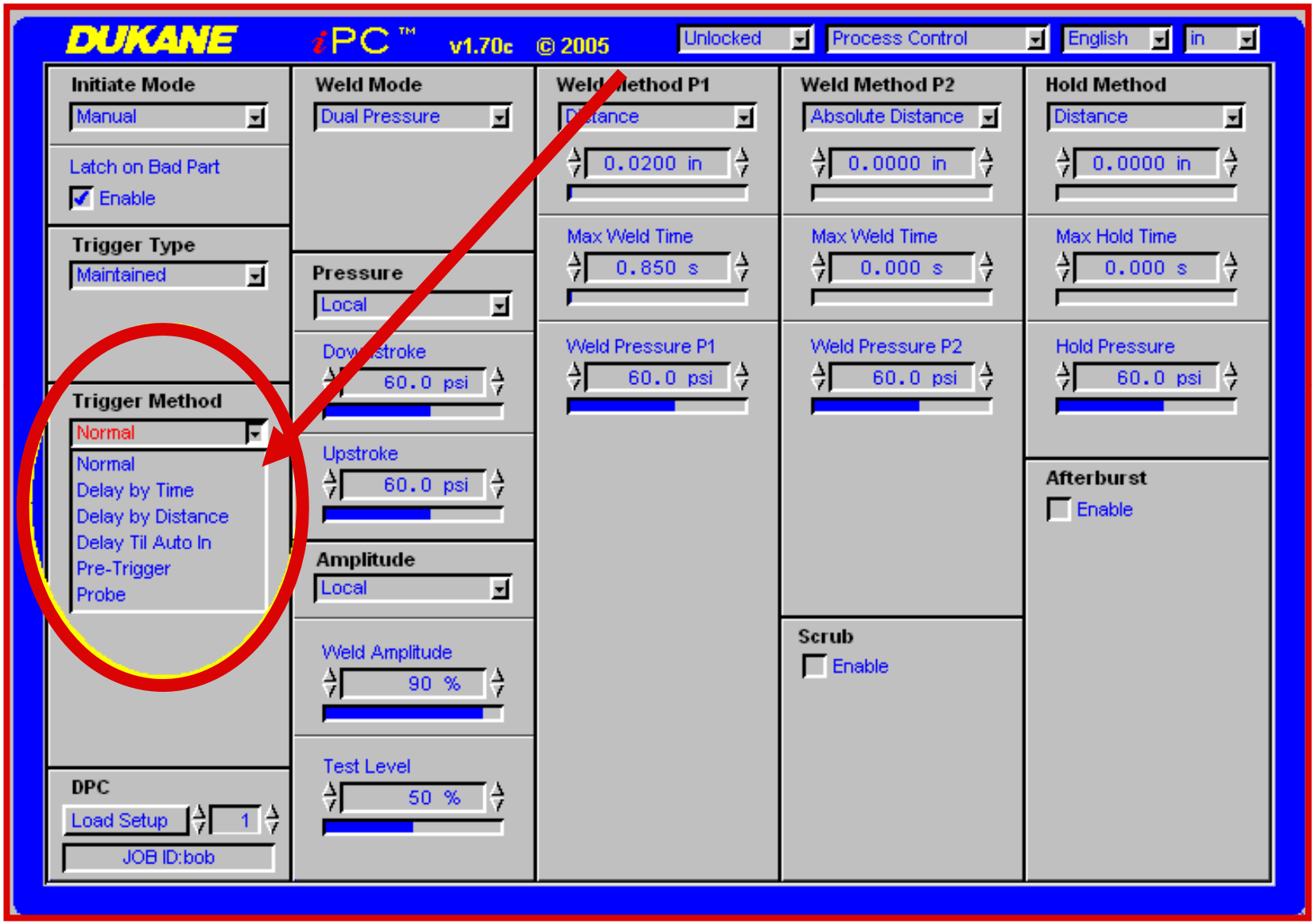
# Trigger Methods

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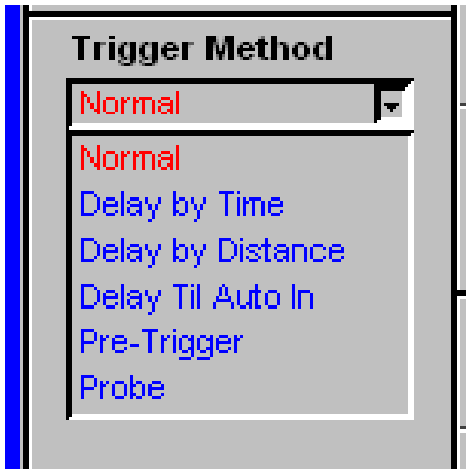
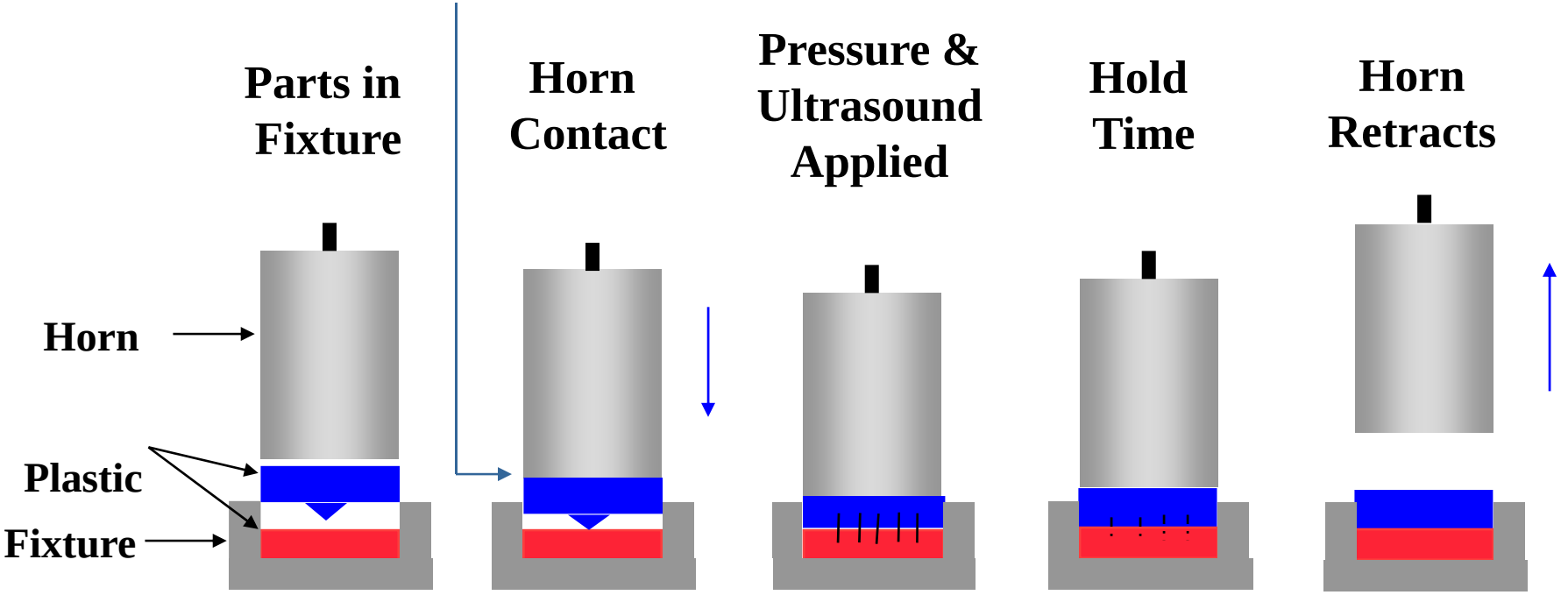
# How a Weld is achieved




**"Normal" trigger point, *the moment the machine starts measurement***

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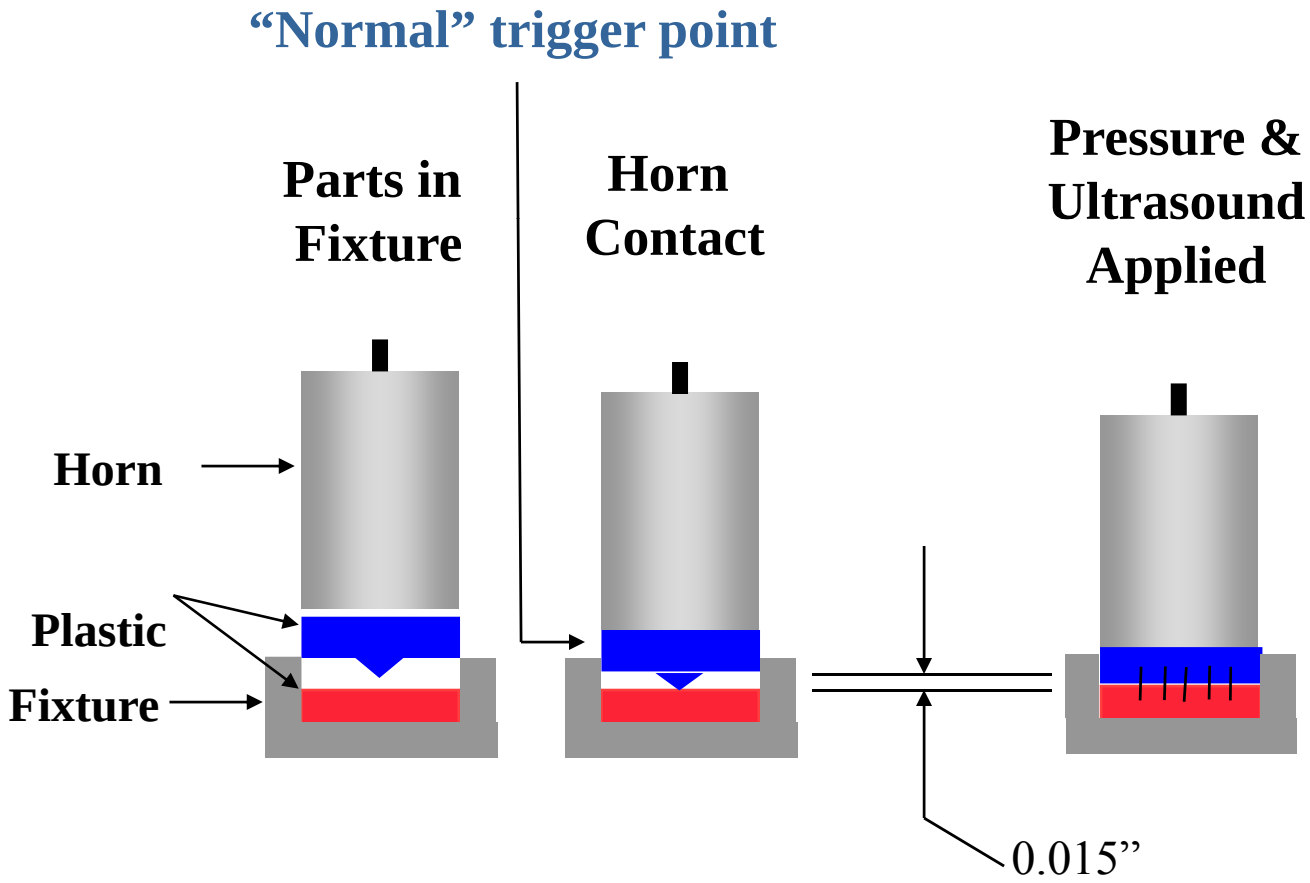
# Weld by (Collapse) Distance

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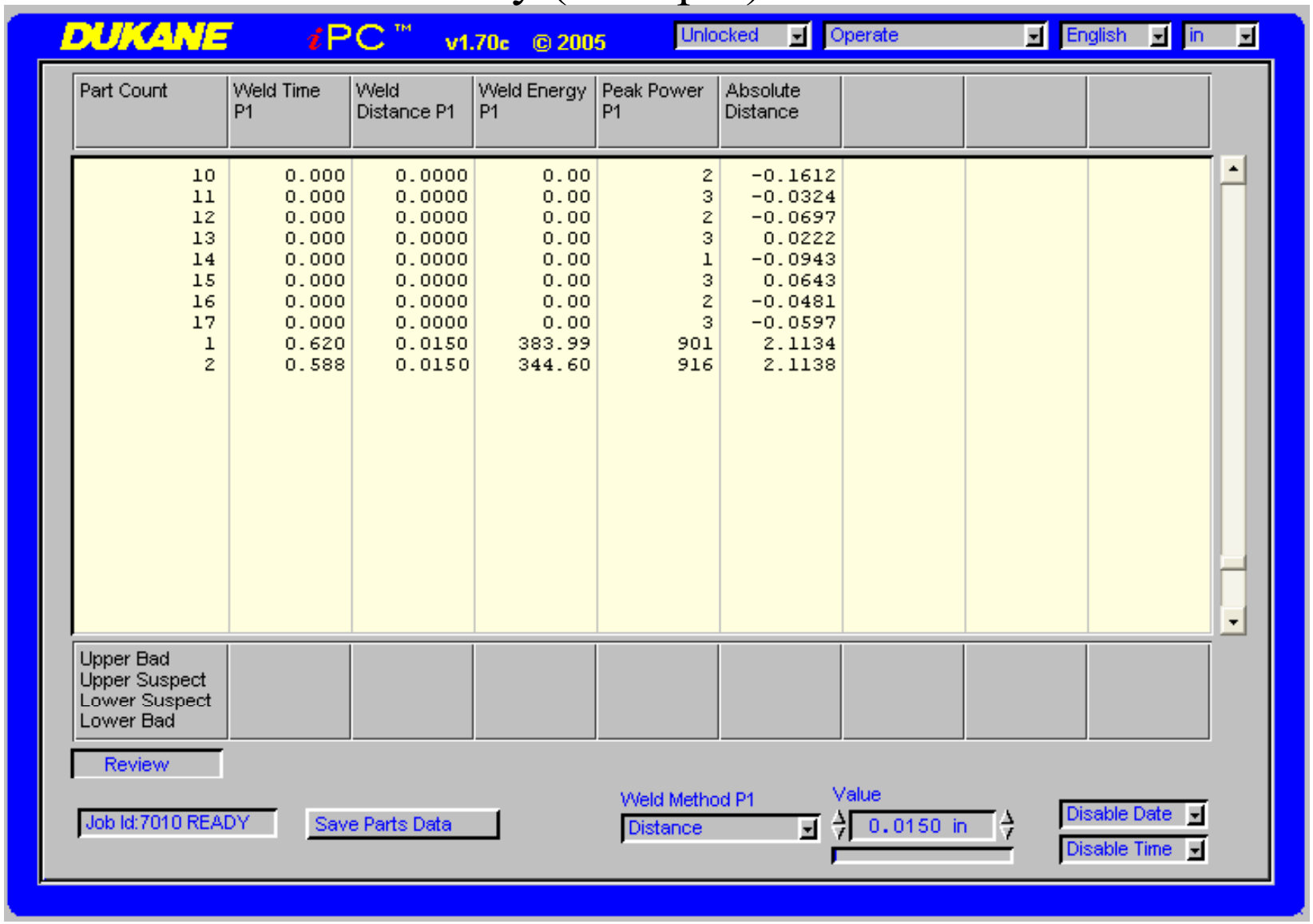
# Weld by (Collapse) Distance

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# Review of all primary weld methods available

- Weld by Time
- Weld by Energy
- Weld by Peak Power
- Weld by (Collapse) Distance
- Weld by Absolute Distance

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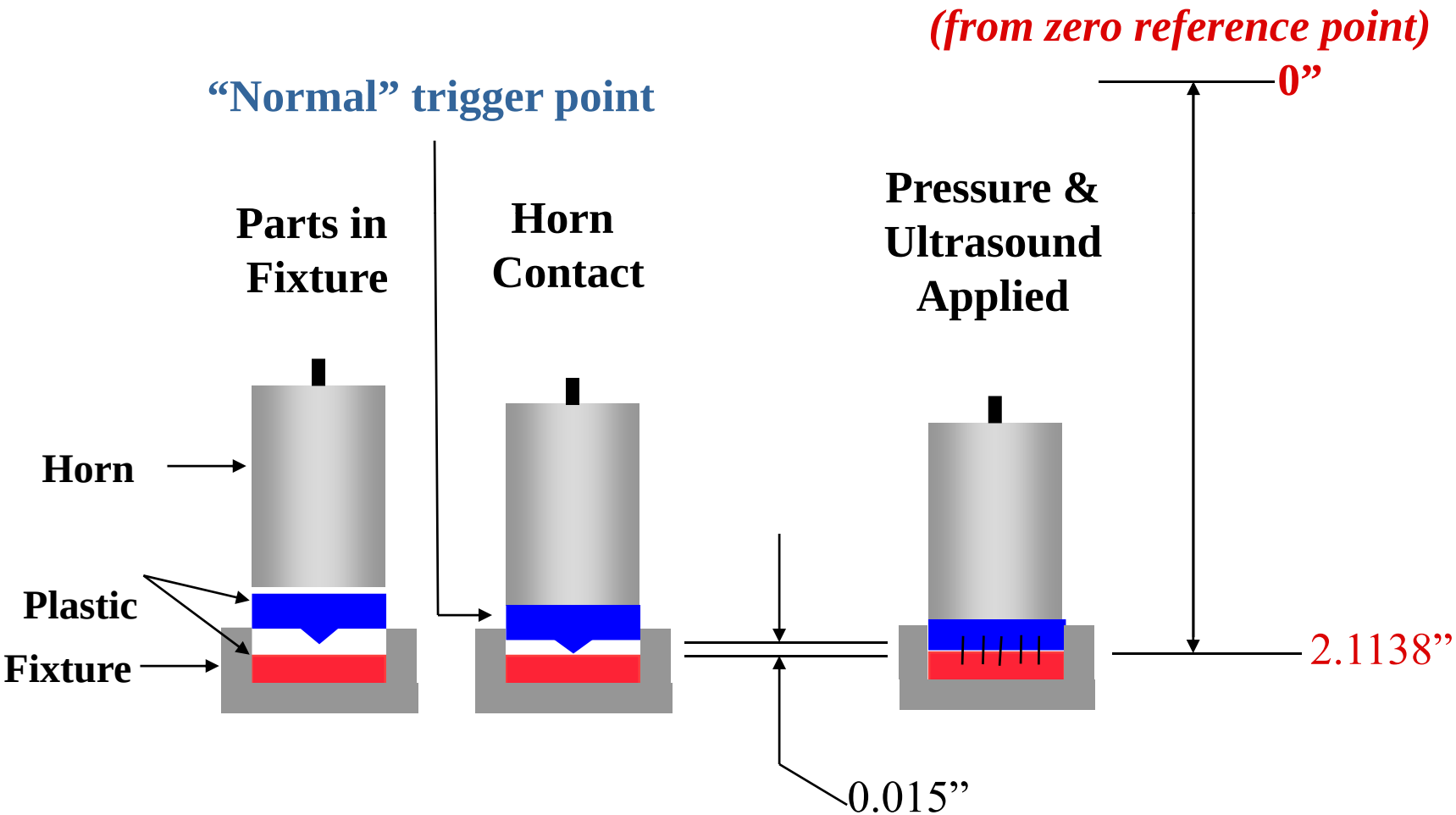
# Weld by Absolute Distance

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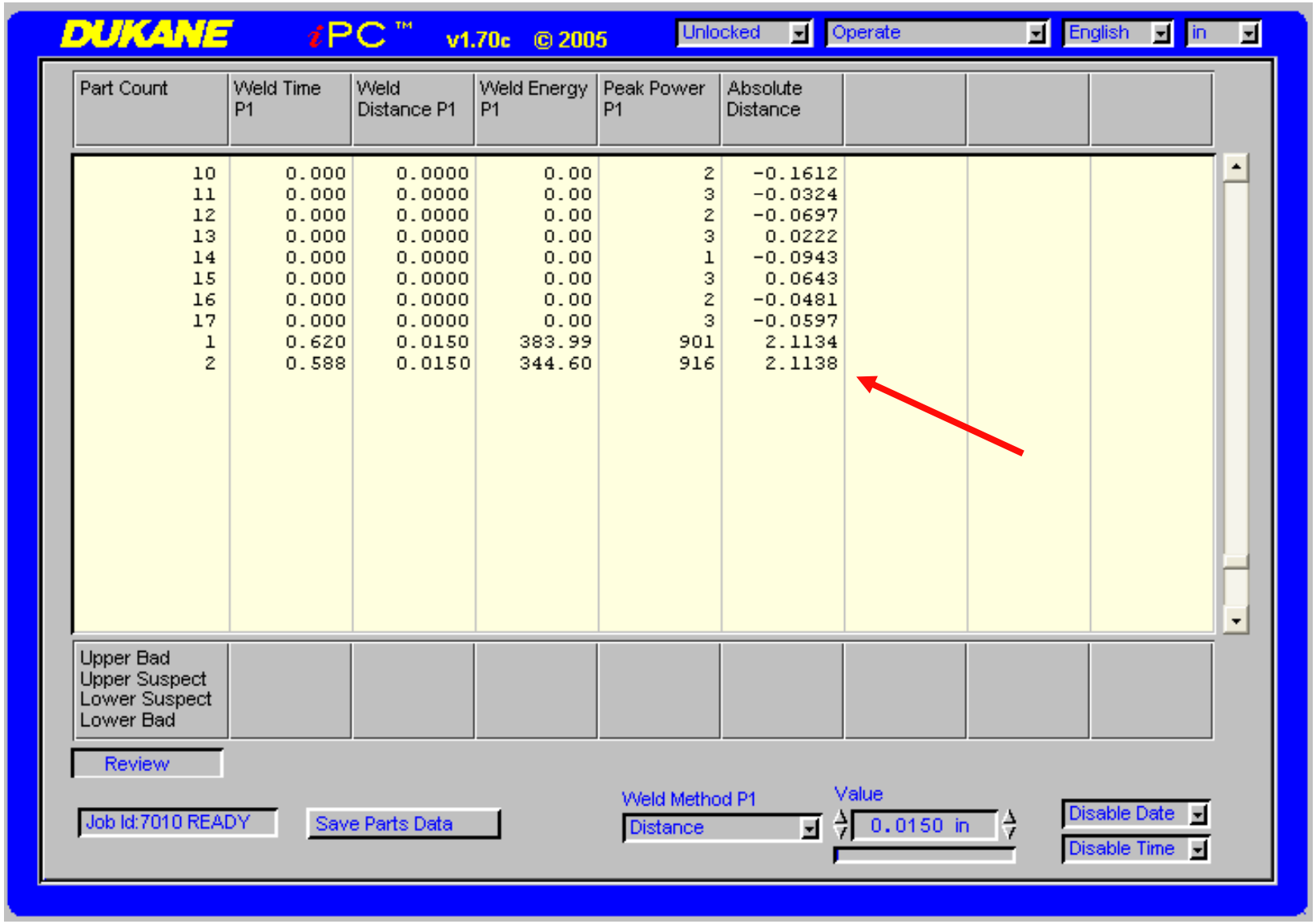
# Weld by Absolute Distance

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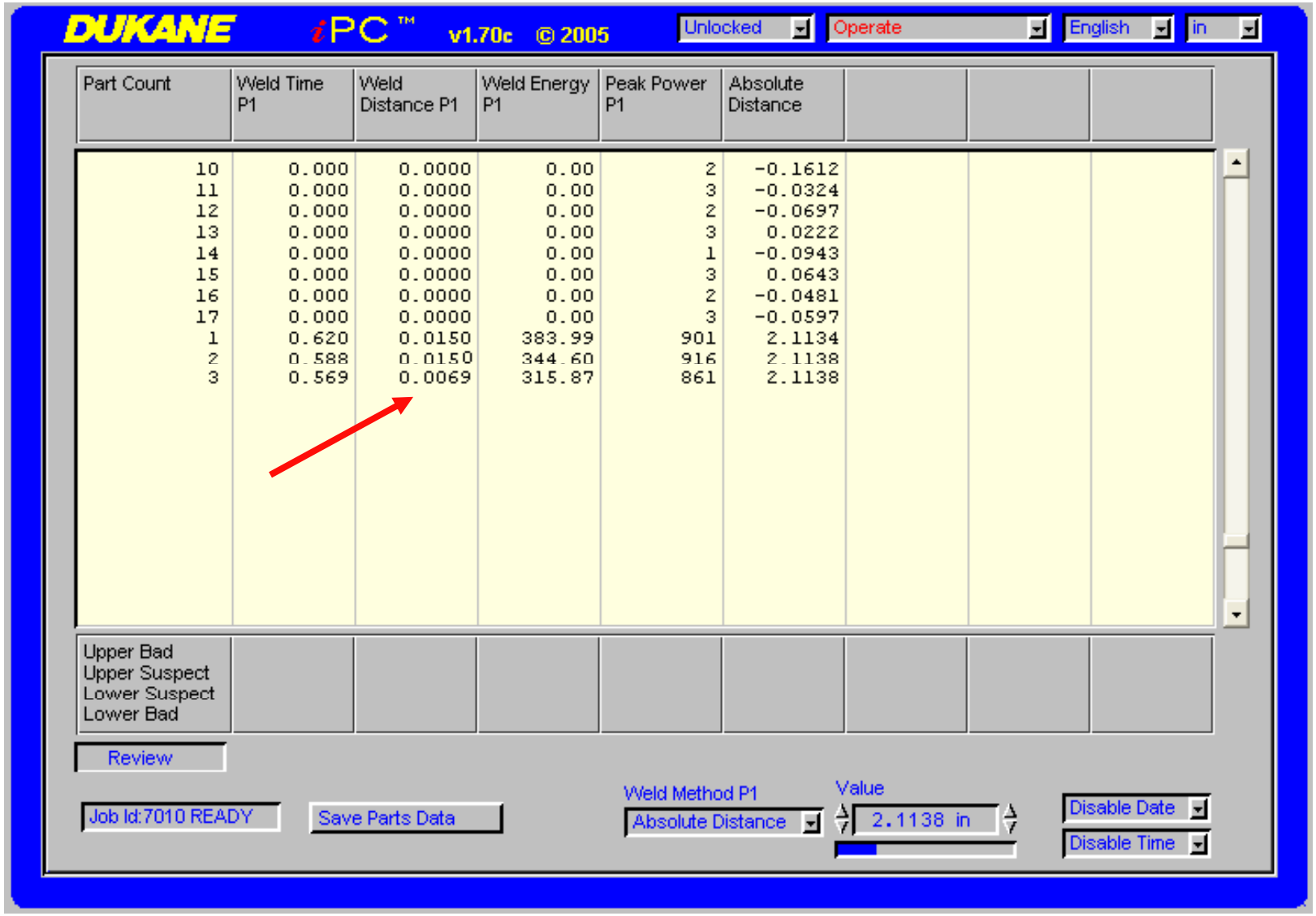
# Weld by Absolute Distance

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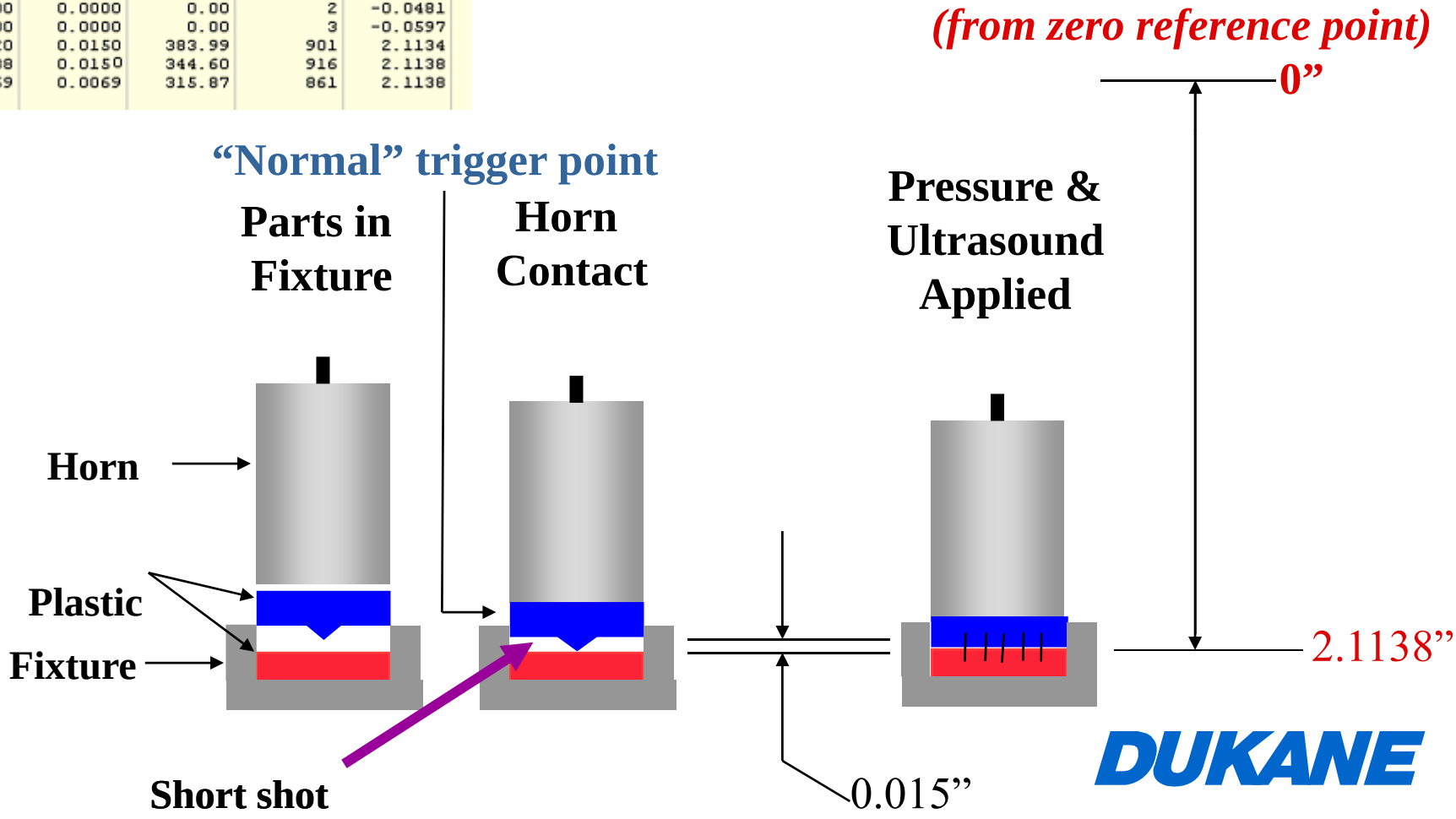
# Weld by Absolute Distance

| | Weld Time P1 | Weld Distance P1 | Weld Energy P1 | Peak Power P1 | Absolute Distance |
|---|---|---|---|---|---|
| 10 | 0.000 | 0.0000 | 0.00 | 2 | -0.1612 |
| 11 | 0.000 | 0.0000 | 0.00 | 3 | -0.0324 |
| 12 | 0.000 | 0.0000 | 0.00 | 2 | -0.0697 |
| 13 | 0.000 | 0.0000 | 0.00 | 3 | 0.0222 |
| 14 | 0.000 | 0.0000 | 0.00 | 1 | -0.0943 |
| 15 | 0.000 | 0.0000 | 0.00 | 3 | 0.0643 |
| 16 | 0.000 | 0.0000 | 0.00 | 2 | -0.0481 |
| 17 | 0.000 | 0.0000 | 0.00 | 3 | -0.0597 |
| 1 | 0.620 | 0.0150 | 383.99 | 901 | 2.1134 |
| 2 | 0.588 | 0.0150 | 344.60 | 916 | 2.1138 |
| 3 | 0.569 | 0.0069 | 315.87 | 861 | 2.1138 |

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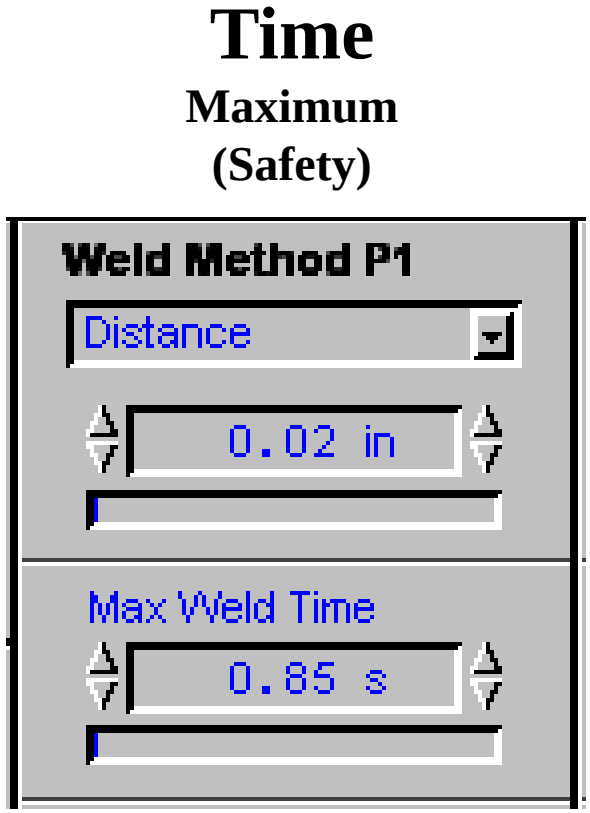
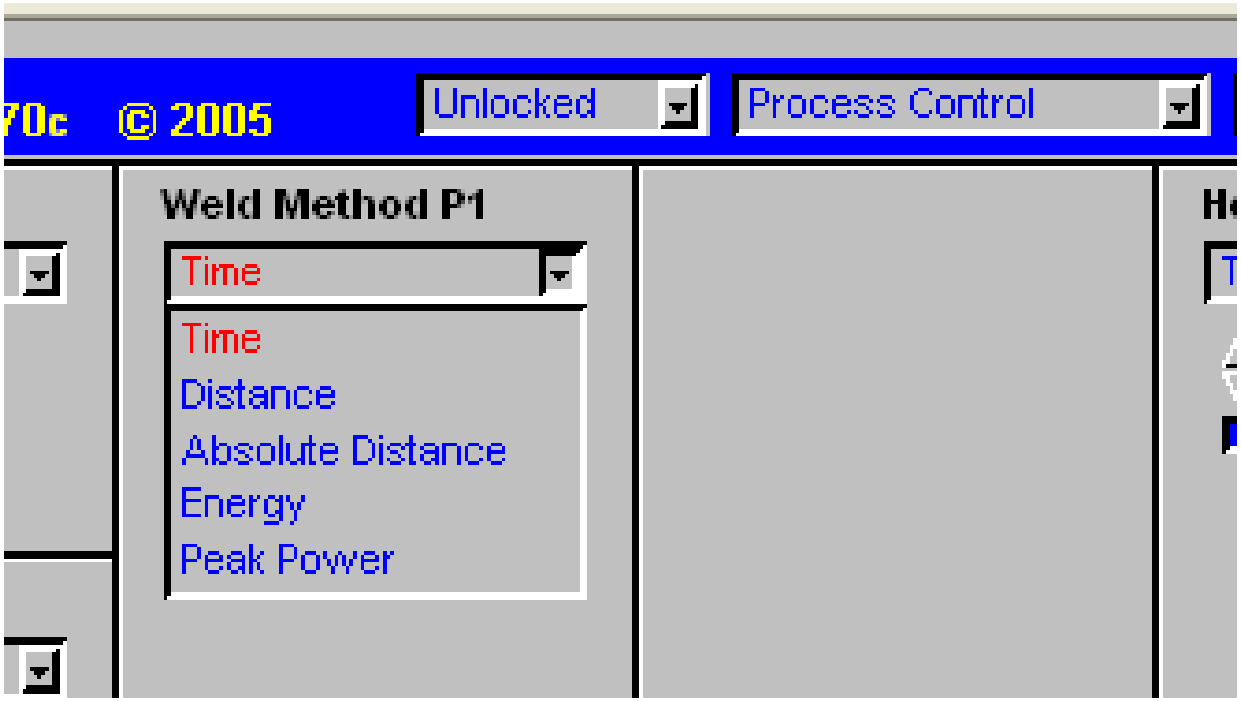
# Review of all primary weld methods available

- Weld by Time
- Weld by Energy
- Weld by Peak Power
- Weld by (Collapse) Distance
- Weld by Absolute Distance



# What primary weld method works the best?

**Process with at least one requirement**

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# List some part requirements and possible weld methods

| Requirement | Method |
| --- | --- |
| - 50 lbs burst test | - Weld by Energy |
| - Part height +/- .002 | - Weld by Absolute Distance |

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# Primary weld methods

# Secondary controls

- *Provide additional ways to end the weld portion of the cycle together with the primary control method specified*
- *This means the control of the weld process can be accomplished either by the primary control or by one or more secondary controls*

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# Secondary Controls

| Primary | OR | Secondary |
| --- | --- | --- |
| • Weld by Time | ⟷ | • Weld by Absolute Distance |
| • Weld by Energy | ⟷ | • Weld by (Collapse) Distance |
| • Weld by Peak Power | ⟷ | • Weld by Time |
| • Weld by (Collapse) Distance | ⟷ | • Weld by Peak Power |
| • Weld by Absolute Distance | ⟷ | • Weld by Energy |

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# Secondary Controls

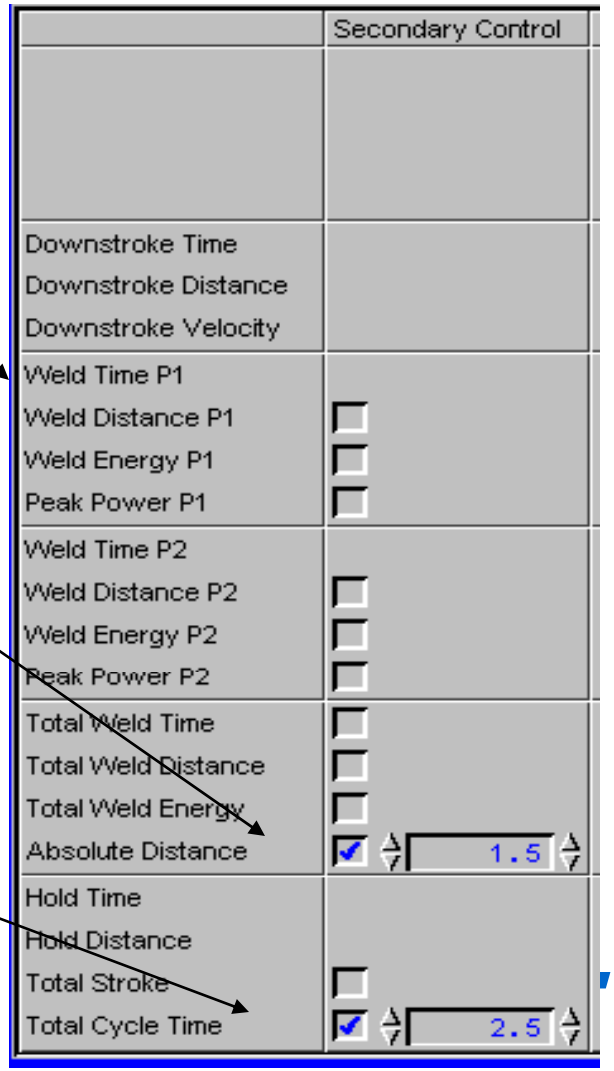
**Primary** Weld by Time

**OR**

**Secondary** Weld by Absolute Distance

**OR**

Total Cycle Time



Primary weld methods
Secondary Controls

Process Limits

***- ability to set upper and lower process control limits (SPC)***

**“Suspect” parts**

***and/or***

**“Bad” part Limits**

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# Process Limits

**"Suspect"** ***weld results that are considered good yet falling outside (Cpk) range. Early warning that the process (or parts) are changing***

**"Bad"** ***weld results that are considered bad - parts did not meet the expected predetermined requirement. (NOTE the welder terminates the cycle once a bad part limit is achieved)***

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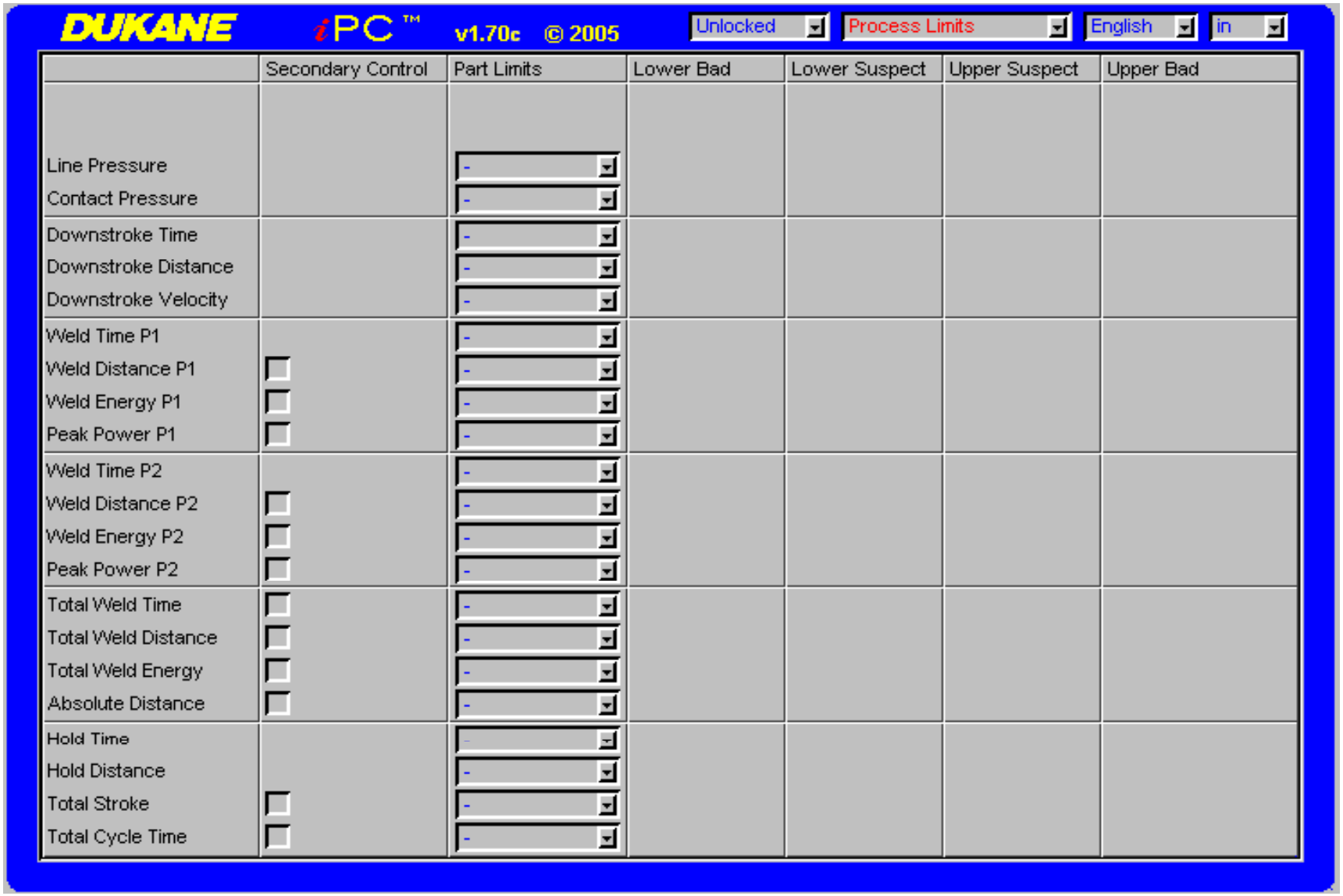
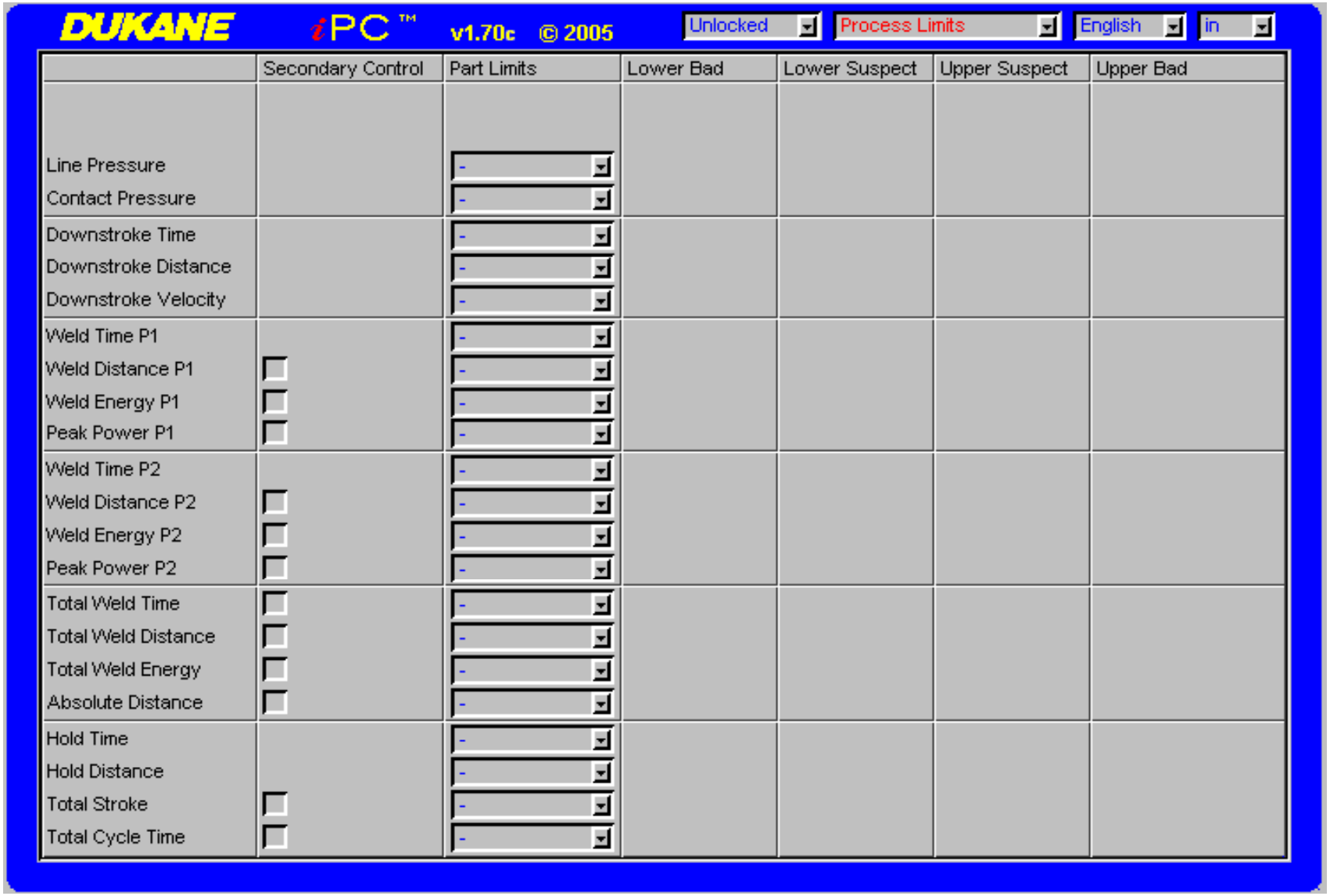
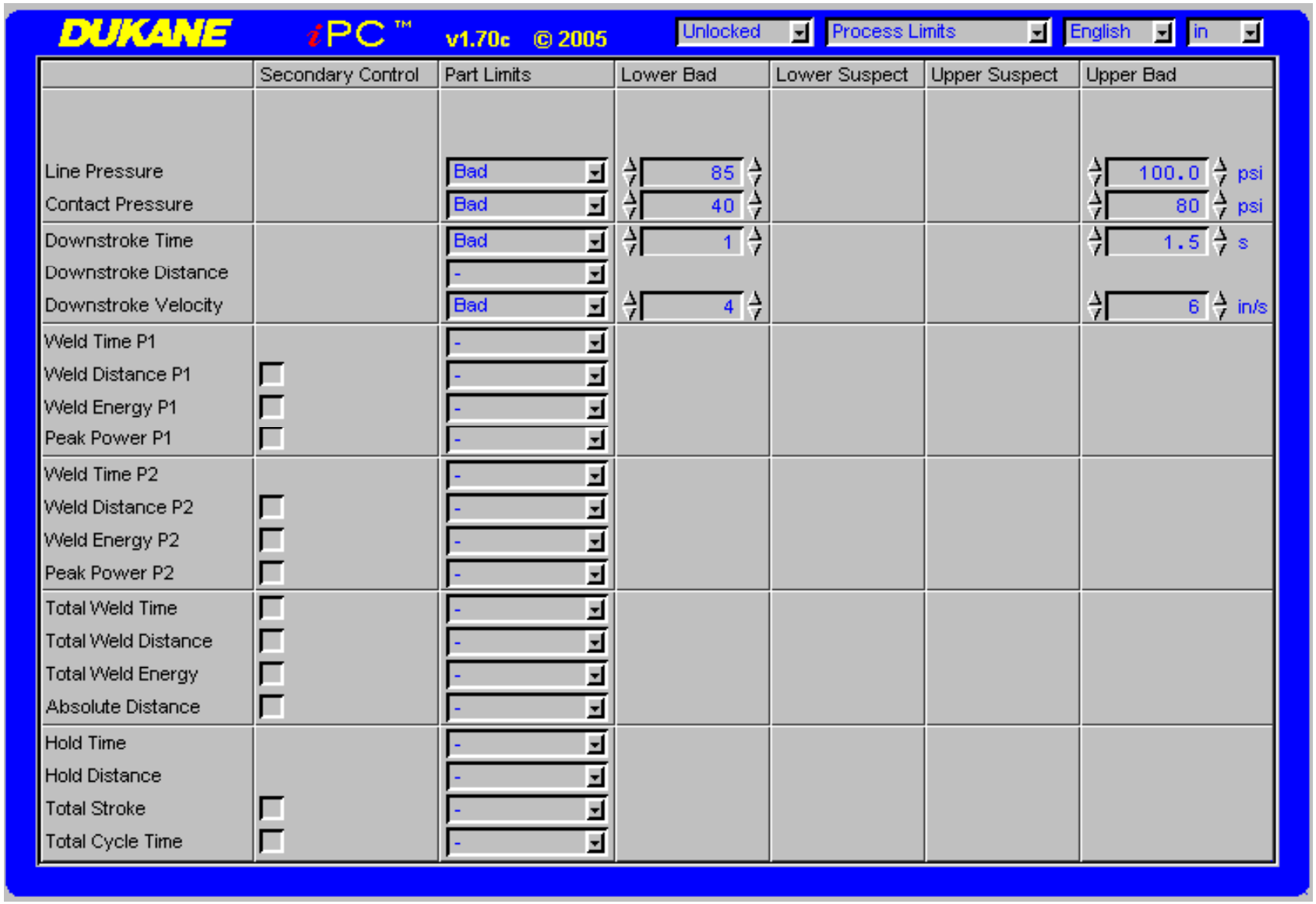
# Process Limits



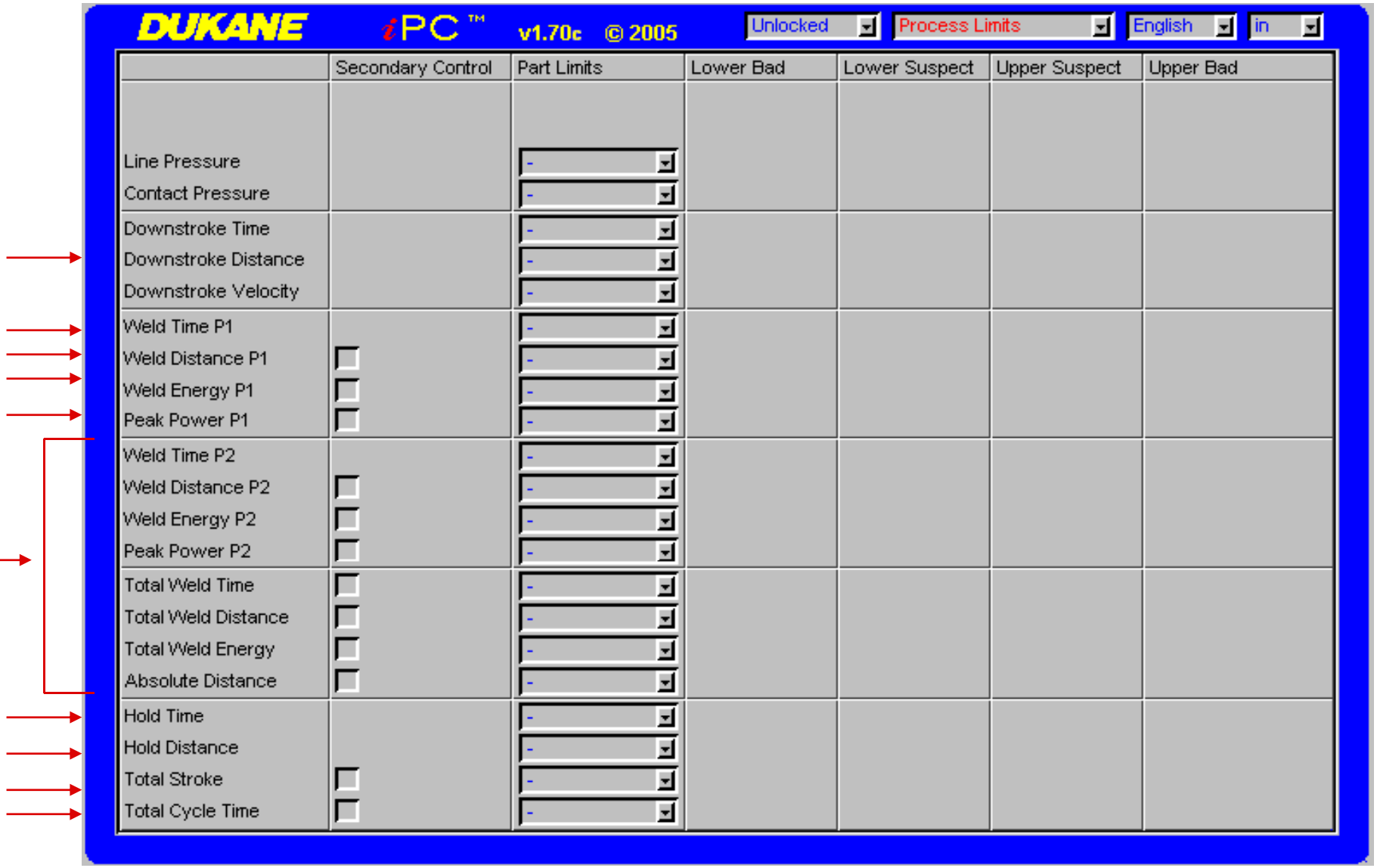
# Process Limits - *not related to the part*



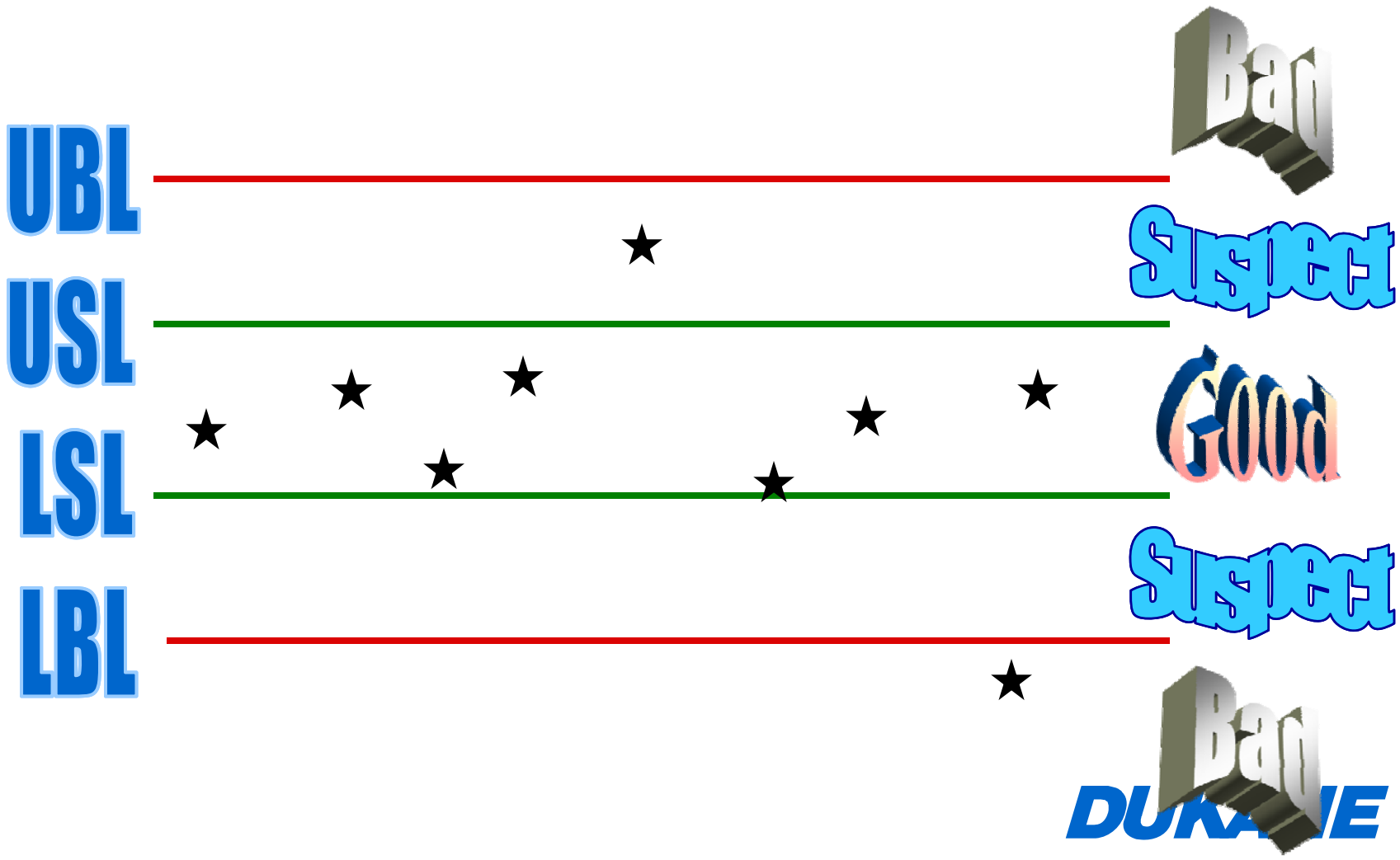
# Process Limits - *not related to the part*



# Process Limits - *related to the part variations*



# Process Limits Concept



**Goal - produce consistent parts that meet customers' requirements 100% of the time!**

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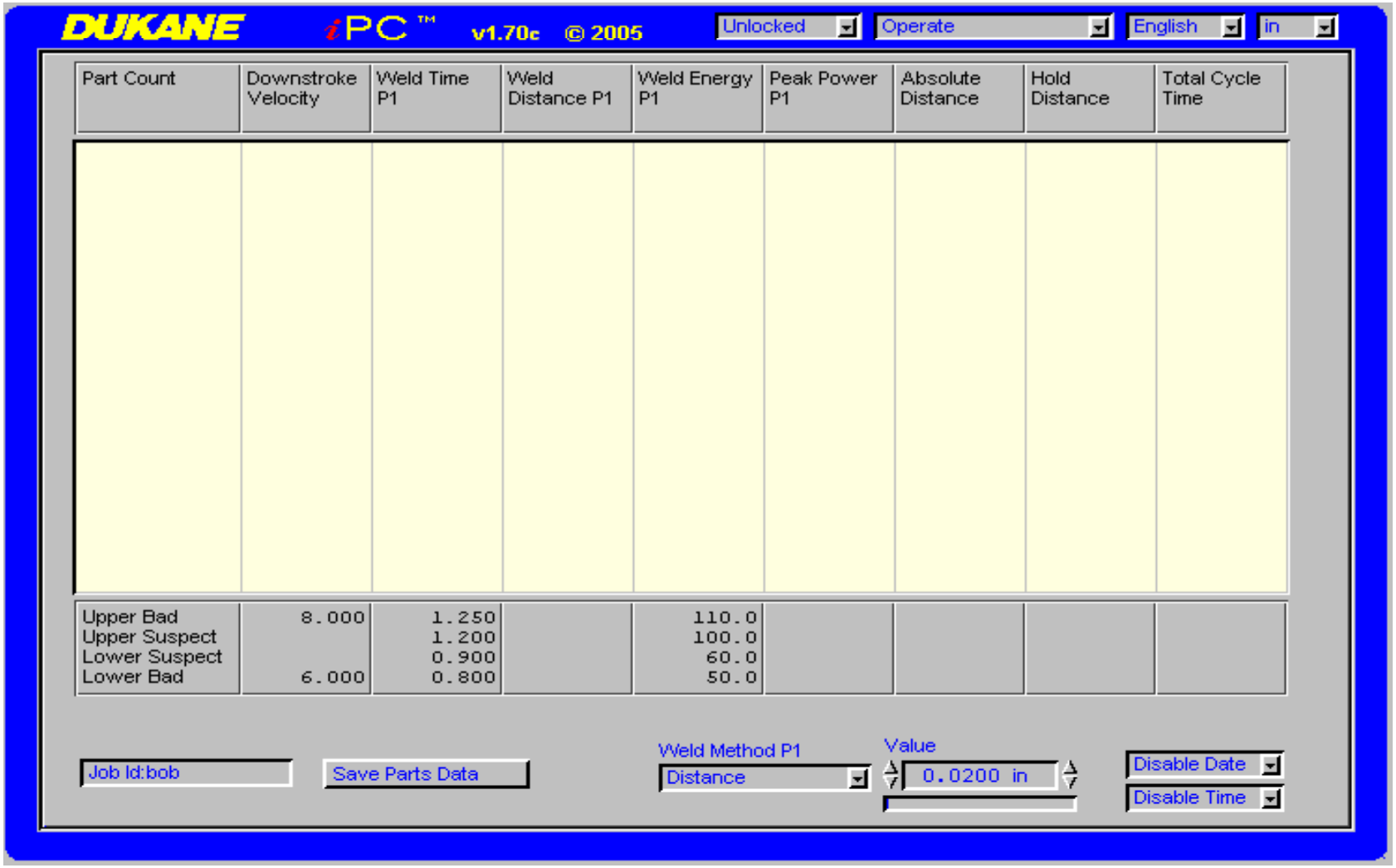
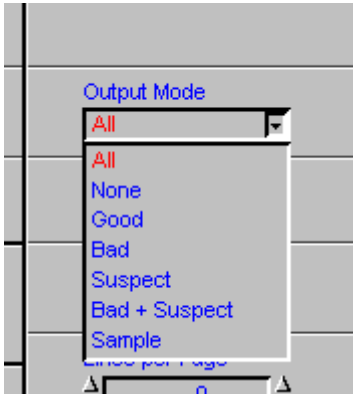
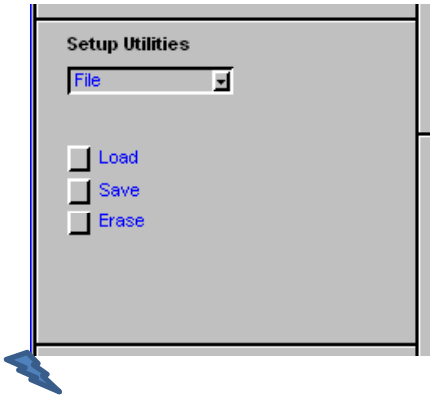
# Goal - produce consistent parts that meet customers' requirements 100% of the time!



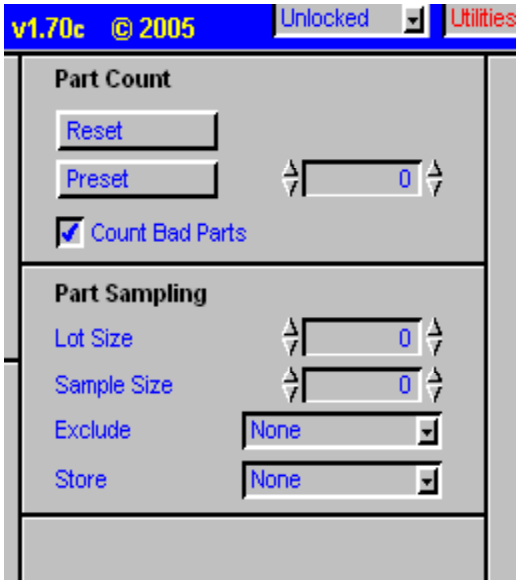
**Goal - produce consistent parts that meet customers' requirements 100% of the time!**

- We defined the requirements
- We set up the measurement system
- Document setup




- Print and post the setups - *identify all parameters*
- Print and document process results



# Dukane Welding System Configuration Report

## Setup Name: TEPE Demo

10/8/2010

### Welder Type

| | |
|---|---|
| | PRESS |
| Booster | 2 |
| Fixture | 0 |
| Horn | 0 |

### Initiate Settings

| | | | |
|---|---|---|---|
| Initiate Mode | Manual | Latch on Bad Part | Disabled |

### Trigger Settings

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Trigger Type | Force | Trigger Force | 8 | lb | Compensation Point | 0 | in |
| | | Max Trigger Time | 3.000 | s | | | |
| Trigger Method | Normal | | | | | | |

### Weld Settings

| | | | |
|---|---|---|---|
| Weld Mode | Single Method | | |
| Weld Method 1 | Time | | |
| Weld Downstroke | | 20.0 | psi |
| Weld Pressure Method 1 | | 20.0 | psi |
| Weld Time Method 1 | | 0.300 | s |
| Weld Pressure Select | Local | | |
| Weld Upstroke | | 40.0 | psi |
| Weld Amplitude Select | Local | 100 | % |
| Weld Ramp Up Time | | 0.050 | s |
| Weld Ramp Down Time | | 0.000 | s |

### Hold Settings

| | | | |
|---|---|---|---|
| Hold Method | Time | 0.500 | s |
| Hold Pressure | | 40.0 | psi |

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**Goal - produce consistent parts that meet customers' requirements 100% of the time!**

- We defined the requirements
- We set up the measurement system
- Document setup
- Put controls in place

  - *enable "Latch on bad part"*
  - *use a bad part alarms external device*
  - *tie signals to automation*


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**Goal - produce consistent parts that meet customers' requirements 100% of the time!**

- We defined the requirements
- We set up the measurement system
- Document setup
- Put controls in place
- Periodic review

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# Ultrasonic welding Process Optimization

*Methods of producing stronger more consistent weld results*

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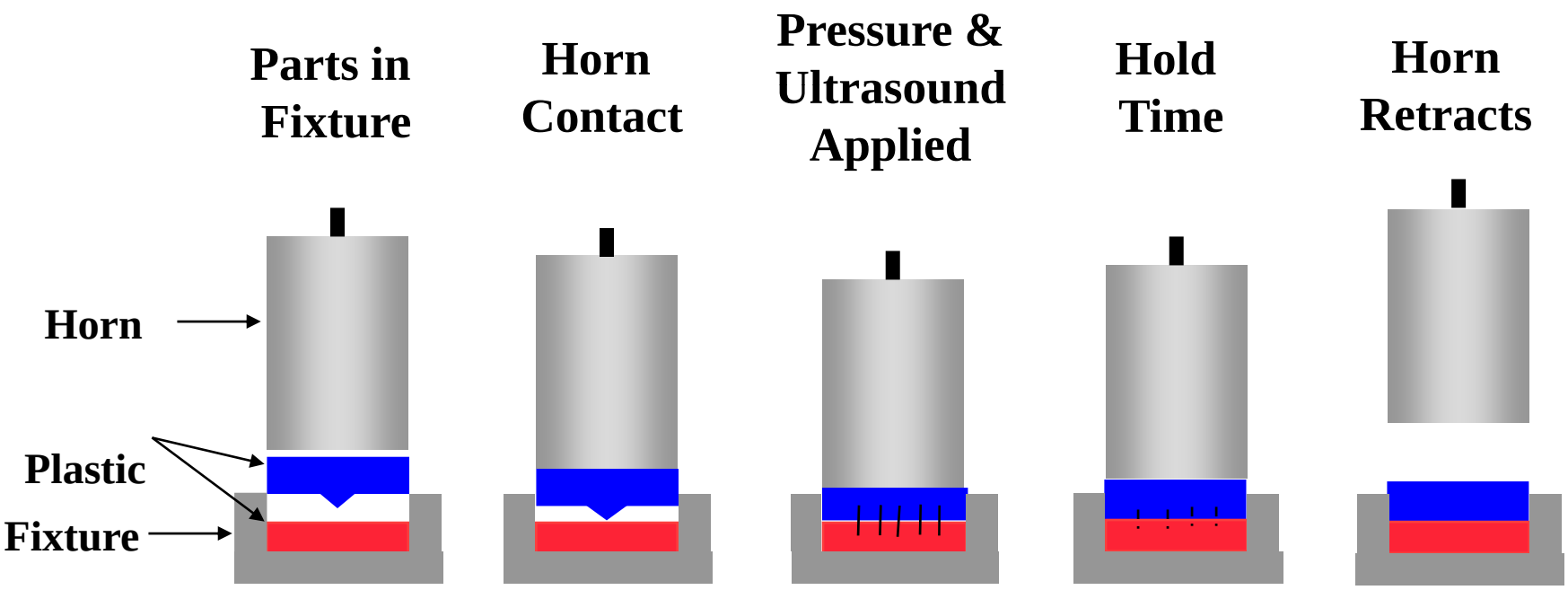
# Ultrasonic welding Process Optimization

| System 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 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 |

# Weld Process Sequence

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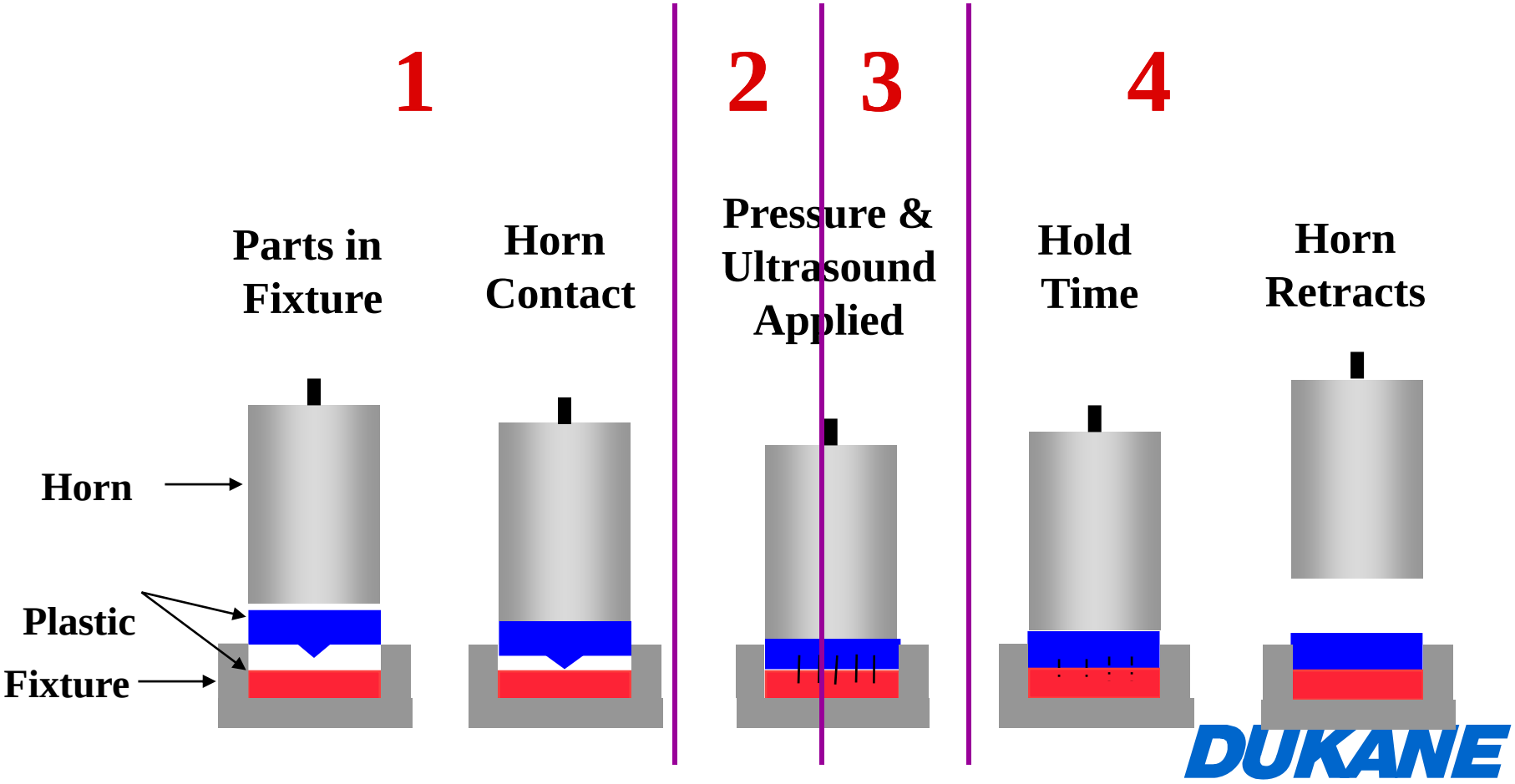
# Weld Phase


1
2
3
4
Parts in Fixture
Horn Contact
Pressure & Ultrasound Applied
Hold Time
Horn Retracts
Horn
Plastic
Fixture

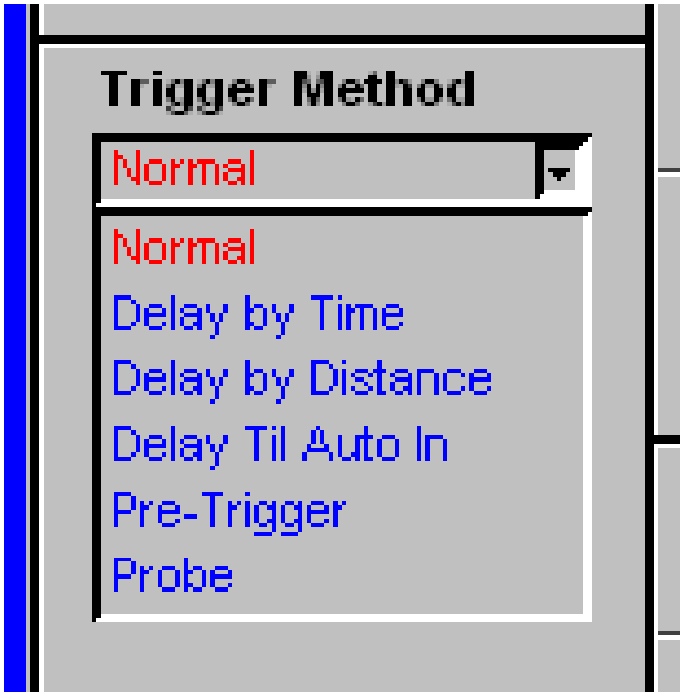
# Ultrasonic welding Process Optimization

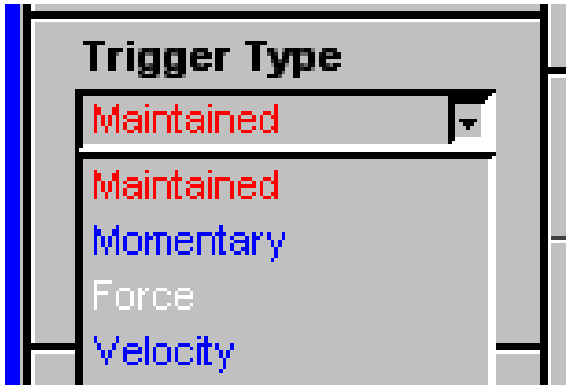
Phase 1 Pre-weld *optimized trigger*

Phase 2 Transition

Phase 3 Molten

Phase 4 Post weld (Cool/solidify)

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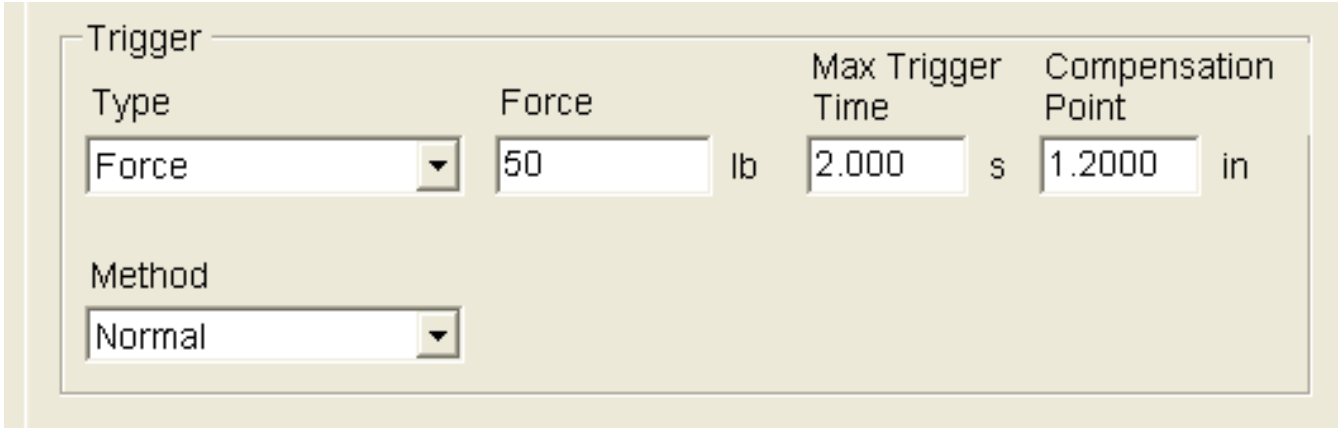
# Ultrasonic welding Process Optimization

## Phase 1 Pre-weld *optimized trigger*

### **Compensation Point (HSC)**

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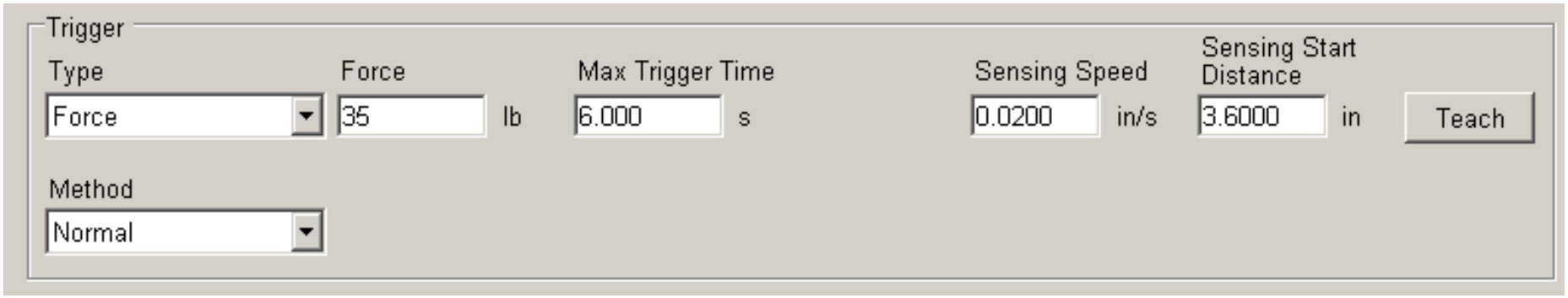
# Ultrasonic welding Process Optimization

## Phase 1 Pre-weld *optimized trigger*

**Sensing Speed (Servo)**

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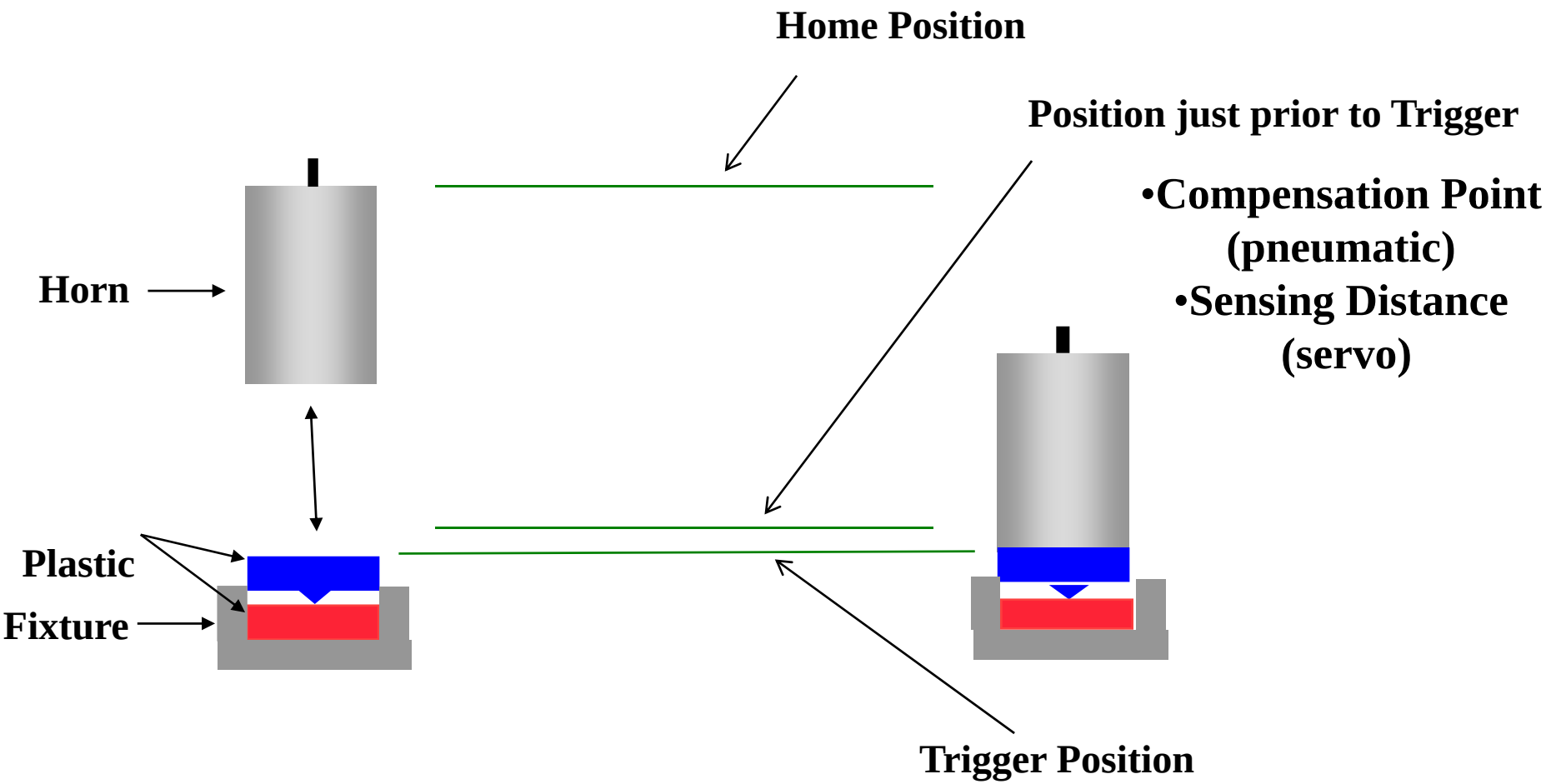
- Phase 1 Pre-weld *optimized trigger*

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# Ultrasonic Welding Process Optimization

Phase 2 Transition

Phase 3 Molten *optimized melt velocity*

- **Start Motion After Force Drop (Servo)**
- **Dual Pressure**
- **Hydraulic Velocity Control**
- **Servo Speed control - Constant**
- **Servo Speed control - Profile**

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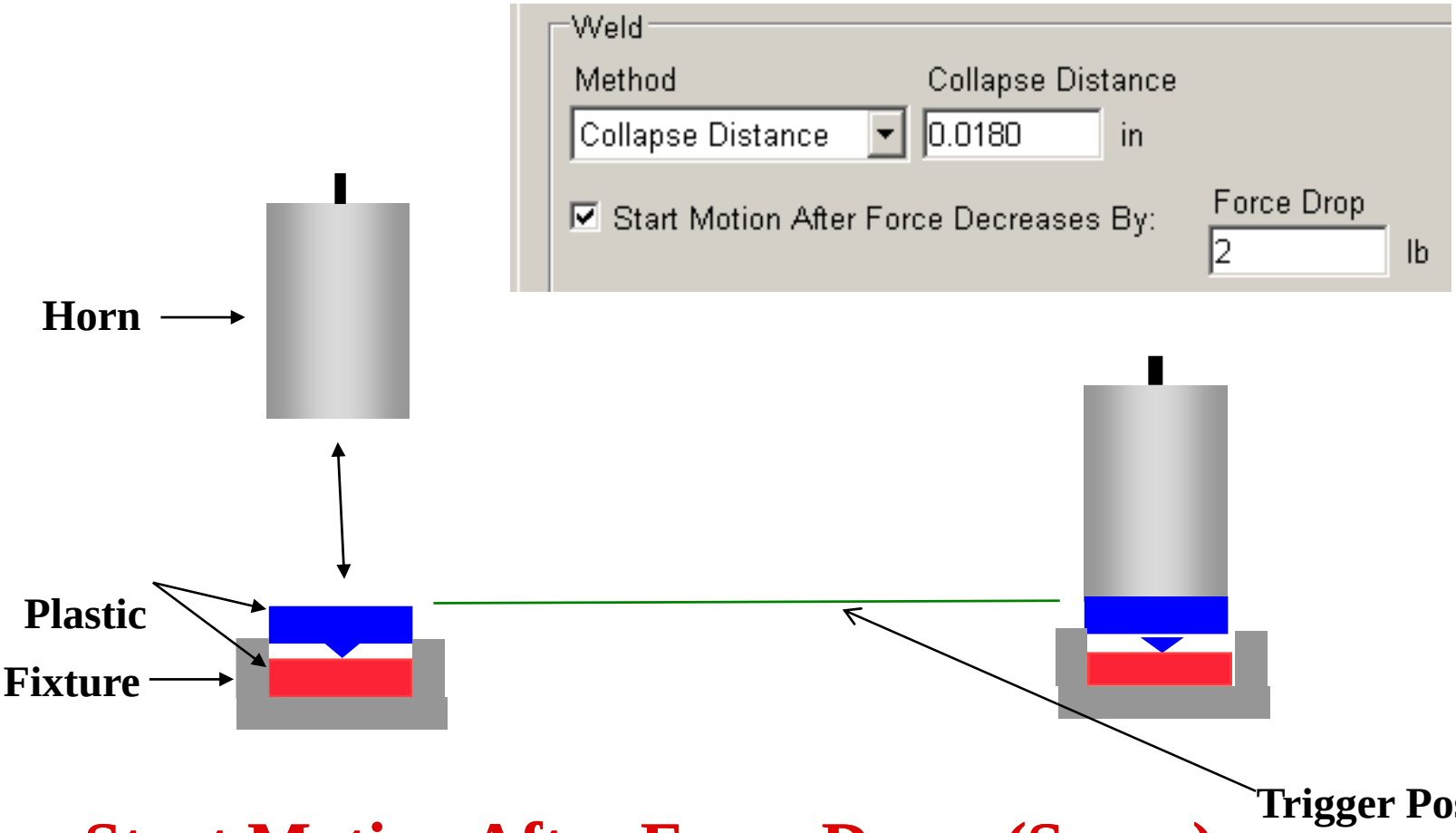
- Phase 2 Transition *optimized melt velocity*




**•Start Motion After Force Drop (Servo)**

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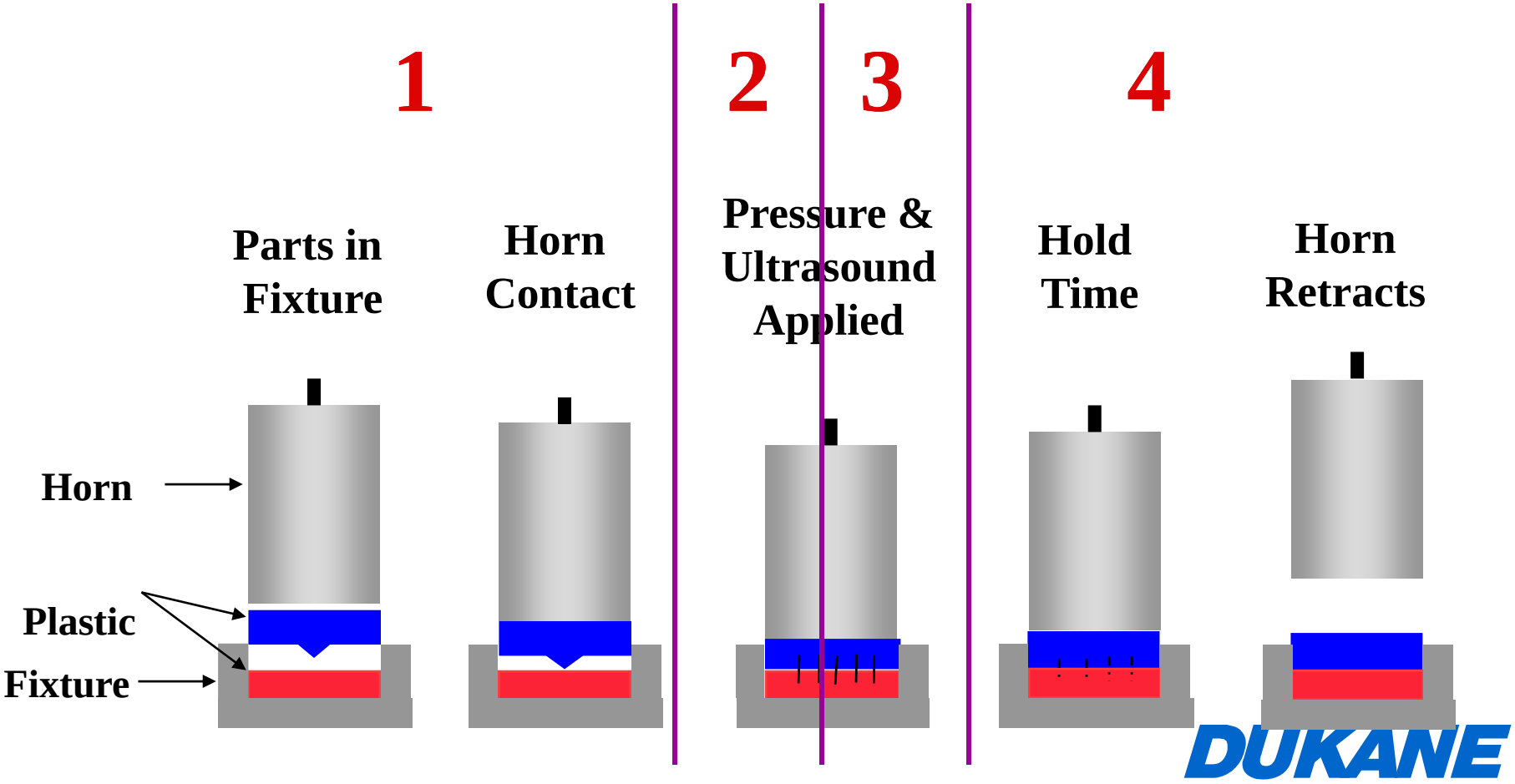
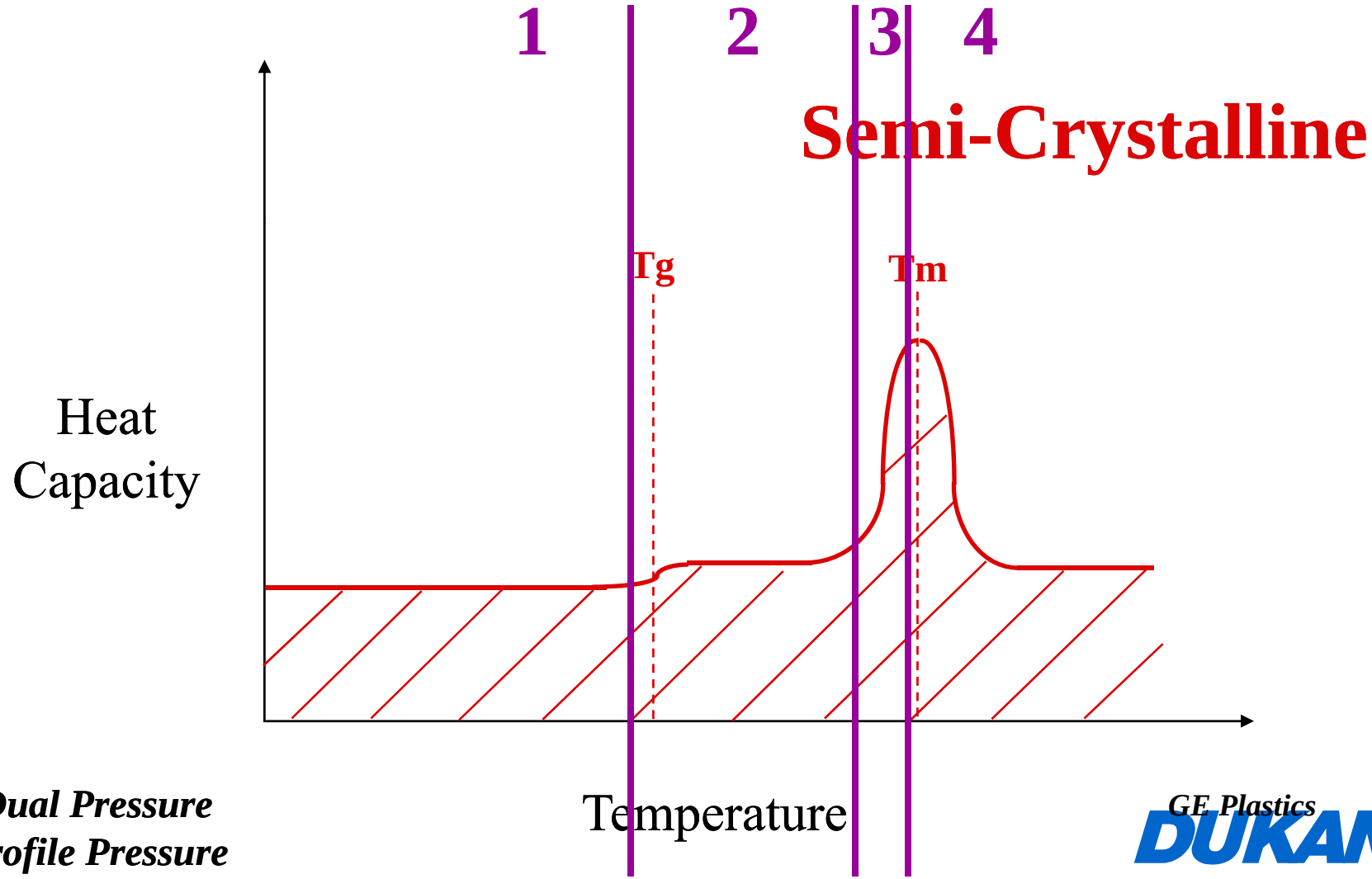
# Weld Phase


1
2
3
4
Parts in Fixture
Horn Contact
Pressure & Ultrasound Applied
Hold Time
Horn Retracts
Horn
Plastic
Fixture

# Melt Characteristics




***Dual Pressure Profile Pressure***

*GE Plastics*
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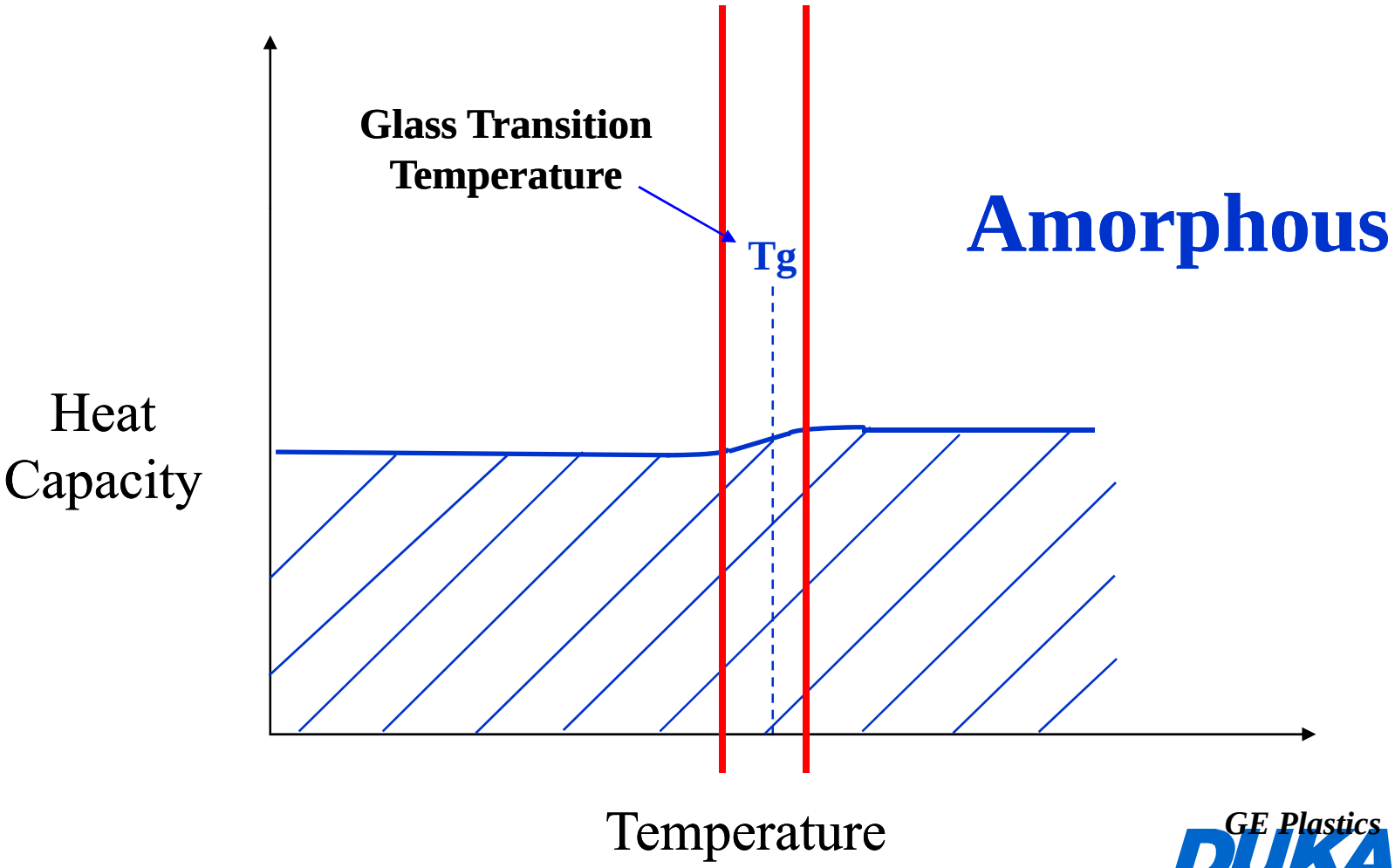
# Melt Characteristics




GE Plastics
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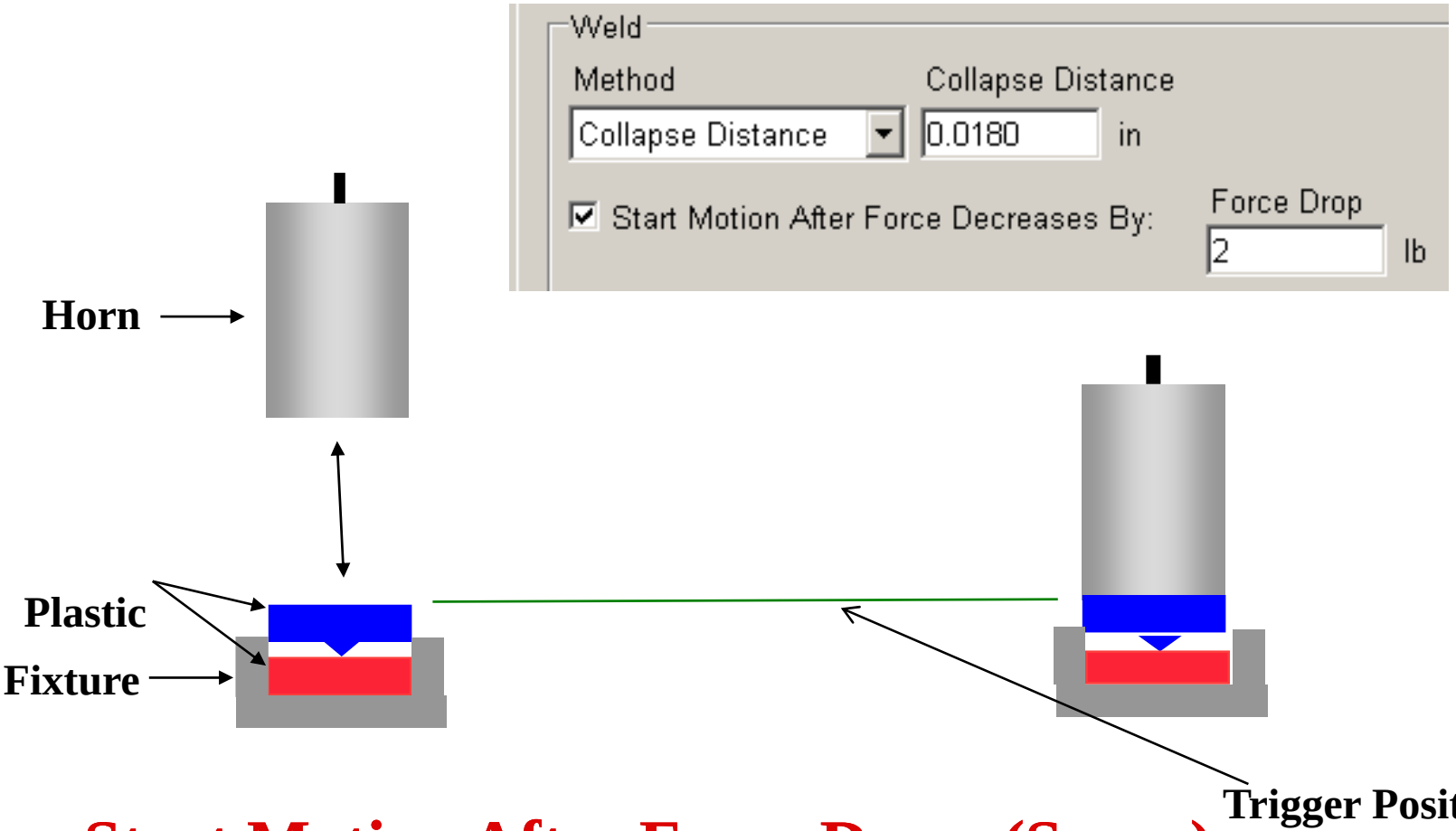
- Phase 2 Transition *optimized melt velocity*




**•Start Motion After Force Drop (Servo)**

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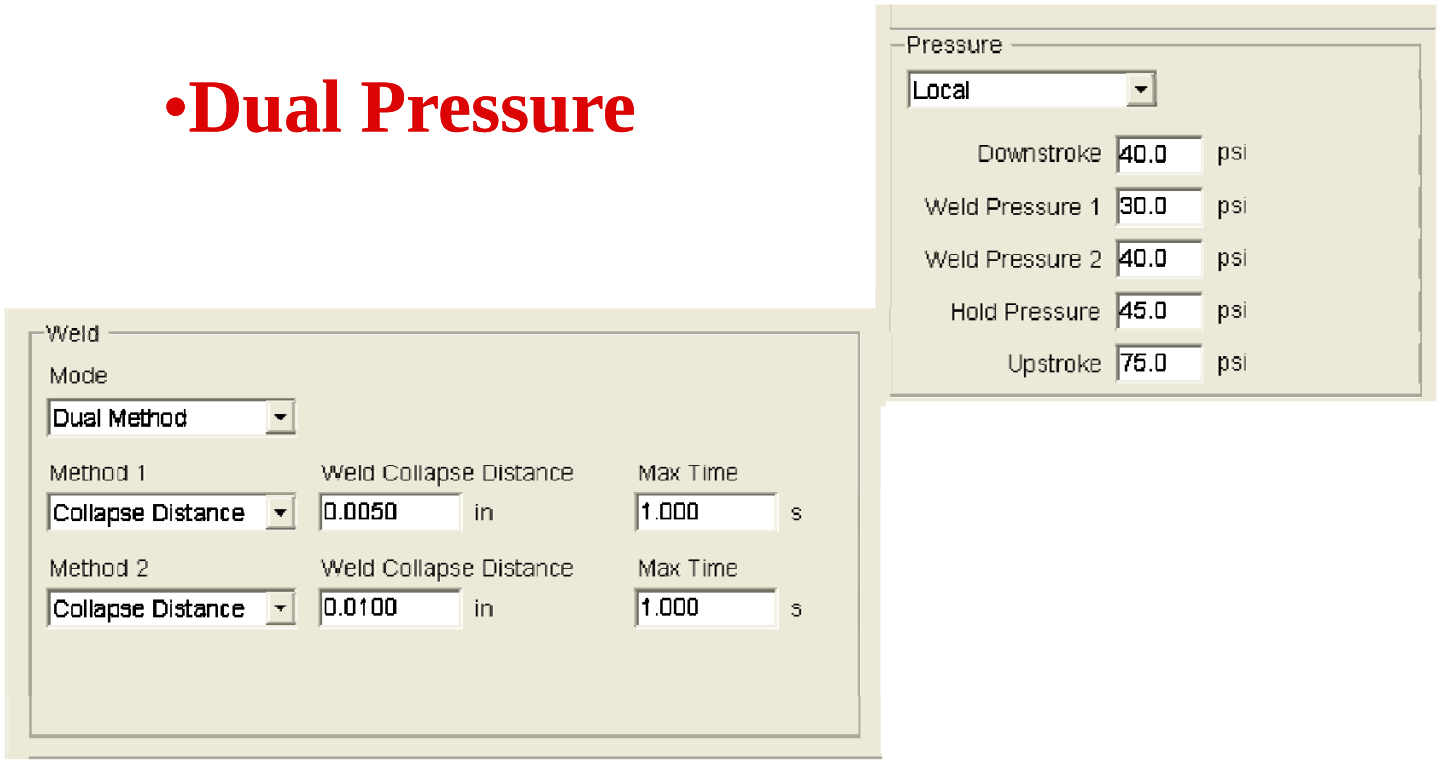
# Ultrasonic welding Process Optimization

Phase 2 Transition
Phase 3 Molten

*optimized melt velocity*

- **Dual Pressure**



# Ultrasonic welding Process Optimization

Phase 2 Transition
Phase 3 Molten *optimized melt velocity*

- **Hydraulic Velocity Control**

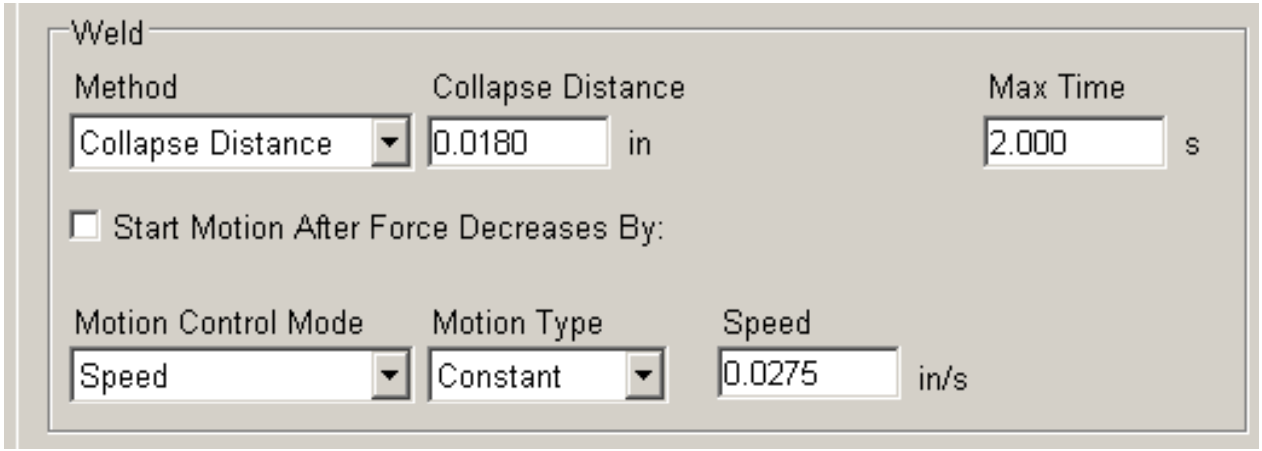
# Ultrasonic welding Process Optimization

Phase 2 Transition

Phase 3 Molten

*optimized melt velocity*

- **Servo Speed control - Constant**




DUKANE

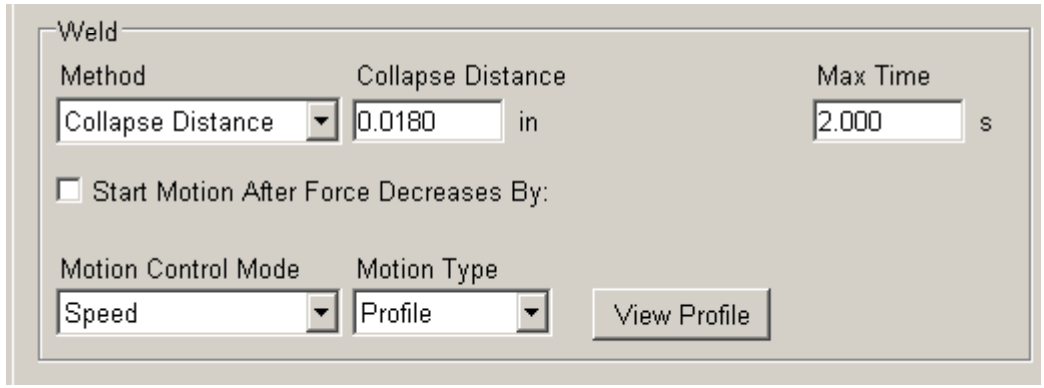
# Ultrasonic welding Process Optimization

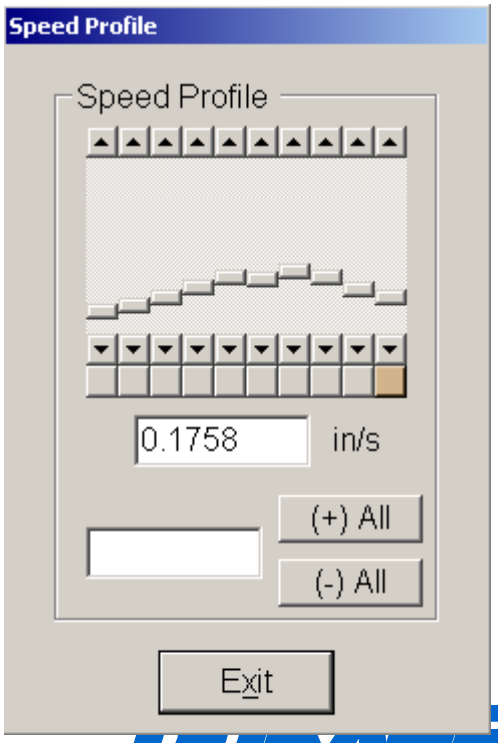
Phase 2 Transition

Phase 3 Molten

*optimized melt velocity*

- **Servo Speed control - Profile**

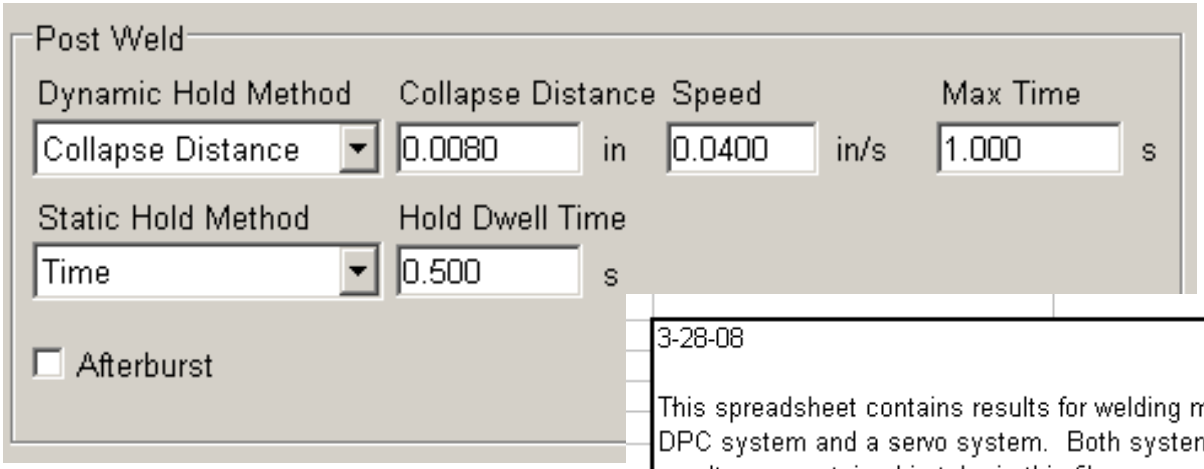


# Ultrasonic welding Process Optimization

## Phase 4 Post weld (Cool/solidify) *optimized hold*

Oftentimes overlooked, higher pressures can give better melt dispersion, stronger bonds and tighter, leak free seals.




3-28-08

This spreadsheet contains results for welding machined Polycarbonate pieces on a pneumatic DPC system and a servo system. Both systems used the same stack and generator. The results are contained in tabs in this file.

**Key results:**

| Parameter | Servo | Pneumatic |
|---|---|---|
| Collapse standard deviation (in.) | 0.0004 | 0.0013 |

# Ultrasonic welding Process Optimization

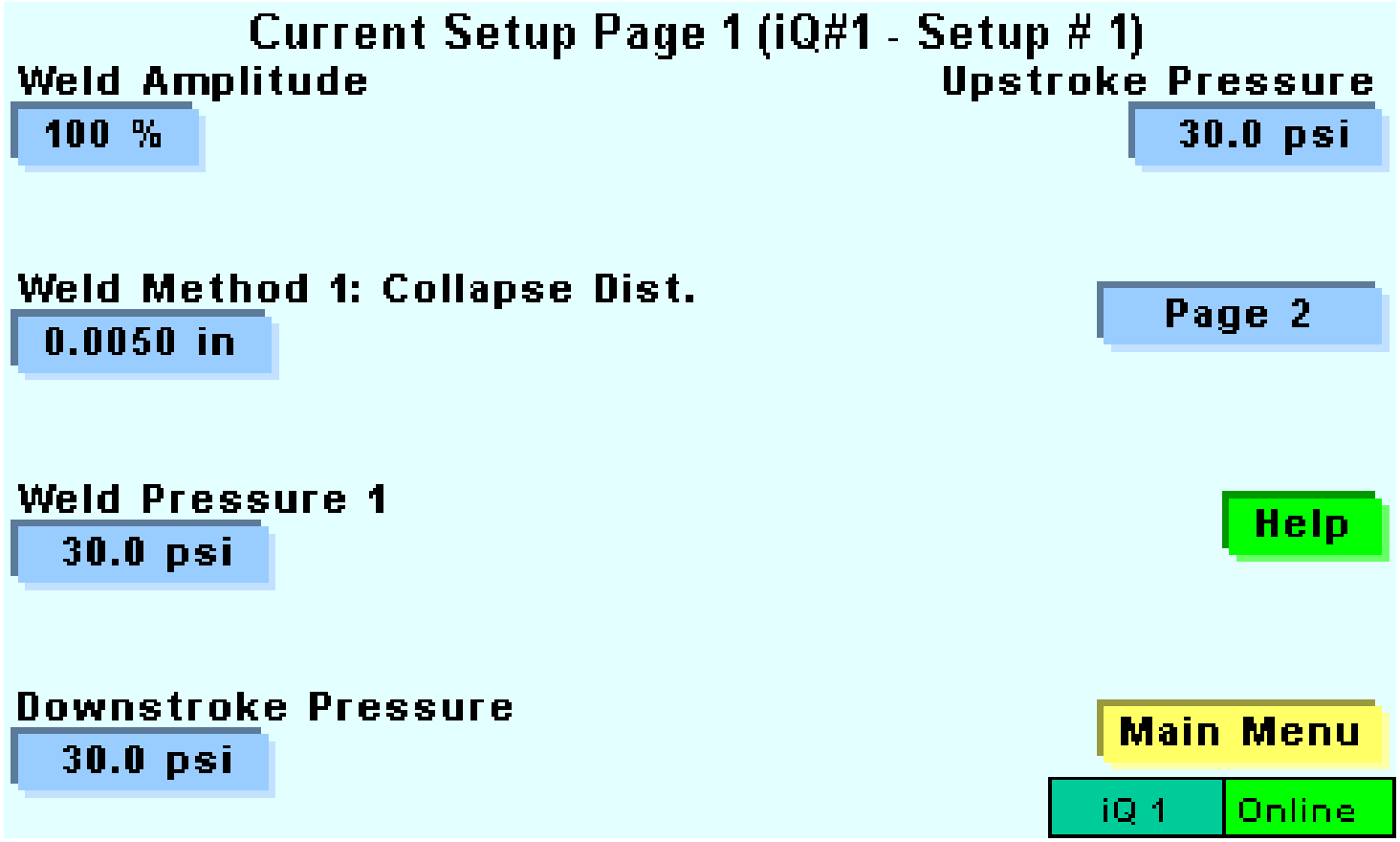
| Welder Control Features | BASIC | GOOD | BETTER | BEST |
|---|---|---|---|---|
| Trigger | Spring | Spring | Force xdcr | Force xdcr |
| Single Pressure | X | X | X | X |
| Dual Pressure | | X | X | X |
| Time | X | X | X | X |
| Energy | | X | X | X |
| Distance | | X | X | X |
| Electronic Pressure | | | 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 |
| Trigger by Force Drop | | | | X |

DUKANE

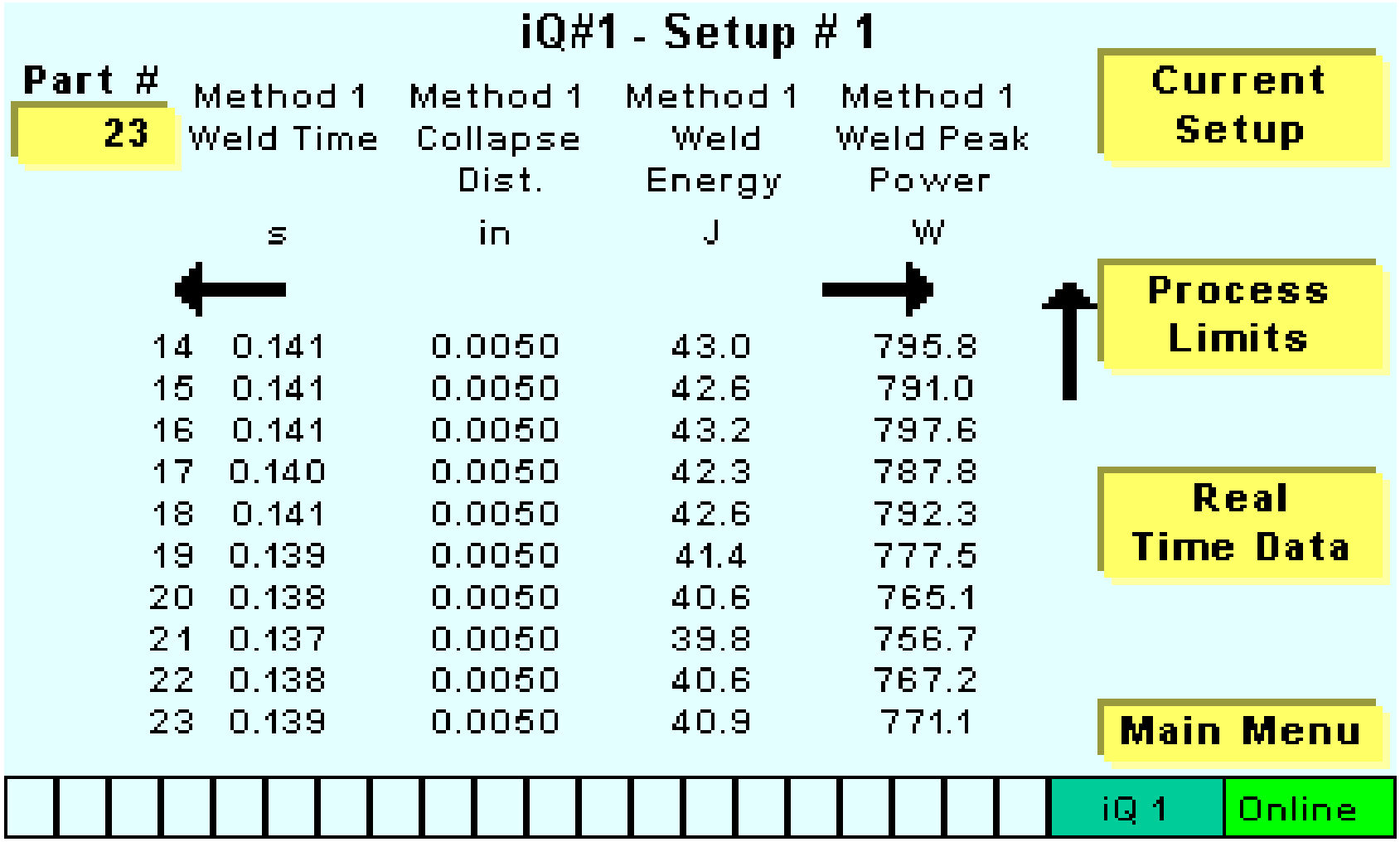
# *iQ* Generator with Color GUI


- WVGA 5” LCD with 800x600 pixels
- Advanced Processing & Control Algorithms

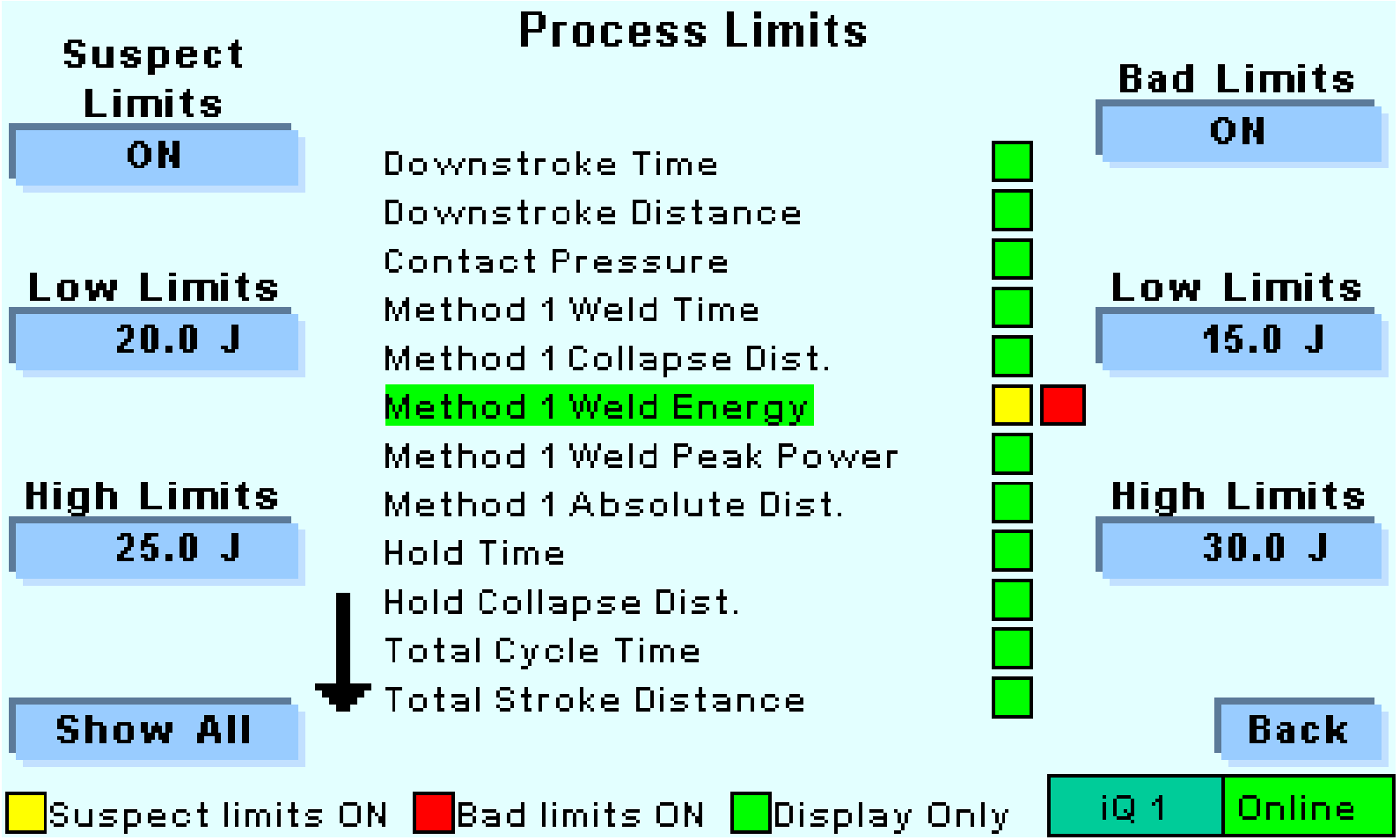
# *iQ* GUI Screens



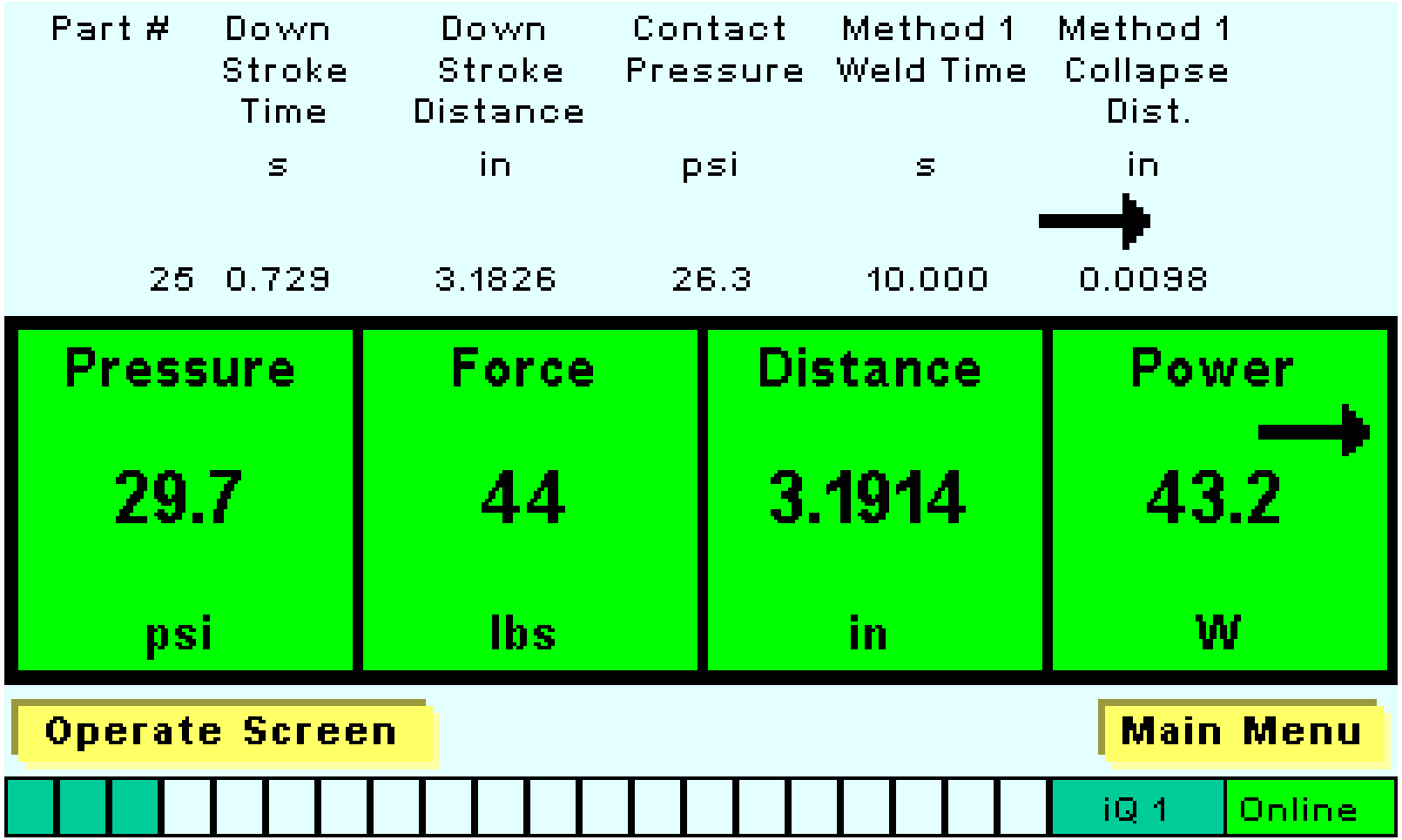
# *iQ* GUI Screens



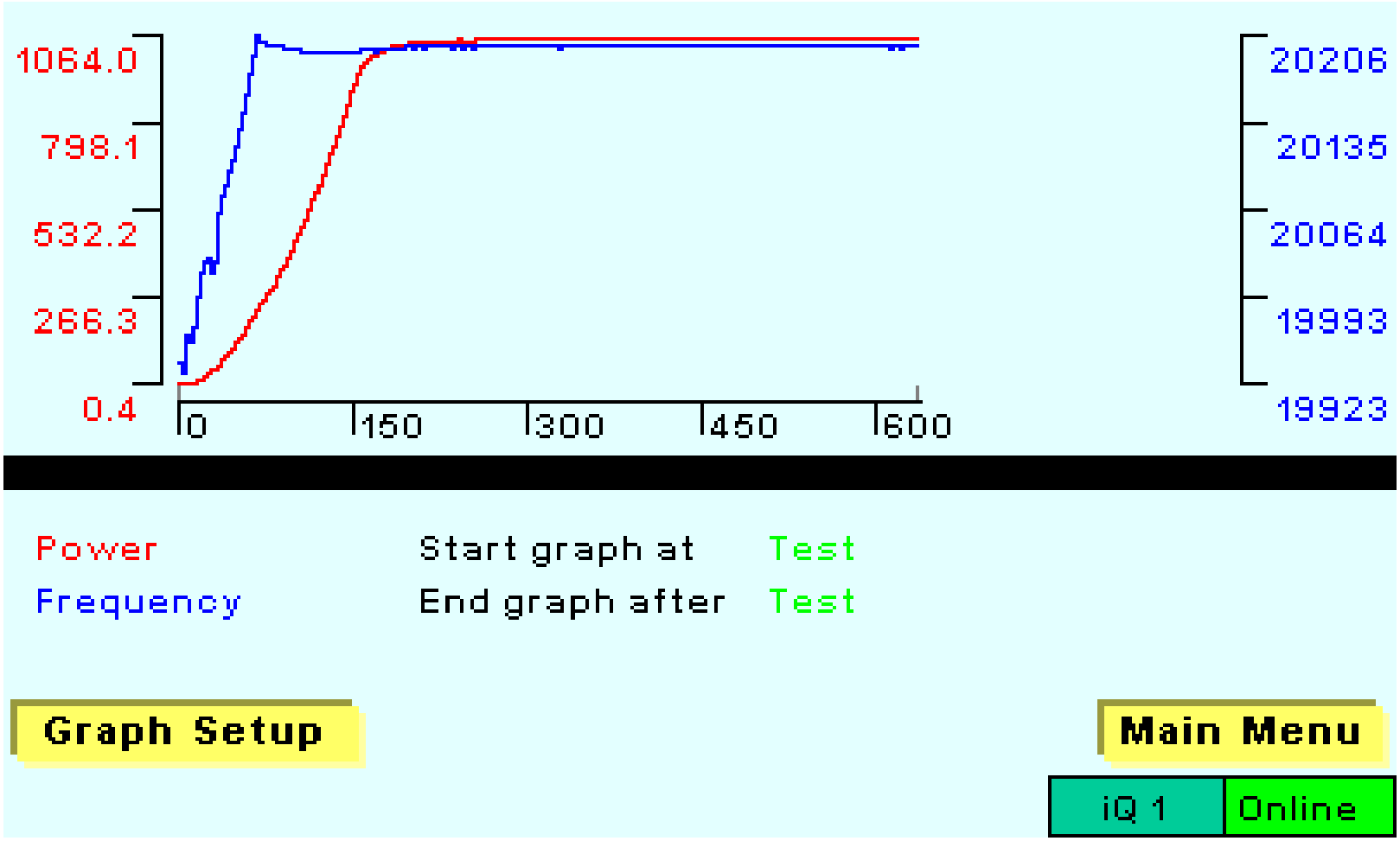
# *iQ* GUI Screens



# *iQ* GUI Screens

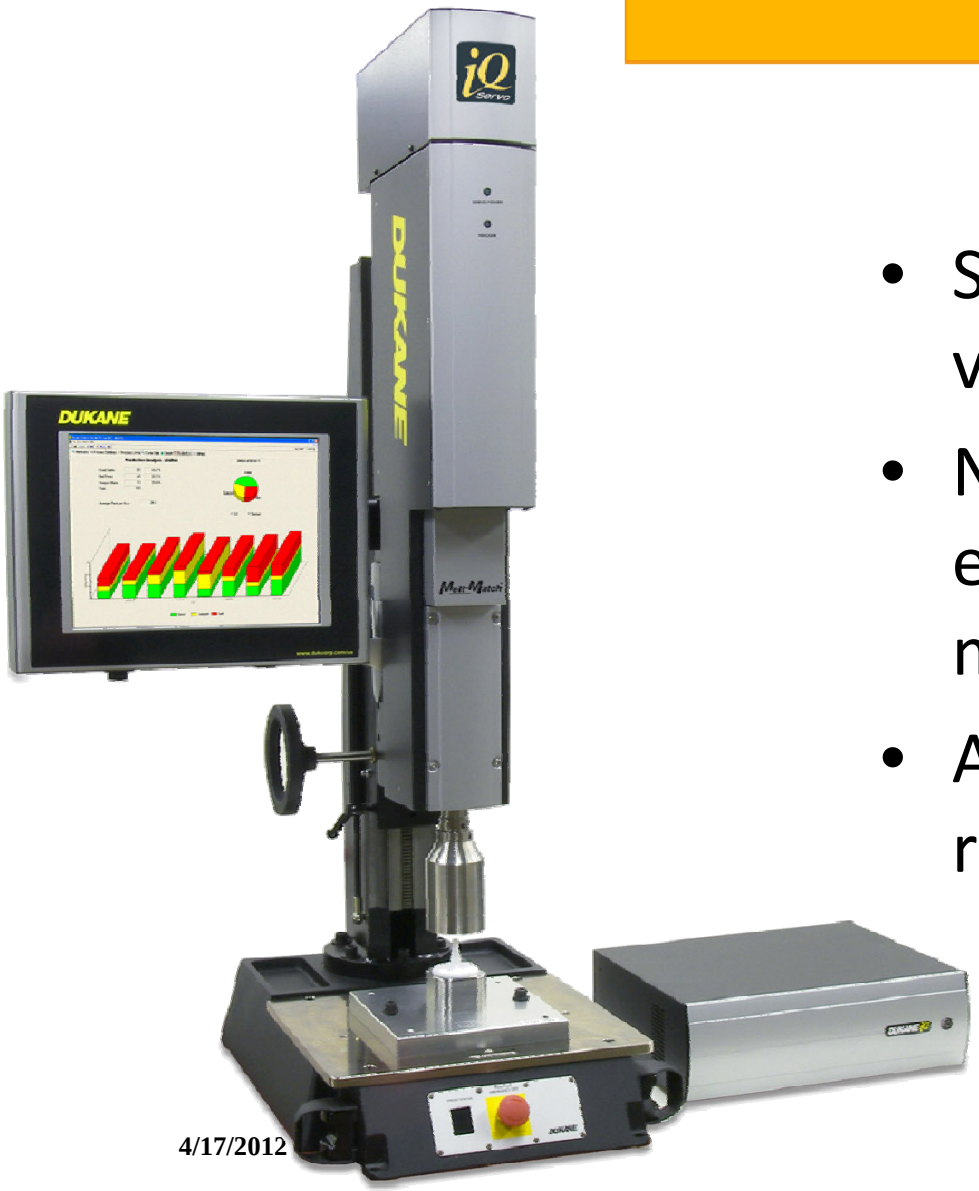


# *iQ* GUI Screens



# *iQ* Servo Models

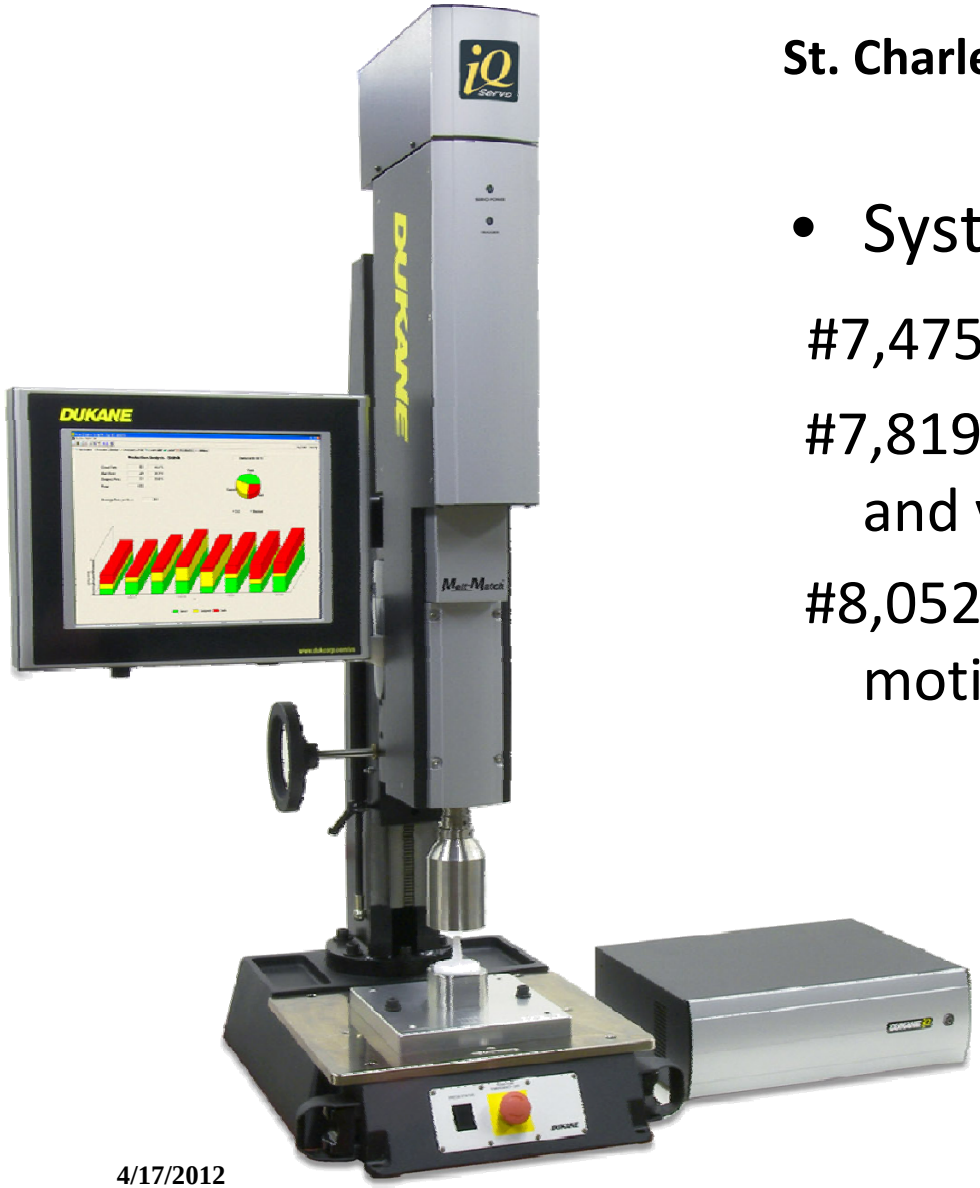
# Validation
# Calibration




## *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**

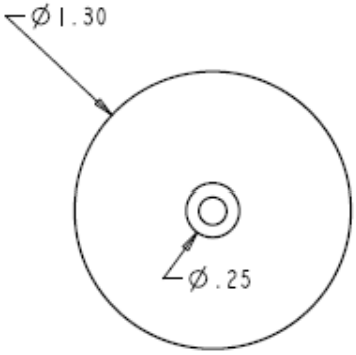
- System Patents

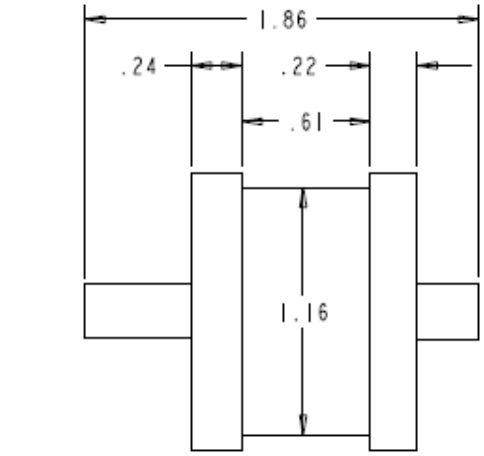
#7,475,801 - iQ Generator

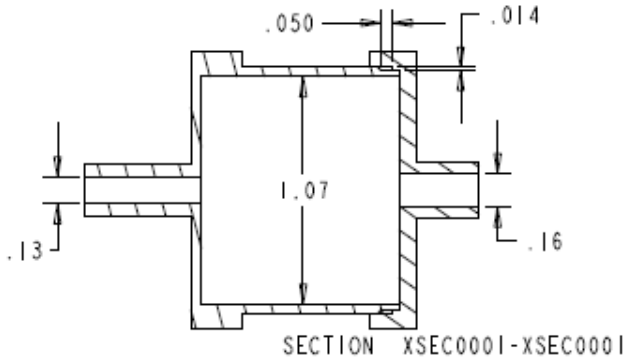
#7,819,158 – Servo packaging and velocity/force profiling

#8,052,816 – Servo with delayed motion

# 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” |

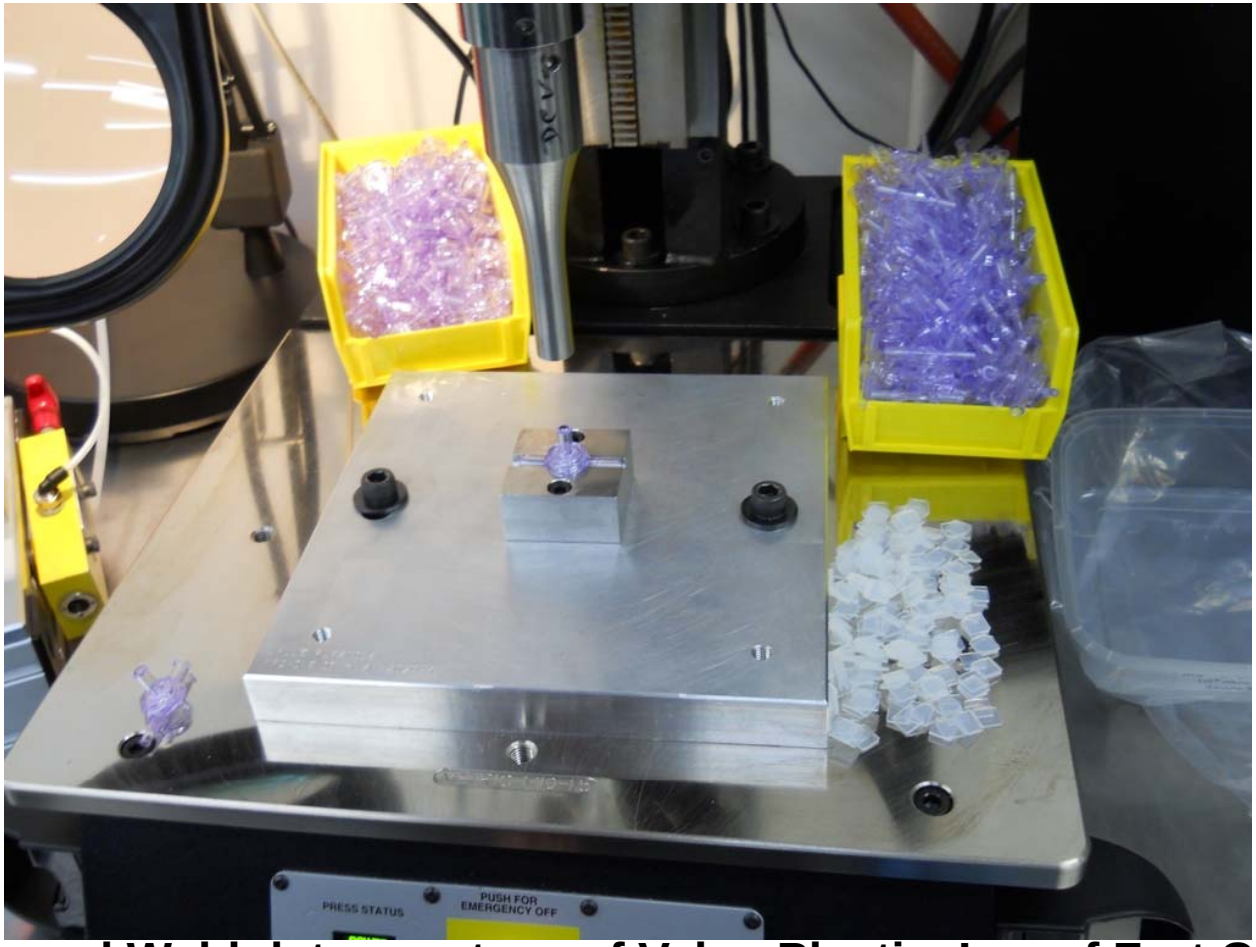
## Comparison of Pull Strength Repeatability For Pneumatic and Servo Welders (round filters Polycarbonate parts)

| 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%) |

# DCV114 - Double Check Valve
# Silicon Disk for Double Valve Activation

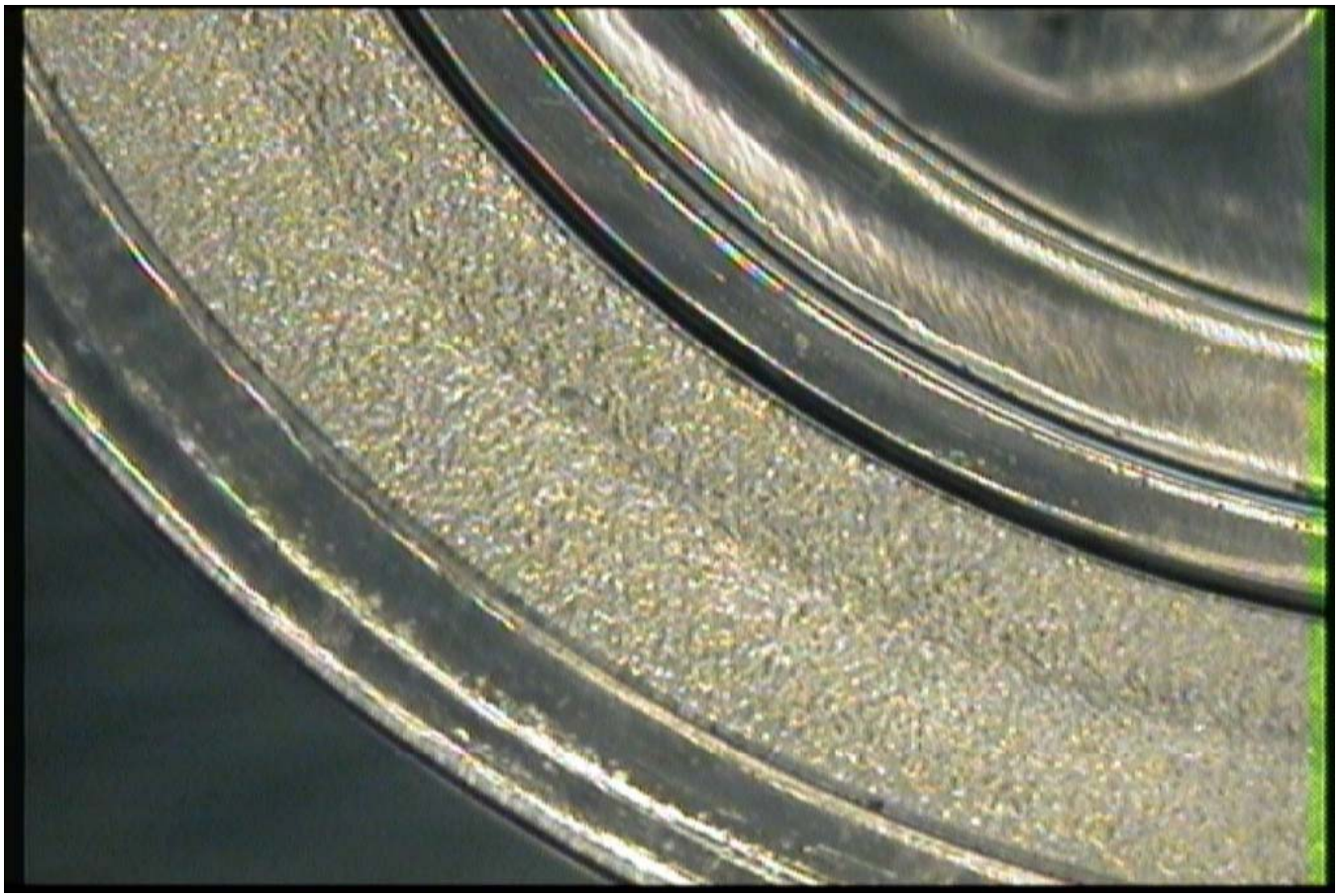

**Parts and Weld data courtesy of Value Plastic, Inc. of Fort Collins, CO**

# DCV114 - Double Check Valve
# Welder Setup



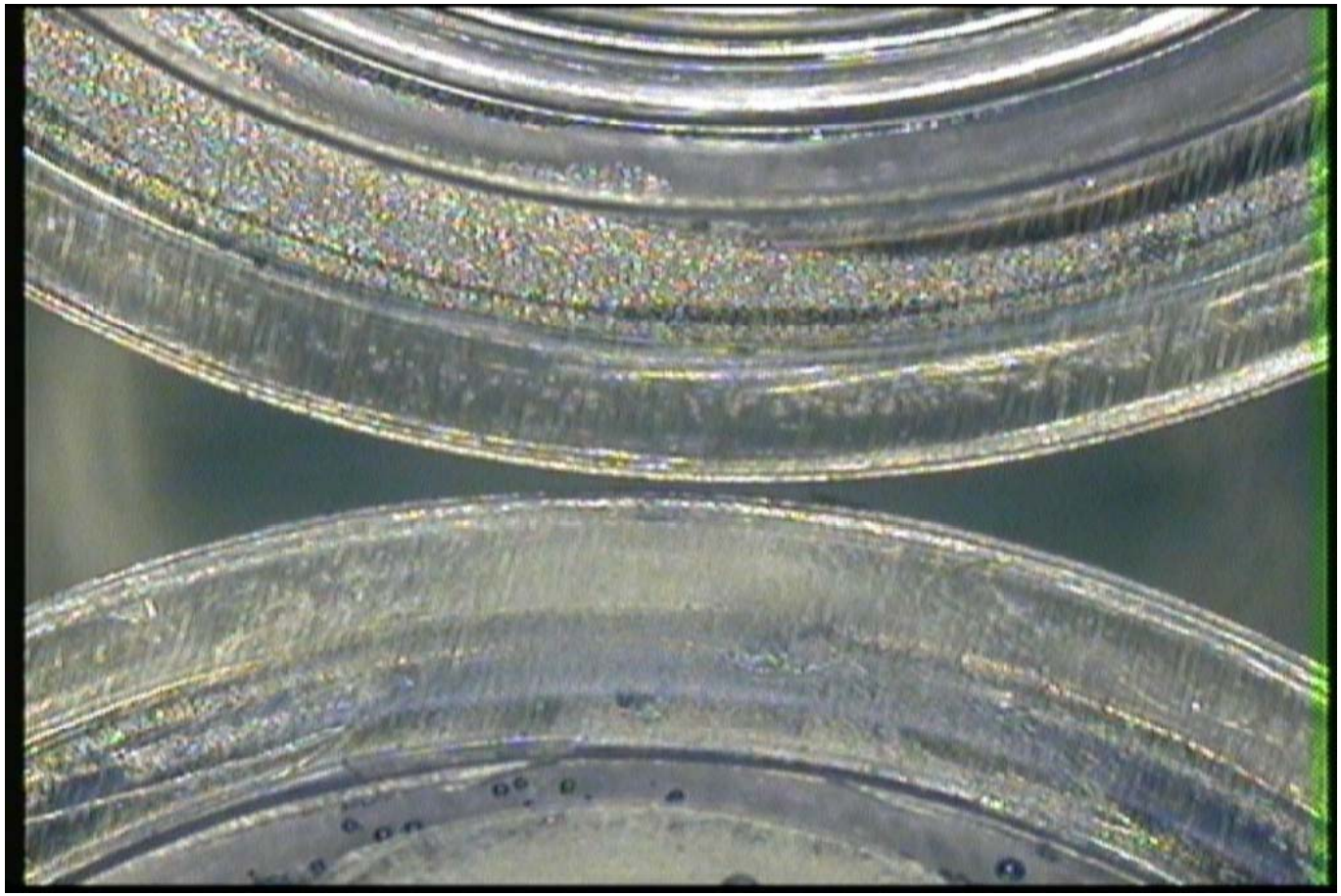

**Parts and Weld data courtesy of Value Plastic, Inc. of Fort Collins, CO**

## DCV114 - Double Check Valve
## Bottom View - not welded



**Parts and Weld data courtesy of Value Plastic, Inc. of Fort Collins, CO**

## DCV114 - Double Check Valve - Welded
## Top - Servo; Bottom - Pneumatic

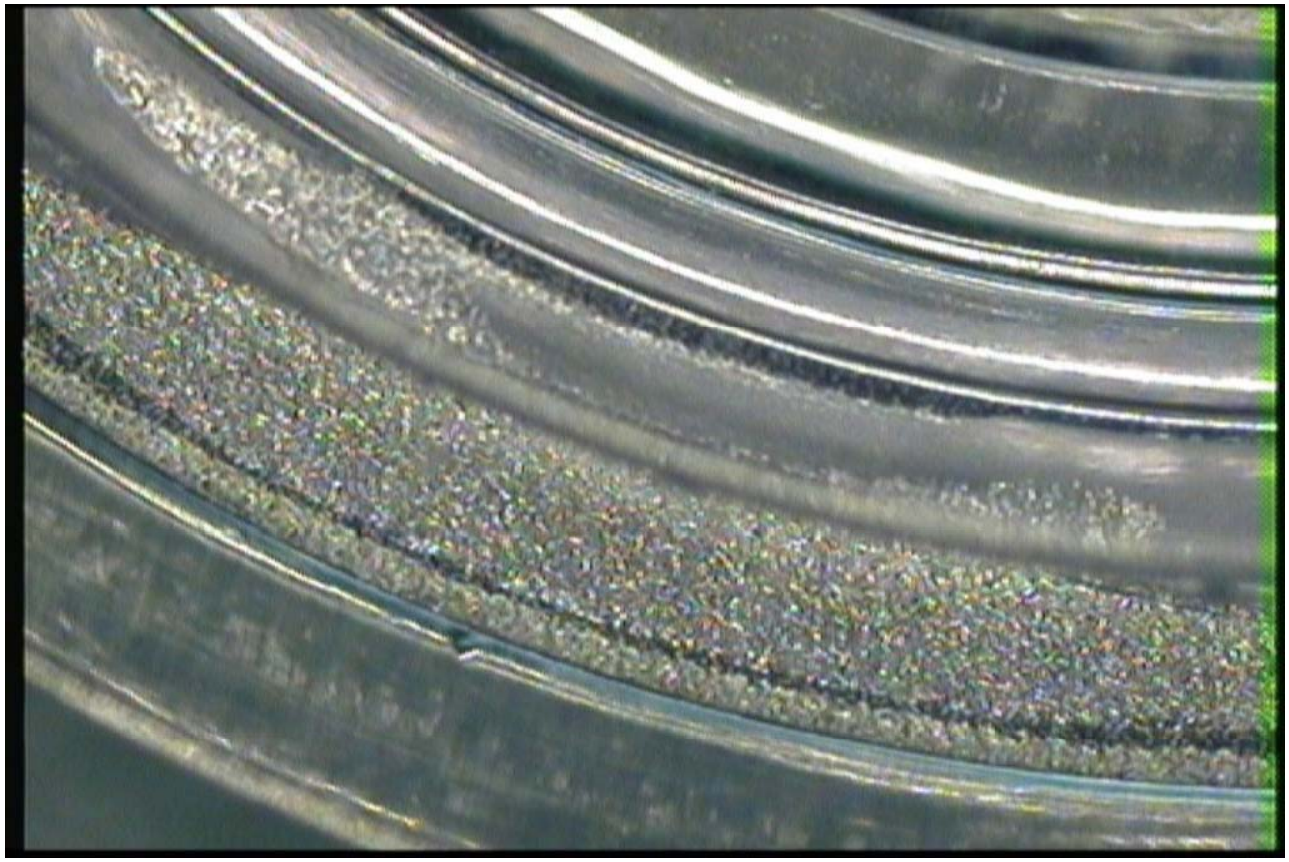


**Parts and Weld data courtesy of Value Plastic, Inc. of Fort Collins, CO**

## DCV114 - Double Check Valve
## Welded - Pneumatic. Flash & Air Bubbles

**Parts and Weld data courtesy of Value Plastic, Inc. of Fort Collins, CO**

## DCV114 - Double Check Valve
## Welded - Servo. No Flash, No Air Bubbles



**Parts and Weld data courtesy of Value Plastic, Inc. of Fort Collins, CO**

## Comparison of Collapse Distance Repeatability for *iQ* Servo (Dukane) and Pneumatic (Competitor) Welders

| 1000 Parts were studied | Pneumatic | *iQ* Servo |
|---|---|---|
| Weld Method | By Energy | By Collapsed Distance |
| Weld Parameters | 48 Joules | 0.0088” |

**Parts and Weld data courtesy of Value Plastic, Inc. of Fort Collins, CO**

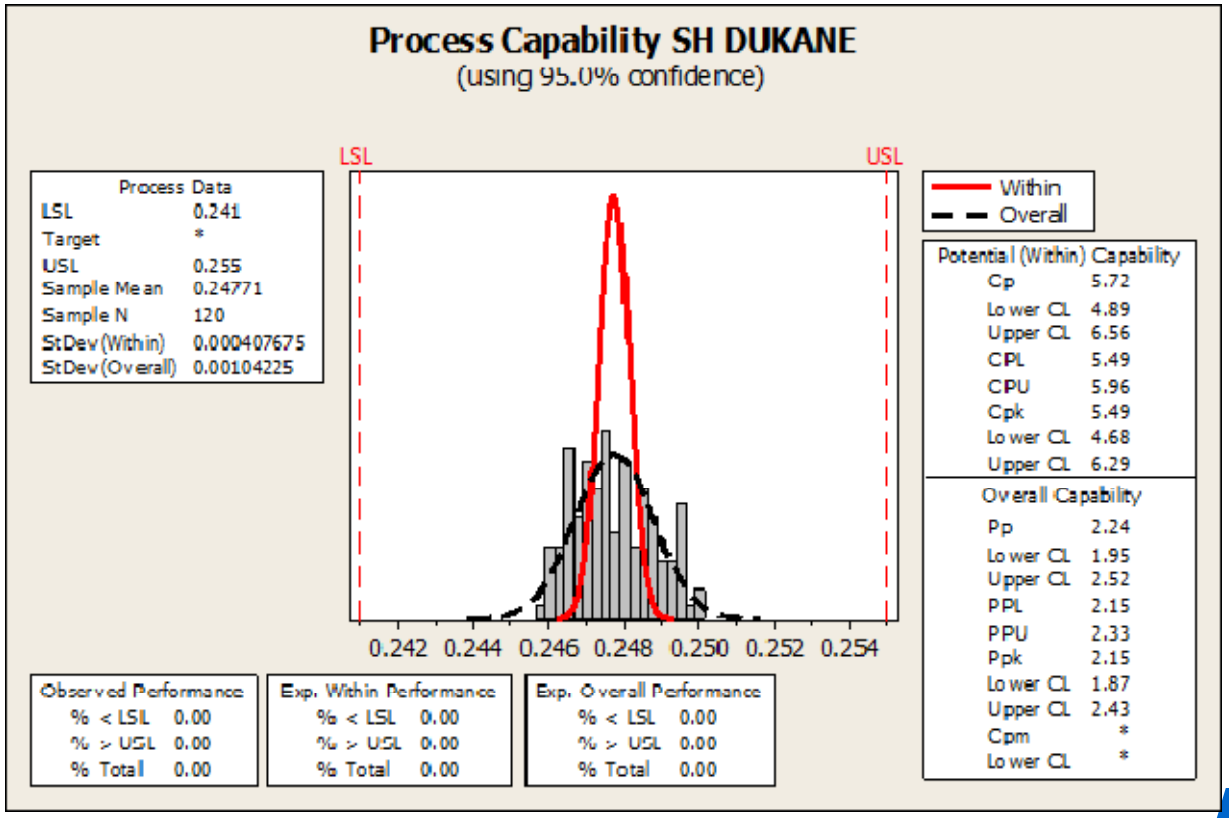
## Comparison of Collapse Distance Repeatability for *iQ* Servo (Dukane) and Pneumatic (Competitor) Welders

| 1,000 parts were studied | Pneumatic | *iQ* Servo |
|---|---|---|
| Average Collapse (in/um) | 0.0080” 203.2 um | 0.0088” 223.5 um |
| Standard Deviation (in/um) | 0.0003” 7.62 um | 0.000076” 1.93 um |

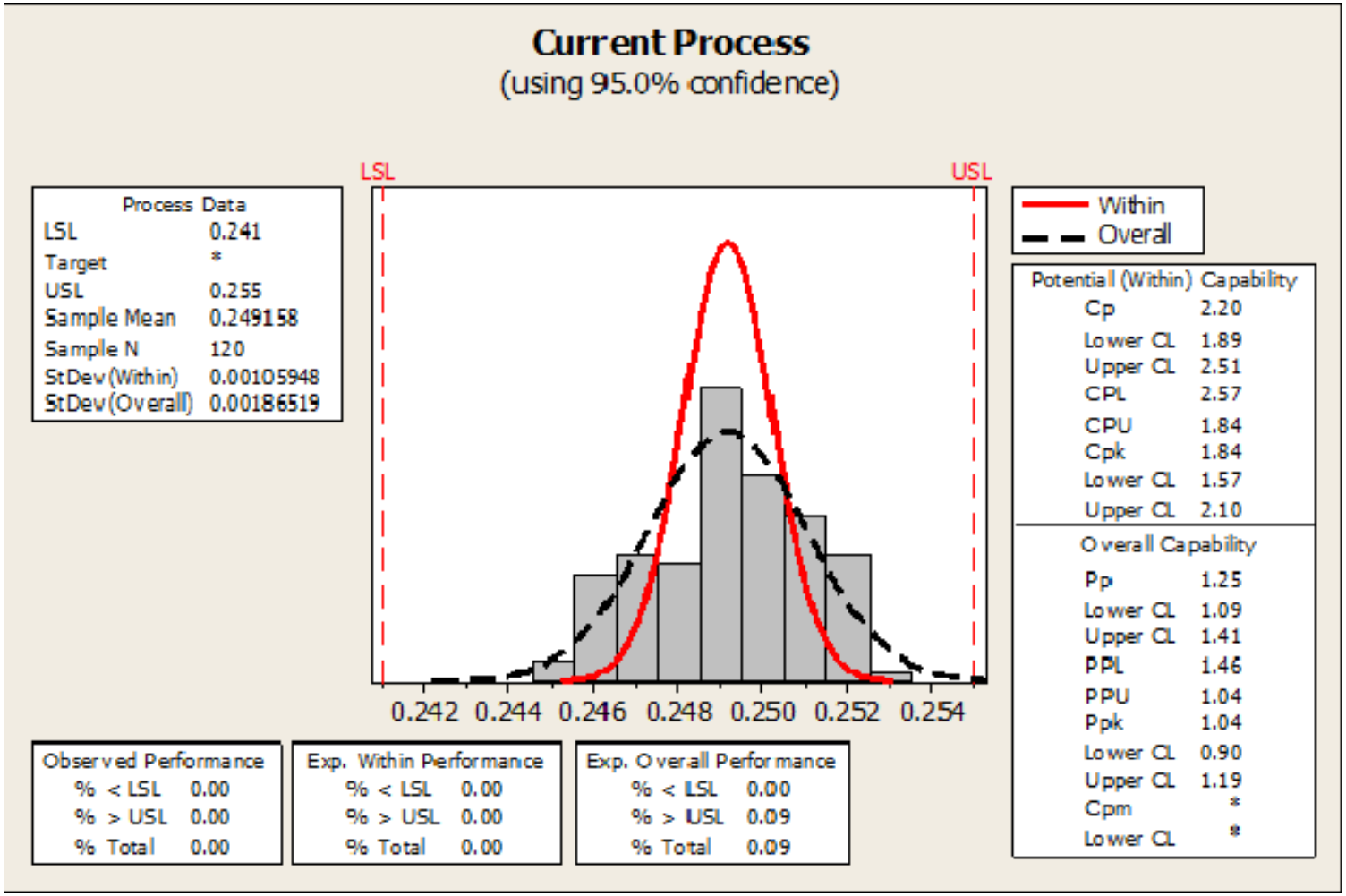
**Parts and Weld data courtesy of Value Plastic, Inc. of Fort Collins, CO**

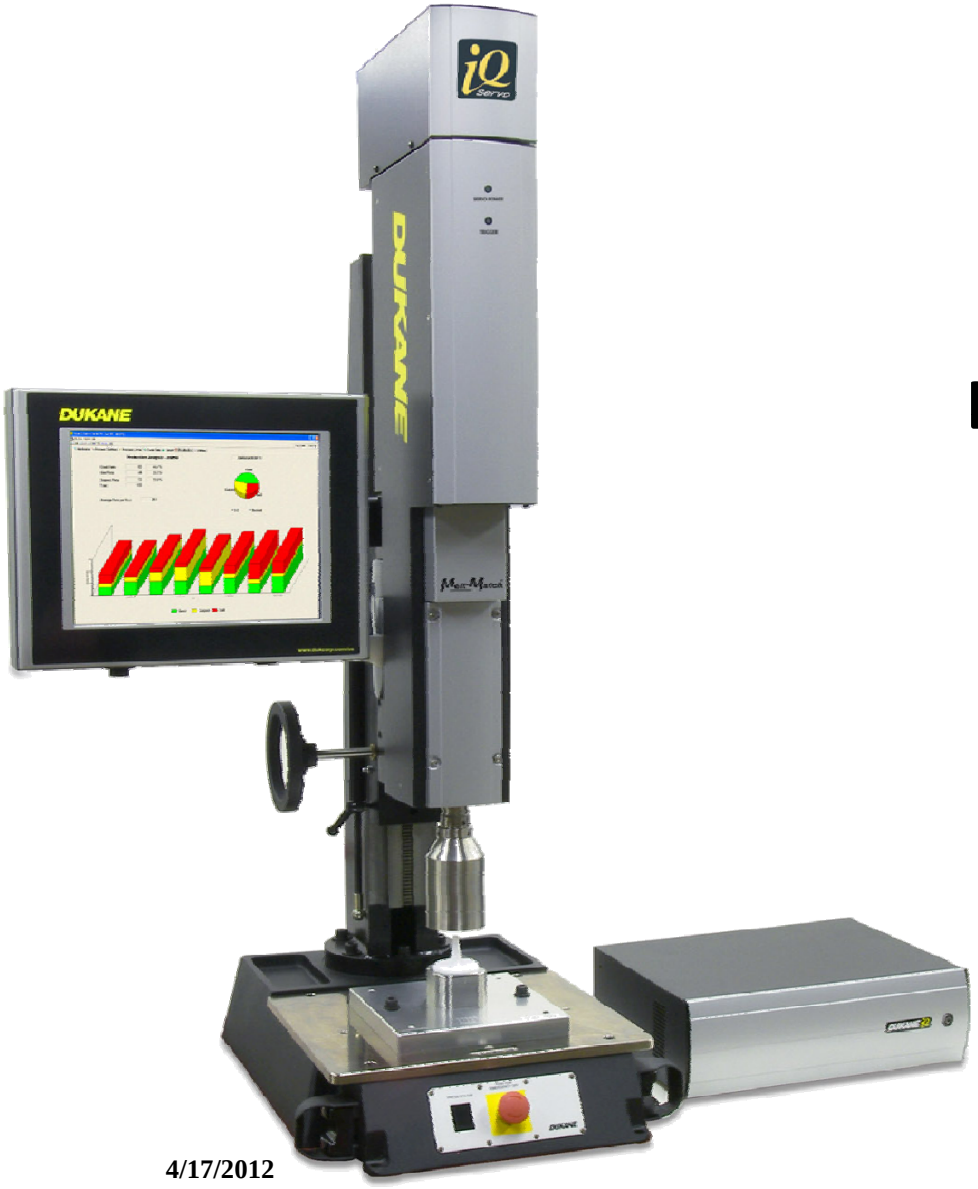
## *iQ* Servo Test against Competitor's Welder

**_iQ_ Servo with Melt-Match vs. brand "X" Pneumatic Press.**
**_iQ_ Servo Cpk = 5.49; and "B" Cpk = 1.84.**
**Five measurements on 30 parts, all setups were performed by the customer – another major medical device manufacturer**



# *iQ* Servo Test against brand "X" Pneumatic Welder






## Questions?

## Let us weld some parts