To: ----
Attn: ----

Quote/App: APP00123
Engineer: Process Development Center
Sales Rep: Extol Inc.
Date: Monday, January 01, 2024

InfraStake & NanoSTAKE

Application Rating

Technology	Part Design	Part Material and Color
nanoSTAKE	Feasible as designed	Feasible as specified
InfraStake	Design changes or another joining method are required, currently application is not feasible	Feasible as specified

Scope

- Determine the feasibility of using the nanoSTAKE and InfraStake process to join the Inner Lens and Bezel

Assembly Information

Component	Material	Filler	Color(s)†
Inner Lens	PC	None	Dark Grey
Bezel	PC	None	Black

†Critical variable to the InfraStake processes

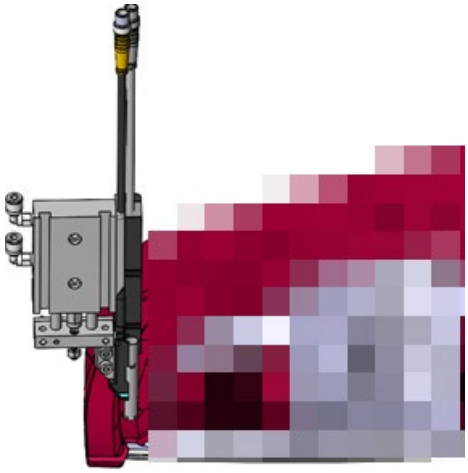
Strength	Unspecified
Hermetic Seal	Unspecified
Critical Dimensions	Unspecified
Appearance	Critical
Cycle Time	Unspecified

Assembly

Results

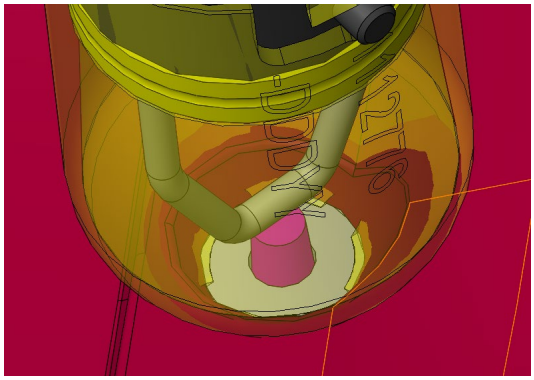
- Staking the Inner Lens and Bezel with the nanoSTAKE process is feasible as designed, with design changes recommended for improved performance
- Staking the Inner Lens and Bezel with the InfraStake process requires a design change to be feasible
    - There is significant interference between the mating component and the ISM20 concentrator as currently designed
- Through holes are oversized, which will negatively affect the appearance and performance of the stake

- **Recommendations**
    - Reduce through holes to 1.1-1.25 times the boss diameter for best staking results
    - Auxiliary clamping will be required with the nanoSTAKE process
    - If InfraStake is pursued, increase clearance around the boss to a diameter of 20mm to accommodate the module diameter



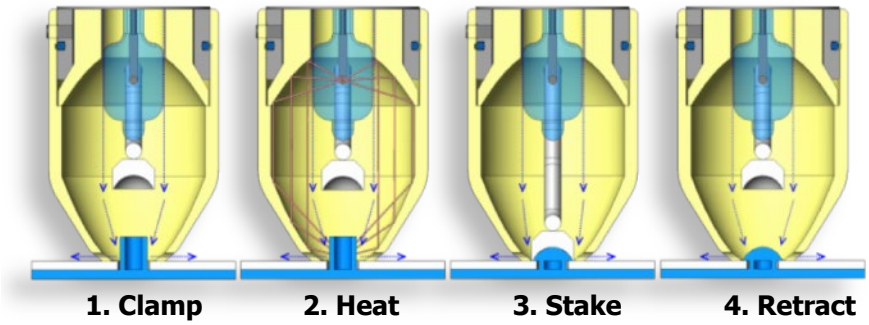
nanoSTAKE Overlay

InfraStake Overlay

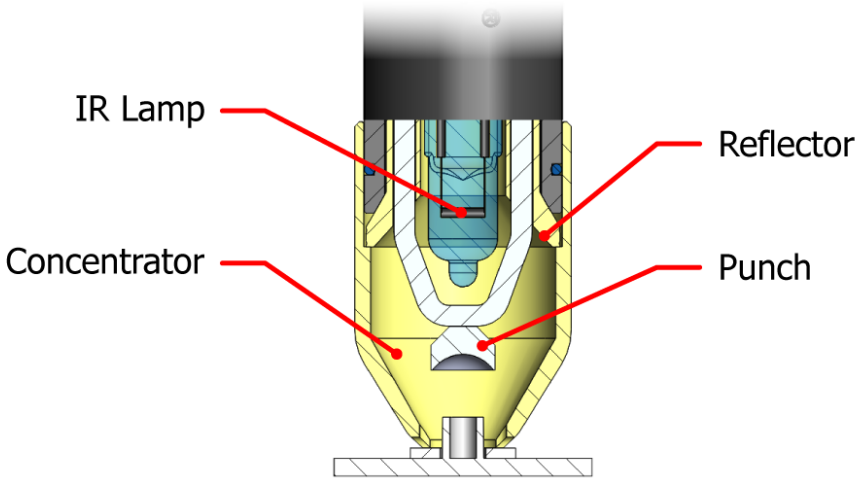


Unfeasible Concentrator Interference

INFRASTAKE® Process

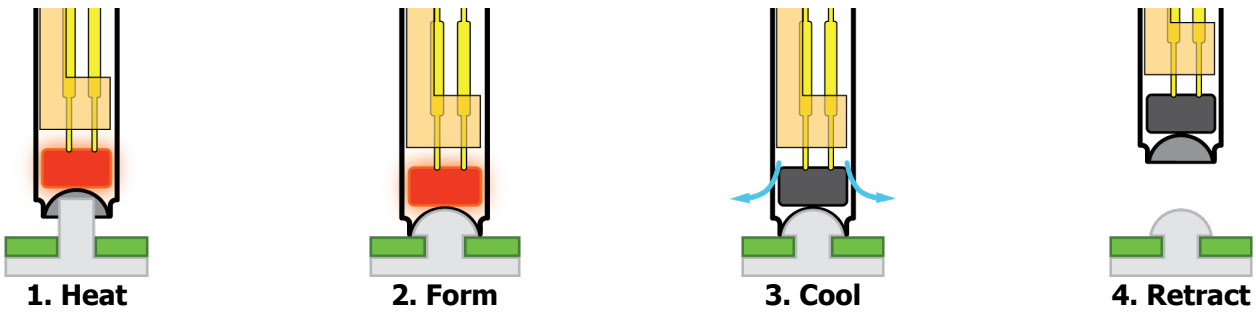


View a video of the InfraStake process: extolinc.com/learning/staking/

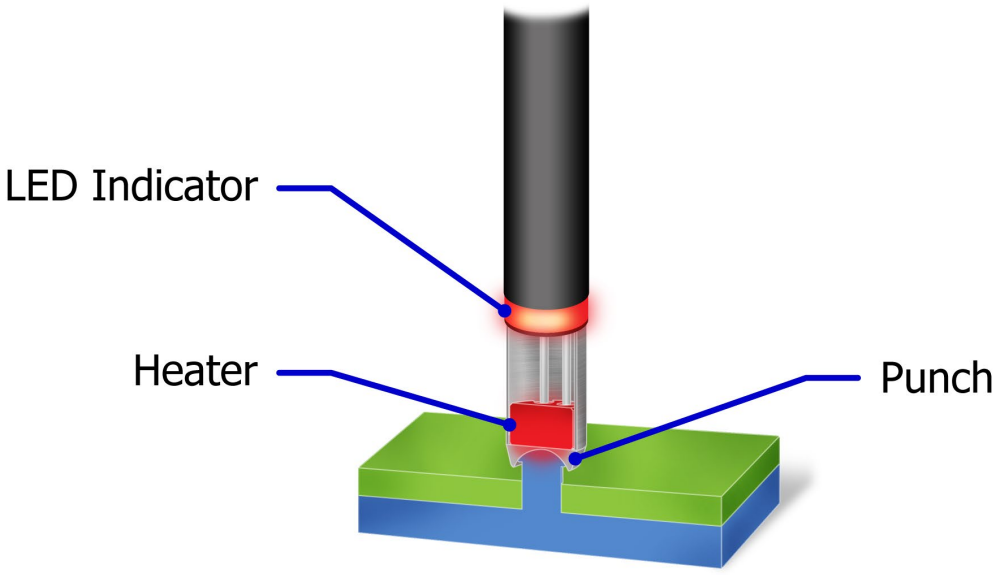


Significant InfraStake Module Components

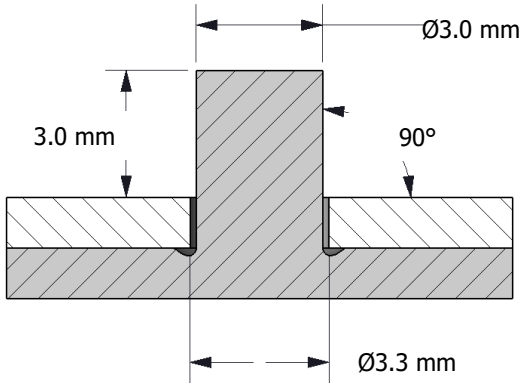
nanoSTAKE Process



View a video of the nanoSTAKE process: extolinc.com/learning/staking/



Significant nanoSTAKE Components



Hot Plate Welding

Application Rating

- **Recommended Technology:** Hot Plate Welding
- **Part Design:** Part changes required for feasibility
- **Part Material and Color:** Feasible as specified

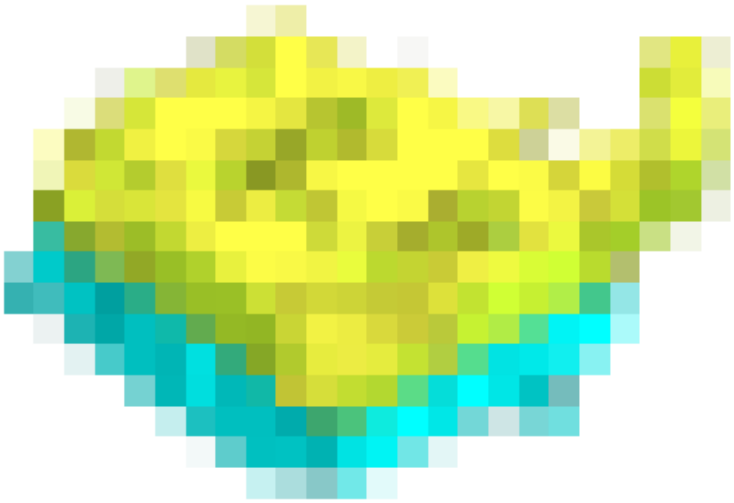
Scope

- Determine the feasibility of using the Hot Plate Welding process to join the Upper and Lower components of the Tank.

Assembly Information

Component	Material	Filler	Approx. Size
Upper	PP	n/a	14”x13”x9”
Lower	PP	n/a	

Strength	Burst at parent
Hermetic Seal	3 psi leak test
Critical Dimensions	Unspecified
Appearance	Unspecified
Cycle Time	Unspecified



Assembly

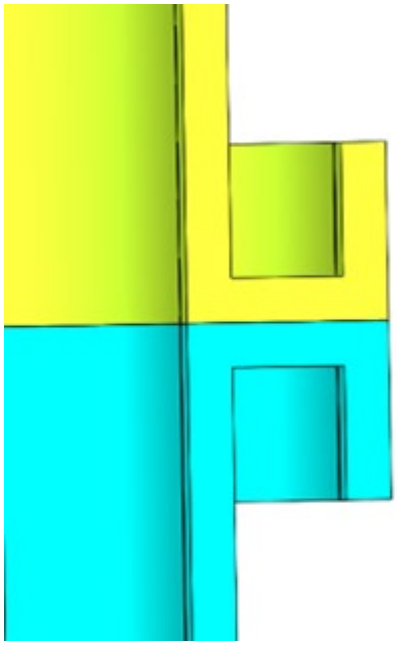
Results

- Design changes are required to determine feasibility of the Hot Plate Welding process to join the Upper and Lower components of the Tank.
- A weld rib is required for both components that is at least 0.08" tall and parallel to the other component.
    - A weld rib overlaps of at least 0.06" is required to provide sufficient material for melting and sealing of the assembly.

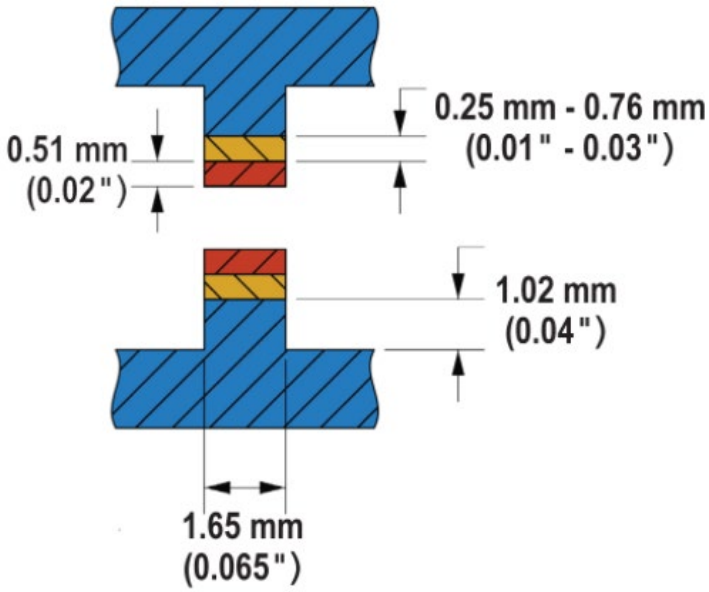
It is required to maintain a minimum of 0.06" gap between the edge of weld rib and adjacent features (side walls, interior components, etc.) for heating tooling clearance.

- If appearance is a concern, a flash trap is recommended to provide space for the displaced weld rib material.
- Both the Upper and Lower components have adequate mechanical retention features
- There are 5 locations on the yellow bottle half and 2 locations on the blue bottle half where there are features that overhang the weld rib but the return flange is not cleared out so the weld rib cannot be properly supported with horizontal slides in the tooling.

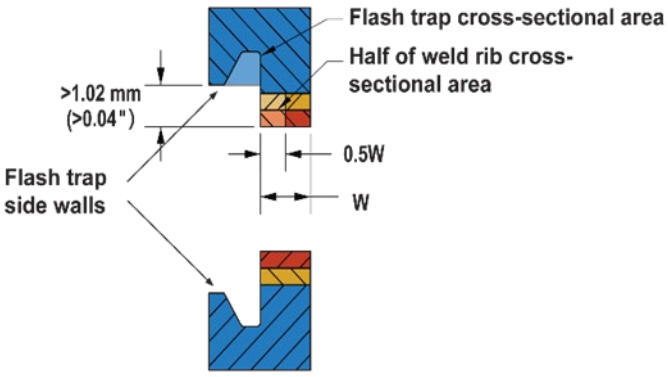
- **Recommendations**
- It is required to add a weld rib to both components that is at least 0.08" tall and parallel to the other component.
- It is required to have a weld rib overlap of at least 0.06."
- It is required to maintain a minimum of 0.06" gap between edge of weld rib and adjacent features.
- A flash trap is recommended if appearance is a concern.
- It is recommended to have the design reviewed for feasibility after a welded rib has been added.
- Remove return flange features in areas that have features over 1" long that overhang the weld rib to allow horizontal slides to be used in the tooling to support directly beneath the weld rib.
- Extols Hot Plate Welding design guidelines can be found here

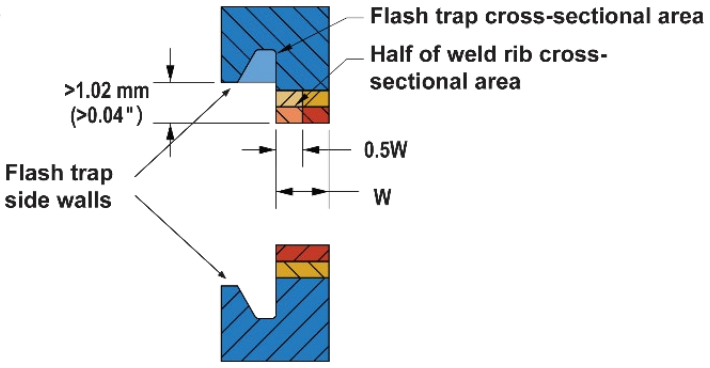


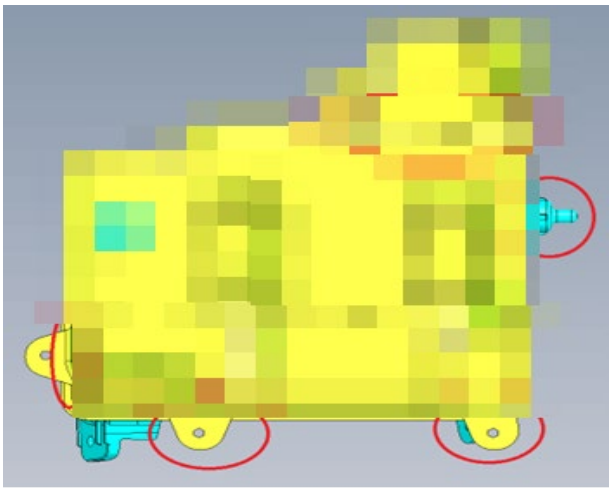
Current Cross-Section



Weld Rib Design Requirements







Flange removal (Red)

Spin Welding

Application Rating

- **Recommended Technology:** Spin Welding
- **Part Design:** Minor part changes required for feasibility
- **Part Material and Color:** Further testing is required to confirm feasibility

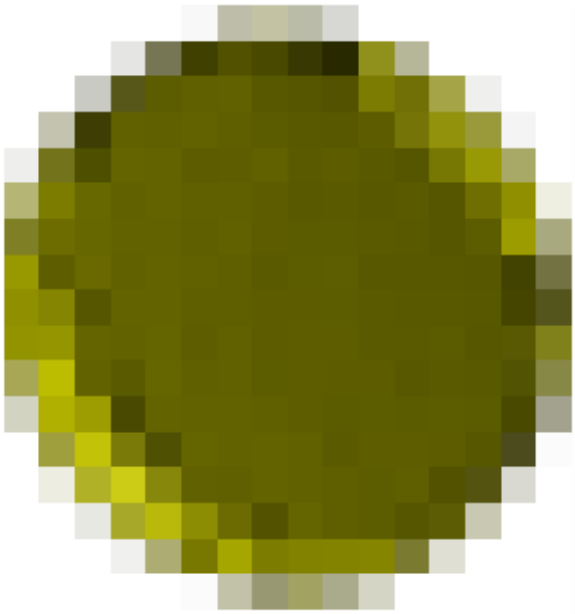
Scope

- Determine the feasibility of using the Spin Welding process to join the Lens to the Housing

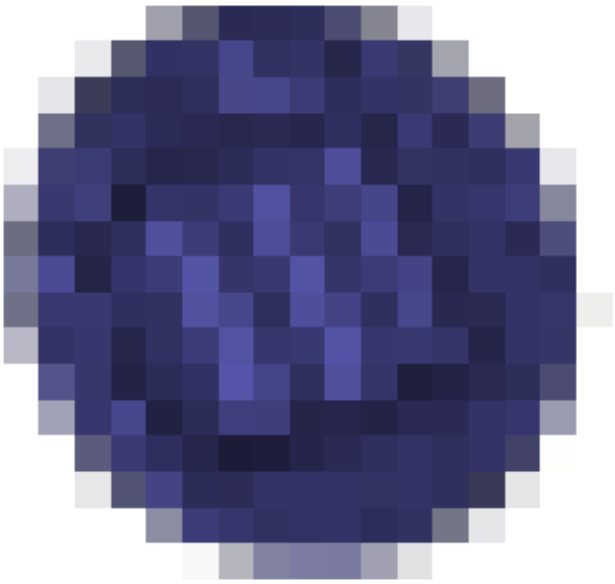
Assembly Information

Component	Material	Filler	Weld Diameter
Lens	COC	Unknown	175mm
Housing	PA	Unknown	175mm

Strength	5 psi
Hermetic Seal	yes
Critical Dimensions	Unspecified
Appearance	No visible flash
Cycle Time	Unspecified



Lens

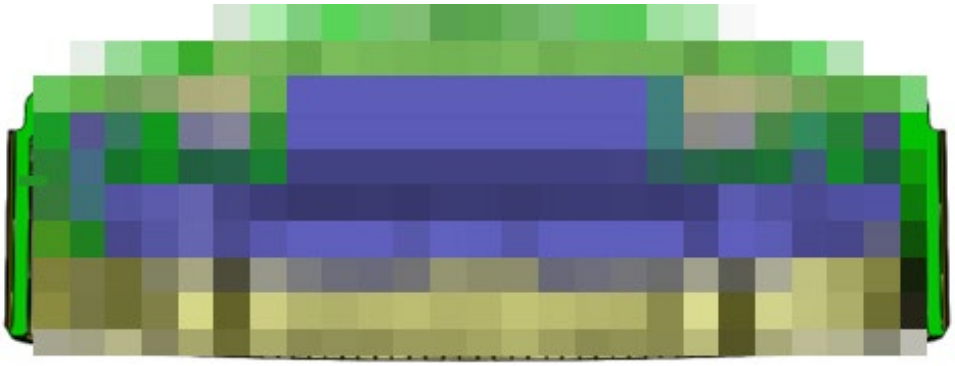


Housing

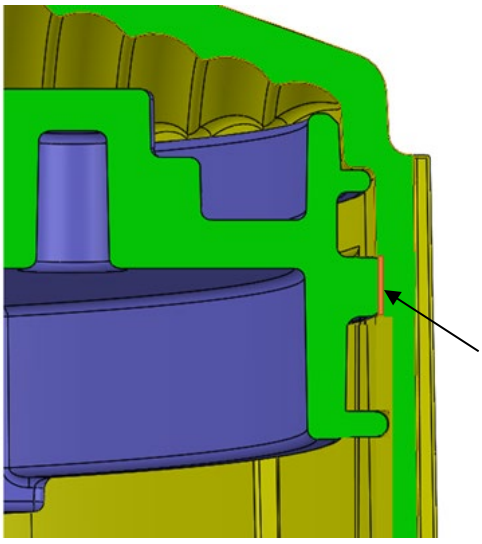
Results

- Joining the Lens to the Housing with the Spin Welding process is not feasible as currently designed
  - Material compatibility has not been verified at Extol

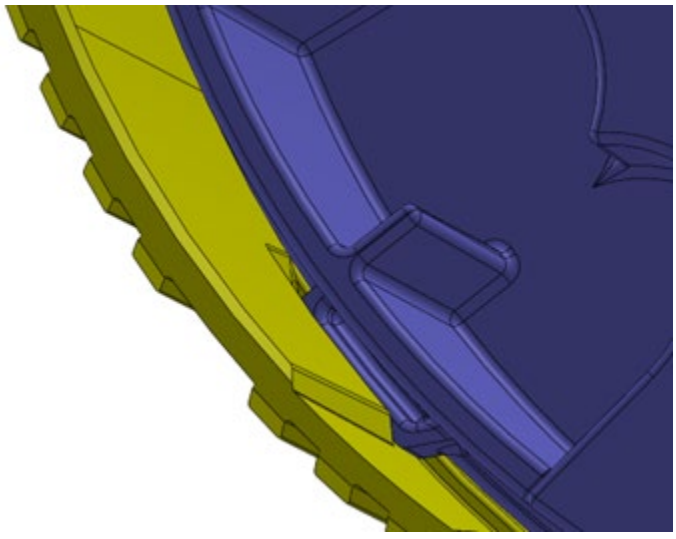
    - Component shape interference occurs at multiple areas
    - Weld joint overlap is minimal, and a hermetic seal will be difficult to achieve.
  - Voids between welding surfaces and tooling support may allow for a leak path to be generated.
    - Voids should be no larger than 18mm
- **Recommendations**
  - Incorporate a lap joint design with flash traps for catching loose particulate flash from the spin weld process.
    - Target between 0.17mm – 0.35mm of material overlap for welding.
    - Length of the lap joint to be dependent on material compatibility to achieve a hermetic seal.
    - Remove all possible component interference geometry to avoid contact with the weld rib/surface.
    - https://www.extolinc.com/learning/spin-welding/design-guidelines/
  - Verify the materials selected are compatible for welding with prototype testing for a hermetic seal.
    - Polycarbonate may be suitable for use on both Lens and Housing components.
  - Consider a gear ratio reduction to the current machine.



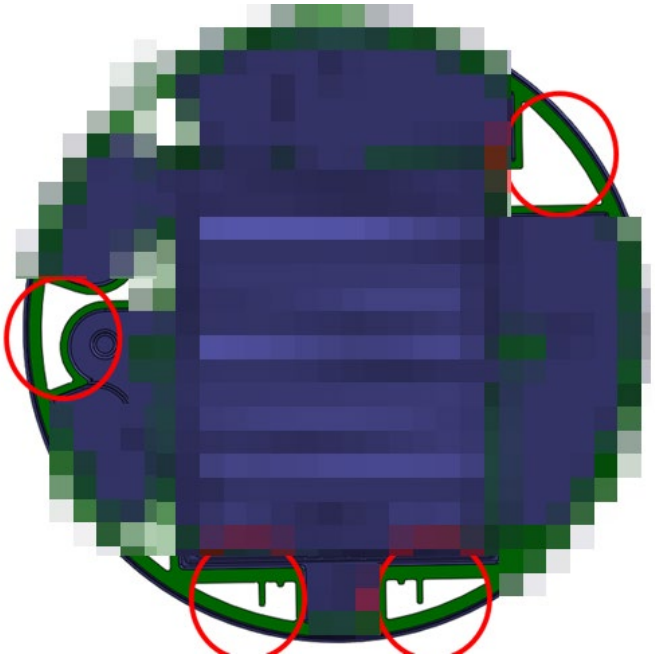
Current Joint Geometry – Unacceptable for Spin Welding



Weld Joint Concept



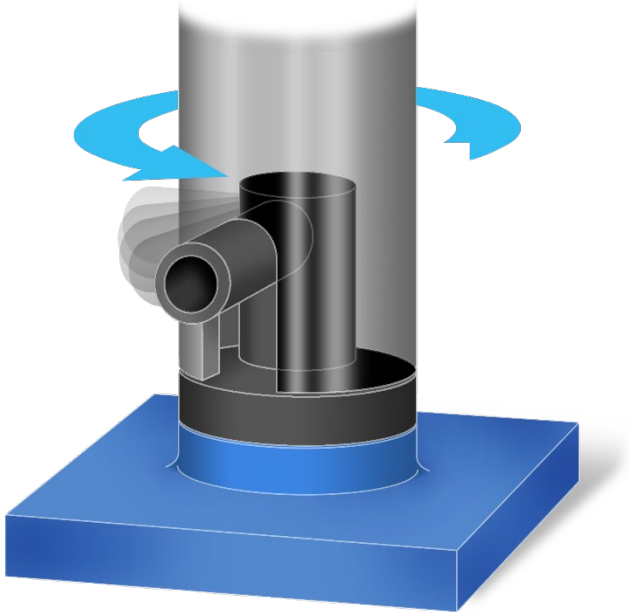
Component Feature Interferences Must Be Removed



Cross-Section View of Housing

Void Length Greater Than 18mm May Flex the Welding Rib and Produce A Leak

Spin Weld Process



View a video of the spin welding process: extolinc.com/plastics-joining/spin-welding/

Laser Welding

Application Rating

- **Recommended Technology:** Laser Welding
- **Part Design:** Minor part changes required for feasibility
- **Part Material and Color:** Feasible as specified

Scope

- Determine the feasibility of using the Laser Welding process to join the Covers to the Housings

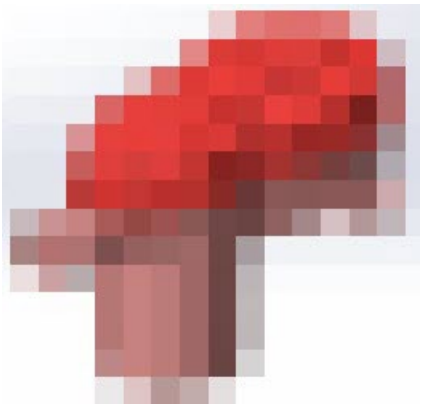
Background

- **Current Process**
  - The components are currently designed for ultrasonic welding.

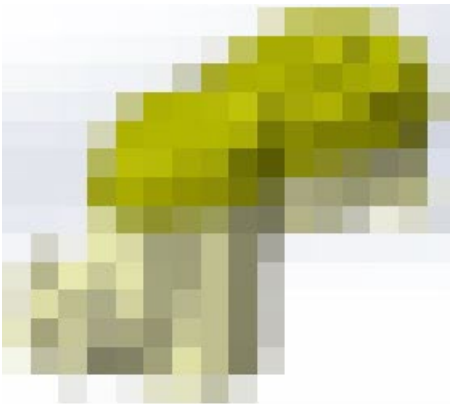
Assembly Information

Component	Material	Filler	Color(s)†	Absorptive or Transmissive	Weld Area [mm²]
Assembly #1 – #3 Covers	PBT	30%GF	Black	Transmissive Grade	306.4
Parking Brake #1 – #3 Housings	PBT	30%GF	Black	Absorptive	320.1 305.3
Assembly #4 Covers	PA66	35%GF	Black	Transmissive Grade	467.5
Parking Brake #4 Housing					187.2

Strength	Unspecified
Hermetic Seal	Unspecified
Critical Dimensions	Unspecified
Appearance	Unspecified
Cycle Time	Unspecified



Assembly 1



Assembly 2

Assembly 3

Assembly 4

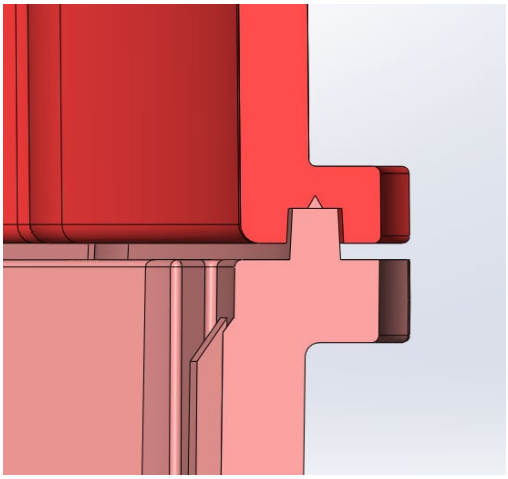
Results

- Welding Assembly #1 - #3 using the Laser welding process requires minor design changes to be feasible.
  - Components are currently designed for ultrasonics which is not a feasible joint design for laser welding.
  - The cover channel for ultrasonic welding needs to be removed.
  - Adding a 1mm wide protruding rib with a 0.5mm offset from the exterior to the housing, allows welding to be feasible.
    - However, for assembly #1, the beam clearance is only 0.25mm in two locations with this design change which is not recommended.
      - Design should be reviewed for other possible design changes to increase the beam clearance such as moving the weld rib out or adding clearance to the cover in these two locations.
    - Assembly strength requirements may require an increase in welding rib width.
  - Cover flange thickness should be reduced from 2.65mm to 2.00mm or less to ensure an optimal welding process is achievable.

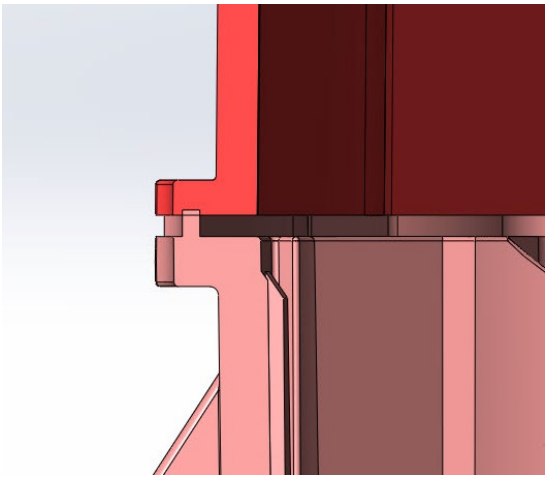
- Welding Assembly #4 using the Laser welding process requires minor design changes to be feasible.
  - The smaller cover does not display material overlap which is required for feasibility.
    - 0.2 – 0.4mm is the recommended material overlap to achieve an optimal welding process
    - A small reduction in weld rib width from the exterior is recommended to allow exterior clamping of the Cover and to keep flash from protruding past the exterior of the assembly (See image below)
  - The current larger cover design may result in a slight transmissive layer thickness variation if any slight X-Y misalignment is present during welding.
    - It is recommended to reduce the weld rib width or move the weld rib outward 0.5mm to ensure good beam clearance throughout the profile.

Recommendations

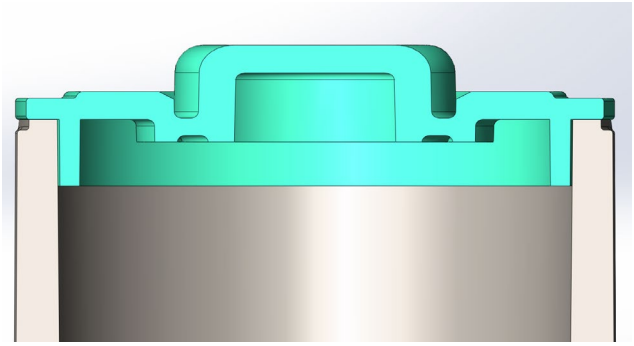
- **Assemblies #1 – #3**
  - Change joint design to utilize a 1.0 mm wide weld rib with a 0.5mm offset from the exterior of the assembly on the Housing.
    - Material overlap should be 0.2 – 0.4mm
    - Weld rib width may need to be increased if substantial weld strength is required.
  - Reduce flange thickness from 2.65mm to 2.00mm or less.
  - Review the two locations on assembly #1 with close beam clearances and improve beam clearance.
    - 0.5mm minimum beam clearance is recommended
  - Material specified in the note section of the prints is feasible for laser welding.
- **Assembly #4**
  - Small Cover
    - Add 0.2 – 0.4mm of material overlap.
    - Add a recess to the exterior of the weld rib to allow exterior clamping and to keep flash from protruding past the exterior of the assembly.
  - Large Cover
    - Reduce weld rib width or move weld joint outward to ensure no beam interference.
      - 0.5mm of clearance is preferred
  - Specific resin grades should be determined to ensure there is no issue with welding.
    - Specified material at recommended design thickness is not expected to be an issue.
- **General Laser Welding Recommendations**
  - Edge gating on the transmissive component near the welding interface may result in a glass concentration within the laser path which may negatively affect the laser welding process.
  - Ejector pin locations cannot be within the welding interface.
  - If materials are to be of different grades or resin, then testing with new materials should be performed.
  - The upper components must be laser transmissive to 980 nm wavelength laser energy.
  - Lower components must be comprised of 0.5-1.0% carbon black for the best welding results.
  - Laser weld design guidelines can be found here



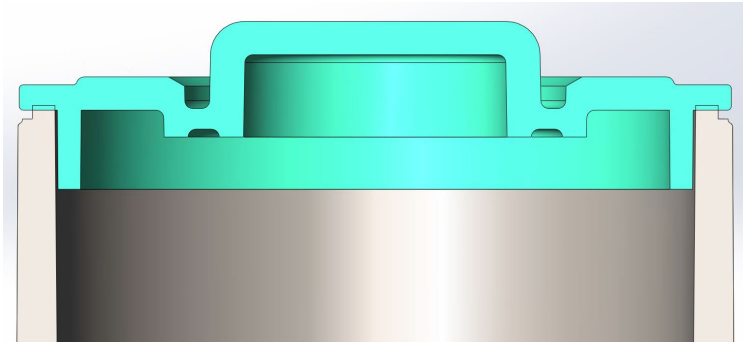
Current Joint Design



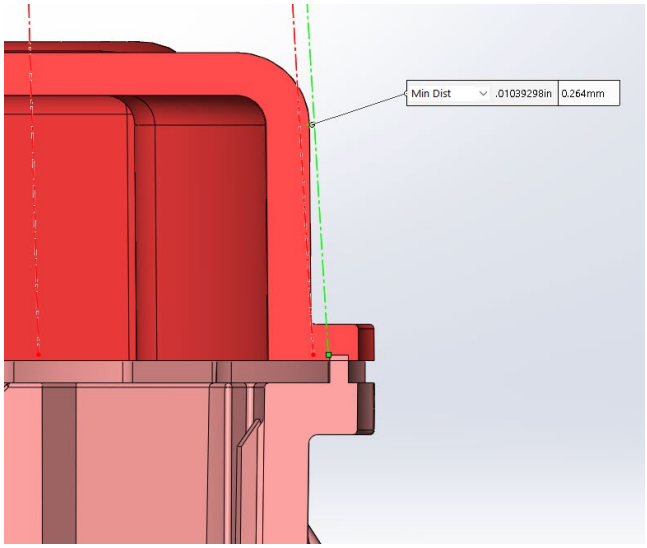
Recommended Joint Design



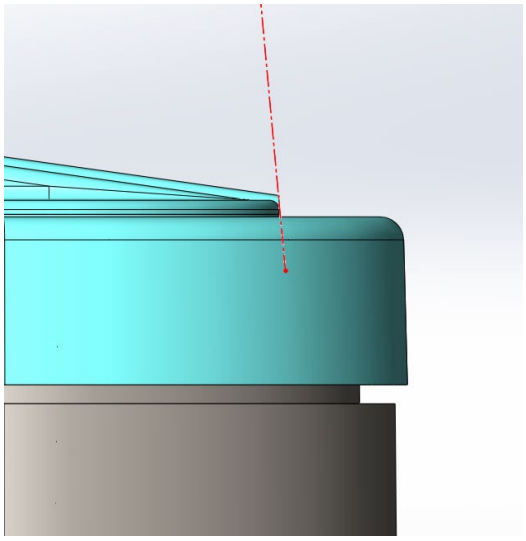
Current Joint Design Assembly #4 Small Cover



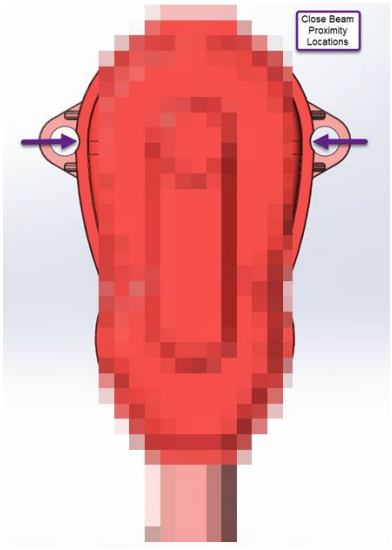
Recommended Joint Design



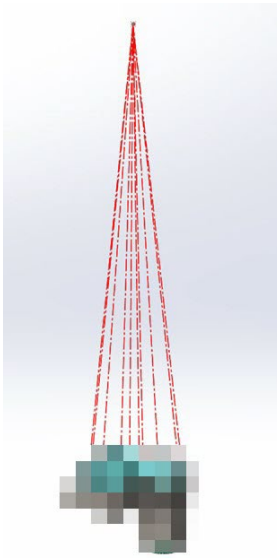
Close Beam Proximity with Recommended Design Changes Two Locations– Review Improving Clearance



Slight Beam Interference Assembly #4 Large Cover

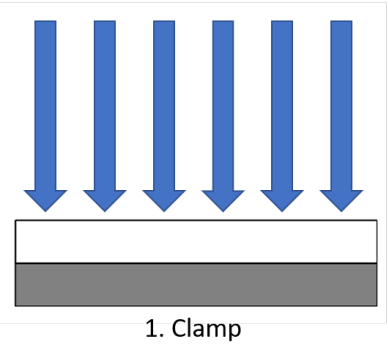


Close Beam Proximity Locations

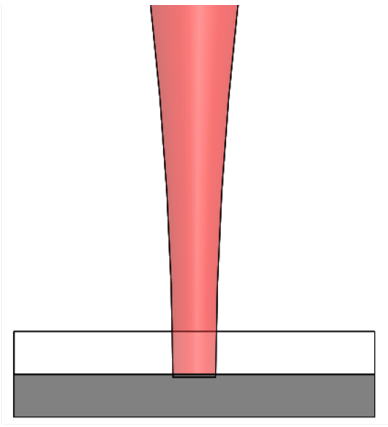


Laser Overview

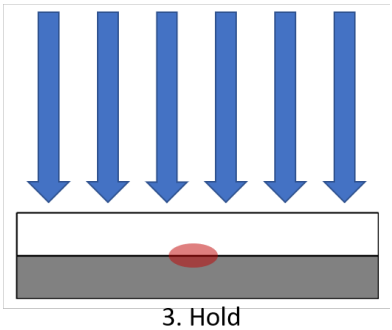
Laser Welding Process



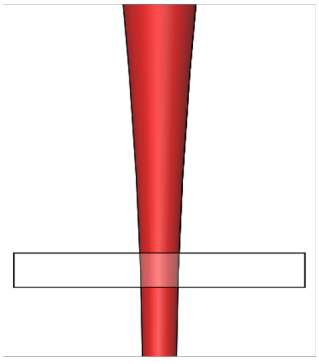
1. Clamp



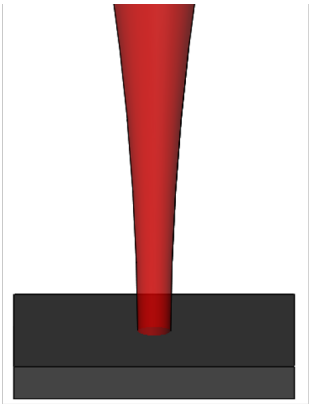
2. Weld



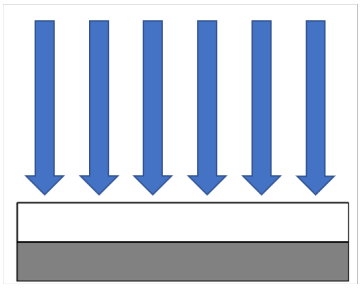
3. Hold



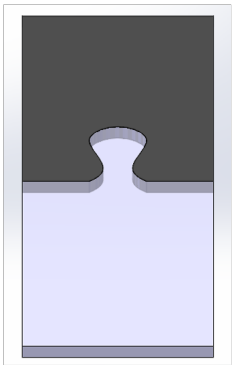
1. Transmissive Layer



2. Absorbing Layer



3. Mechanical Contact



4. Material Compatibility

Comparing Multiple Technologies

Application Rating

Technology	Part Design	Part Material and Color
Vibration Welding	Design changes or another joining method are required, currently application is not feasible	Feasible as specified
Hot Plate Welding	Design changes or another joining method are required, currently application is not feasible	Feasible as specified
InfraStake	Design changes or another joining method are required, currently application is not feasible	Feasible as specified

Scope

- Determine the feasibility of joining the Duct with the appropriate technology.

Assembly Information

Component	Material	Filler	Color(s)†
Duct	CX02-81 or EF150HP	Unspecified	Black

†Critical variable to the InfraStake and InfraWeld processes

Strength	Unspecified
Hermetic Seal	Unspecified
Critical Dimensions	Unspecified
Appearance	Unspecified
Cycle Time	Unspecified

Assembly

Results

- Joining the Duct using the Vibration Welding process is not feasible as currently designed.
  - There is no way to support under complex contoured part geometry.
  - The weld rib traverses several parts contours.
    - Multi-action Vibration Welding is not feasible, all features must be in line with each other.
  - The walls of the part are tall and unsupported and will flex under the force of welding.
    - Location and grip features are required at the weld joint to support it during welding.
  - Vibration welding generated particulate during the welding process.
    - Hybrid vibration welding will help to decrease particulate but not eliminate it.
- Joining the Duct using the Hot Plate Welding process is not feasible as currently designed.
  - Both components require a weld rib for a strong, hermetic, and visually appealing weld.
    - Add a uniform weld rib to the lower component for hot plate welding feasibility.
  - The weld rib traverses several parts contours.
    - The maximum angle feasible with Hot Plat Welding is 30 degrees.
      - Reduce part curvature to 30 degrees or less when normalized for hot plate feasibility.
  - The walls of the part are tall and unsupported and will flex under the force of welding.
    - Reduce tall walls as much as possible.
      - Add support ribs or return flanges to tall walls where reduction is not possible to avoid rib deflection.
      - Increase weld rib thickness to 1.65 mm or more for a more robust welding process.
  - The Hot Plate Welding process generates less particulate than the Vibration Welding process, but particulate will still be present after welding.
  - Copolymers (CX02-81) have a negative effect on the welding process and prototype testing is required when used with large part angles.
- Joining the Duct using the InfraStake process is not feasible as currently designed.
  - The current design is not set up for staking.
    - Eliminate welded ribs and add a flange to the upper component for maximum contact with the lower component.
    - Add bosses to the lower component and add corresponding through holes to the flange of the upper component.
      - Boss design guidelines can be located here
  - The upper and lower components have several contours.
    - Staking will not achieve a hermetic seal, but a tight mechanical bond is possible.
      - Match part contours between the components for a tight mechanical bond from staking
    - Z-axis springs are heavily recommended to mitigate part warping.
  - The InfraStake technology is a particulate free process.
  - Multiple press actions may be required depending on stake locations.

Recommendations

- InfraStake is the recommended technology due to minimal part changes required for feasibility and lack of particulate.