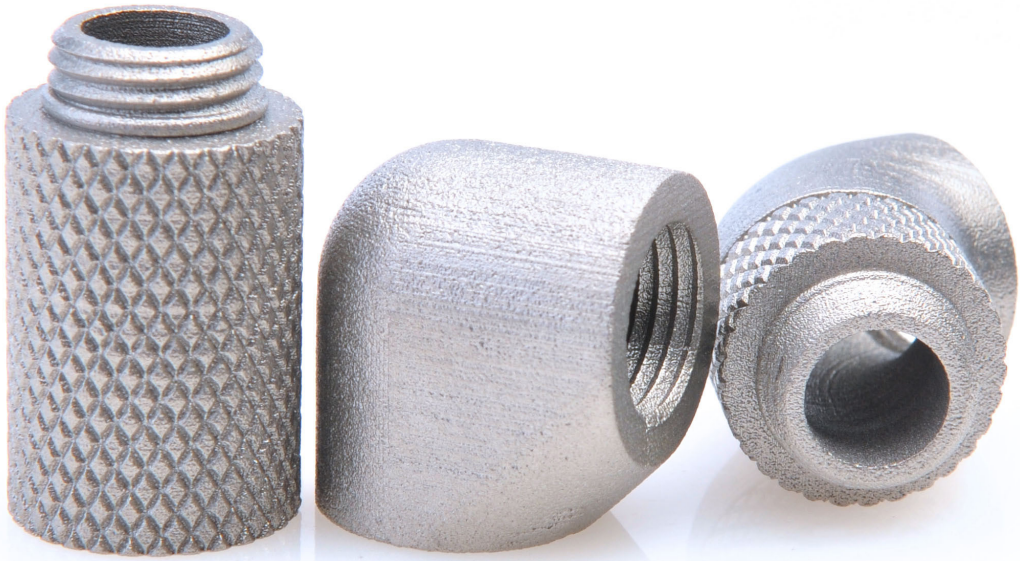

2020 METAL 3D PRINTING MANUFACTURING DESIGN GUIDELINES

On-Demand Metal Binder Jetting Design Considerations & Finishes

- Print Resolution
- Shrinkage
- Tolerances
- Wall Thickness
- Interior Holes, Cavities
- Moving Parts
- Finishing

ExOne™

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Table of Contents

The ExOne Company

Manufacturing Guidelines for ExOne Metal Sintered Parts

NH-PSC-GL-011

The ExOne Company

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USA

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Legal Notice

ExOne Sintered Materials

- 316L
- 17-4PH
- 304L

General Considerations

- **Shrinkage**
  - Materials have typical shrinkage rates for different cross-sections thicknesses. Design parts with consistent cross sections.
  - All overhangs will need to be supported during sintering. Features such as fillets and larger cross sectional thicknesses on supporting structures can help prevent sagging.
    - Please consult your sales or applications representative for design considerations.

- **Tolerances**
  - ExOne attempts to produce parts with the tightest tolerances possible. Typical expected tolerances are within 1% (0.5mm [0.02in] minimum) of a given overall dimension for single part production.
  - Tighter tolerances and feature specific quality control are achievable in many situations, such as with high-volume production batches. Please consult your sales or applications representative for design considerations.

- **Print Resolution**
  - Parts smaller than 250 x 400 x 250mm [9.8 x 15.7 x 9.8in]
    X and Y: 0.063mm [0.002in]
    Z: 0.05mm [0.002in]

Wall Thickness

- The minimum thickness your model should have at main supportive walls:

Part Size	Minimum Wall Thickness
3 – 75mm [0.12 – 3in]	1mm [0.04in]
75 – 150mm [3 – 6in]	1.5mm [0.06in]
150 – 200mm [6 – 8in]	2mm [0.08in]
200 – 300mm [8-12in]	3mm [0.13in]

- Actual minimum thickness vary with actual part geometry.
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  - Larger parts require thicker walls.

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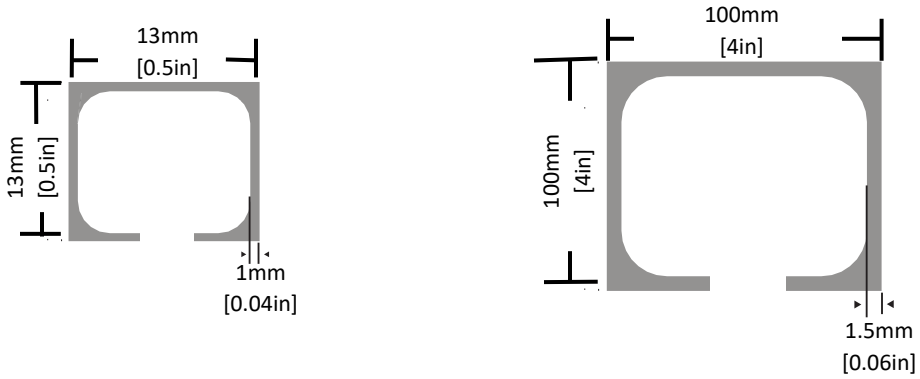

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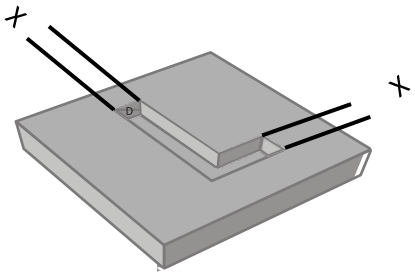

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- Overhangs must be designed to not collapse under their own weight.
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- Interior cavities must have a loose powder drain hole with enough area to allow the powder to be removed during the loose powder removal process.
  - The minimum size of a loose powder removal hole for an interior cavity is approximately 1.5mm [0.06in].
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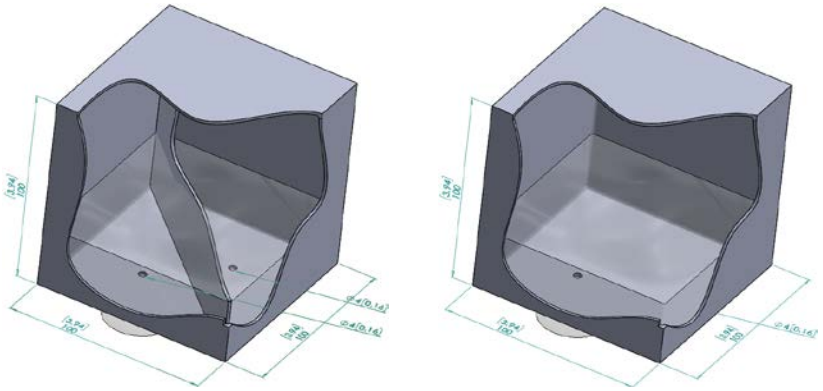
  - Cavity geometry should determine placement of drain holes. The more centralized the hole to each pocket, the higher the success of the powder removal.
  - The greater the depth of the hole, the larger the required diameter to ensure successful loose powder removal.
  - Please note that parts with liquid holding cavities cannot be plated.

EXAMPLE:

Good Practice

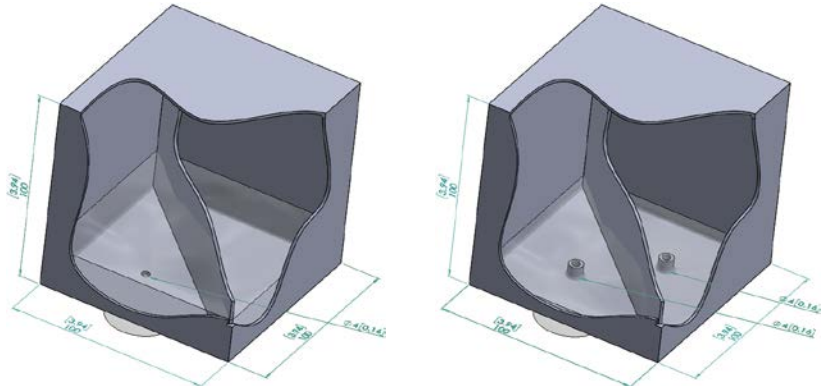
Both cavities have access to a loose powder removal hole



The full cavity has access to a loose powder removal hole

Bad Practice

Only half of the cavity has direct access to a loose powder removal hole



The internal bosses will prevent loose powder from flowing out of the hole

Inside Corners

- Inside corners and sharp intersection should have a filleted edge.
  - Fillet radius size should be approximately equal to the connecting wall thickness.
  - Wall terminations on inside cavities also need to meet the wall thickness minimums.
  - Filleted edges help to prevent distortion and cracking during sintering.

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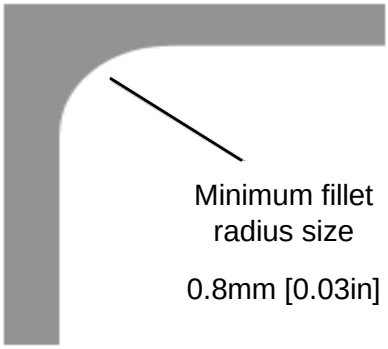

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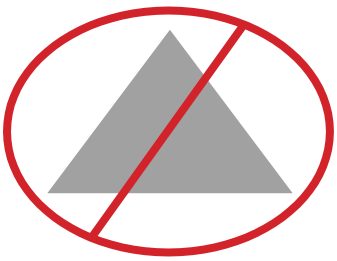

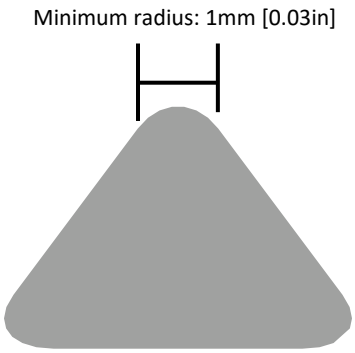

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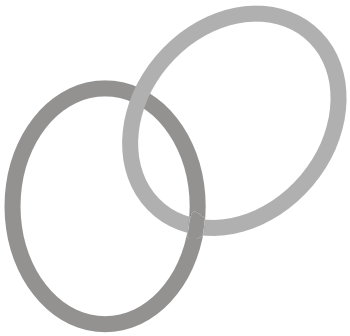

Connected or Sprued Parts

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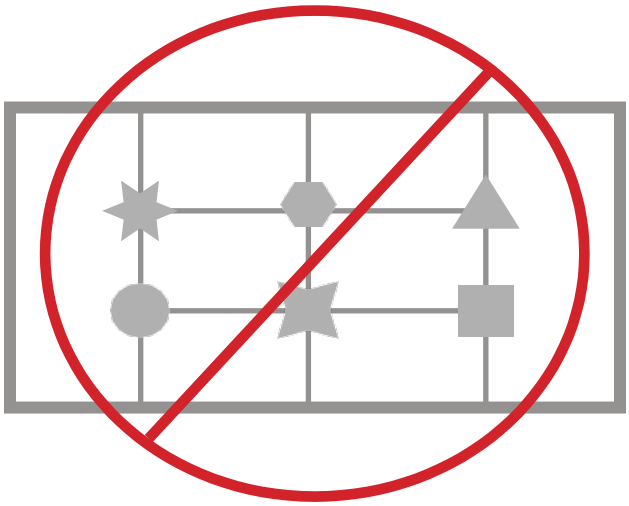

Finishing - Polishing

- ExOne used a high-energy process which tumbles parts in several different polishing media. The part can only be polished where the polishing media can contact and move around the part.
  - Maximum part size is 150 x 150 x 75mm [6 x 6 x 3in].
  - Not all parts can be polished. ExOne can only determine if polishing is possible once a part has been produced.
  - Part geometry can directly affect polishing success or degree. The following geometry types may not polish well.
    - Wire framed parts
    - Fragile parts
    - Thin-walled parts
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Finishing – Plating and Patina

- ExOne used a small plating line that requires manual setup and unload.
  - Part size maximum is 180 x 180 x 180mm [7 x 7 x 7in].
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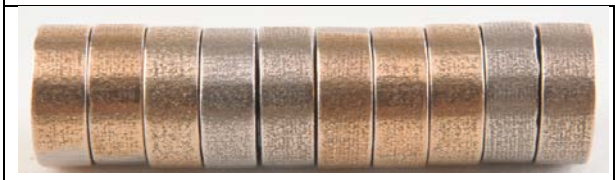
  - Plating is purely decorative and will not survive excessive wear.
  - Colors may vary.

Sample Finishes

Bead Blasted



Polished

Zirconia Blasted

Polished Nickel Plating

Nickle Plating

Polished Bronze Patina

Bronze Patina

Polished Black Patina

Black Patina

Polished Gold Plating

Gold Plating

- **High Pressure Bead Blast** – The minimum finish that every part receives after stilt removal. It is done using alumina oxide powder in a pressurized controlled cabinet, and is a requirement before all optional finishes.
- **Polish (P)** – Requires a high energy tumbling machine with various media, soap and polishing material. It is not suitable for geometrically fragile parts and parts over 7" in diameter and/or parts over 10" long. Please note: this is not a "buffing" operation, and degree of polish is directly related to part geometry. Part is finished with a gloss lacquer.
- **Ceramic Blasting (ZB)** – Creates a polish finish to parts that are too geometrically fragile or too large for the high energy polishing machine. It will not create as much shine as the high energy machine. Part is finished with a gloss lacquer.

- **Antique Bronze (AB)** – A light to medium bronze patina that is done through a heat cycle and completed after polishing. Chemicals are not involved in this process. Part is finished with a gloss lacquer.
- **Wheat Penny (WP)** – A medium to dark bronze patina that is done through a heat cycle without polishing, which provides a matte finish. Chemicals are not involved in this process. Part is finished with a matte lacquer.
- **Medieval Pewter (MP)** – A gray to black patina that is done through a heat cycle after polishing. Chemicals are not involved in this process. Part is finished with a gloss lacquer.
- **Damascus Steel (DM)** – A medium to dark black patina that is done through a heat cycle without polishing which provides a matte finish. Chemicals are not involved in this process. Part is finished with a matte lacquer.
- **Nickel Plating (N)** – An electroless nickel plating finish that is very ductile. It is applied on an unpolished part and has a gray to silver finish. Part is finished with a matte lacquer.
- **Nickel Polish Plating (NP)** – An electroless nickel plating finish that is very ductile. It is applied on a polished or ceramic blasted part and has a silver finish. Part is finished with a gloss lacquer.
- **Gold Plating (G)** – An electroless immersion gold plating finish that is very ductile. It is applied over a nickel plated unpolished part and has a matte gold finish. Part is finished with a matte lacquer.
- **Gold Polish Plating (GP)** – An electroless immersion gold plating finish that is very ductile. It is applied over a nickel plated polished or ceramic blasted part and has a polished gold finish. Part is finished with a gloss lacquer.

For more information, please contact:

Brandon Cary
Manager of Industrial Sales
Brandon.Cary@exone.com

The ExOne Company

Manufacturing Guidelines for ExOne Metal Infiltrated Parts

NH-PSC-GL-006

The ExOne Company

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North Huntingdon, PA 15642
USA

Phone: + 1 877-773-9663
Fax: +1 724-864-9663

ExOne Infiltrated Materials

420 Stainless Steel/Bronze

- The ExOne Company 3D Printed 420 Stainless Steel infiltrated with Bronze is a matrix material composed of 60% stainless steel and 40% bronze infiltrant. This material offers good mechanical properties, is available in both an annealed and non-annealed condition, is able to be machined, welded and polished, and offers excellent wear resistance.

COMPOSITION:

Printed Base: Alloy 420 Stainless Steel
Infiltrant: 90% Cu / 10% Sn

316 Stainless Steel/Bronze

- The ExOne Company 3D Printed 316Stainless Steel infiltrated with Bronze is a matrix material composed of approximately 60% stainless steel and 40% bronze infiltrant. This material offers good mechanical properties and fair corrosion resistance. The material is easily machined, welded and polished.

COMPOSITION:

Printed Base: Alloy 316 Stainless Steel
Infiltrant: 90% Cu / 10% Sn

Tungsten/Bronze

- The ExOne Company 3D Printed Tungsten infiltrated with Bronze is a matrix material composed of approximately 55% tungsten and 45% bronze infiltrant. This material is a versatile high-density shielding material with an excellent tensile strength.

COMPOSITION:

Printed Base: Tungsten
Infiltrant: 90% Cu / 10% Sn

General Considerations

- **Shrinkage**
  - Materials have typical shrinkage rates for different cross-sections thicknesses. Design parts with consistent cross sections.
  - All overhangs will need to be supported during sintering. Features such as fillets and larger cross sectional thicknesses on supporting structures can help prevent sagging.
    - Please consult your sales or applications representative for design considerations.

- **Tolerances**
  - ExOne attempts to produce parts with the tightest tolerances possible. Typical expected tolerances are within 1% (0.5mm [0.02in] minimum) of a given overall dimension for single part production.
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- **Print Resolution**
  - Parts smaller than 250 x 400 x 250mm [9.8 x 15.7 x 9.8in]
    X and Y: 0.063mm [0.002in]
    Z: 0.1mm [0.004in]

Infiltration Geometry (Stilting)

- ExOne application specialists will typically add additional infiltration geometry (stilts) to your part. Stilts are necessary to allow bronze to infiltrate the part. Stilt placement is influenced by part design. A smooth area is required to add stilt geometry. Typically, the larger the part, the larger the required stilt area.
  - Textured surfaces: Stilts need a smooth surface to be placed on.
  - Smooth surface area: Stilts require area of 1.5 x 1.5mm [0.06 x 0.06in] minimum
    - Larger parts require larger suitable stilt area
  - Part will have blemish from stilt removal.
  - ExOne will make every attempt to keep the blemish minimal in an unnoticeable area.

Wall Thickness

- The minimum thickness your model should have at main supportive walls:

Part Size	Minimum Wall Thickness
3 – 75mm [0.12 – 3in]	1mm [0.04in]
75 – 150mm [3 – 6in]	1.5mm [0.06in]
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- Actual minimum thickness vary with actual part geometry.
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  - Part minimum dimensions must be met for the part to be printable.

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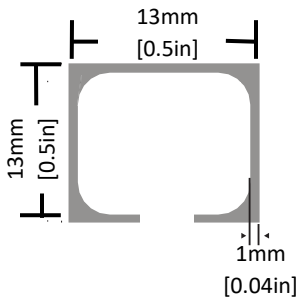

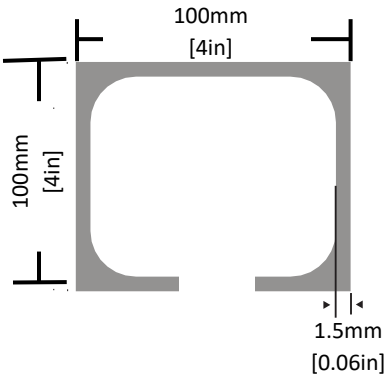

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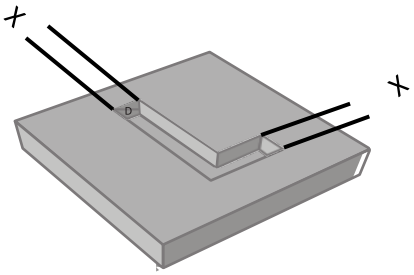

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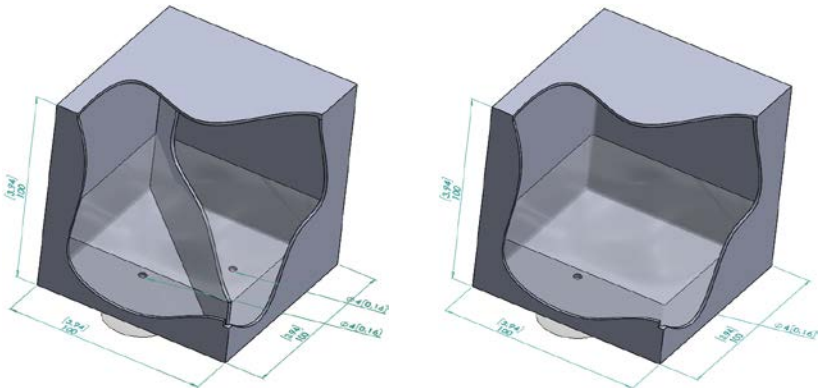

The full cavity has access to a loose powder removal hole

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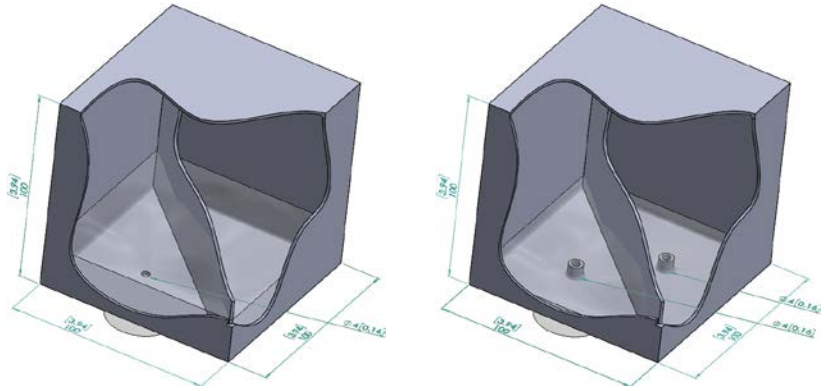

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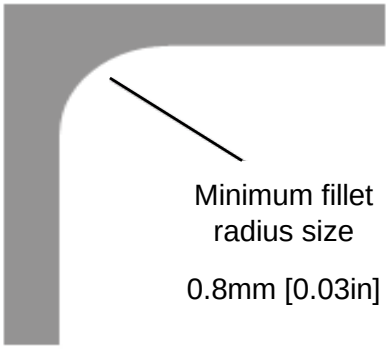

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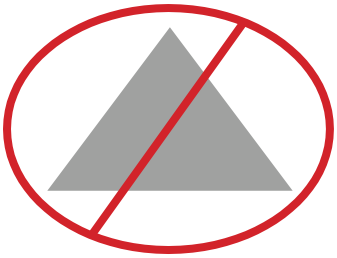

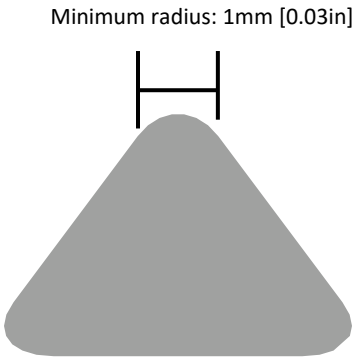

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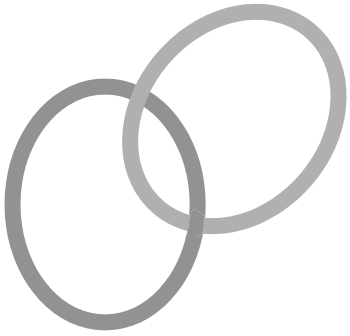

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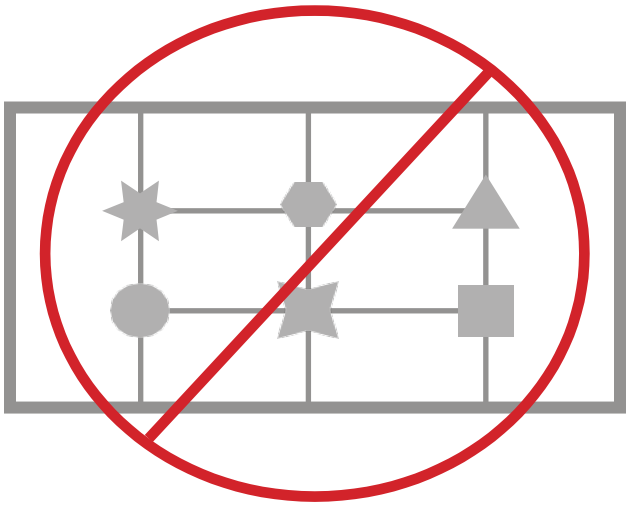

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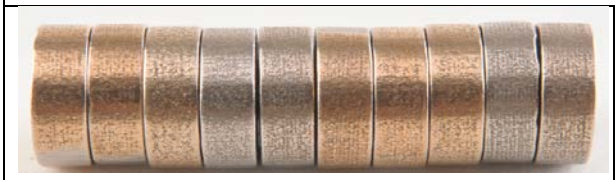

Polished

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Nickle Plating

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For more information, please contact:

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LET'S SOLVE THE TOUGHEST PROBLEMS. AND CHANGE THE WORLD.