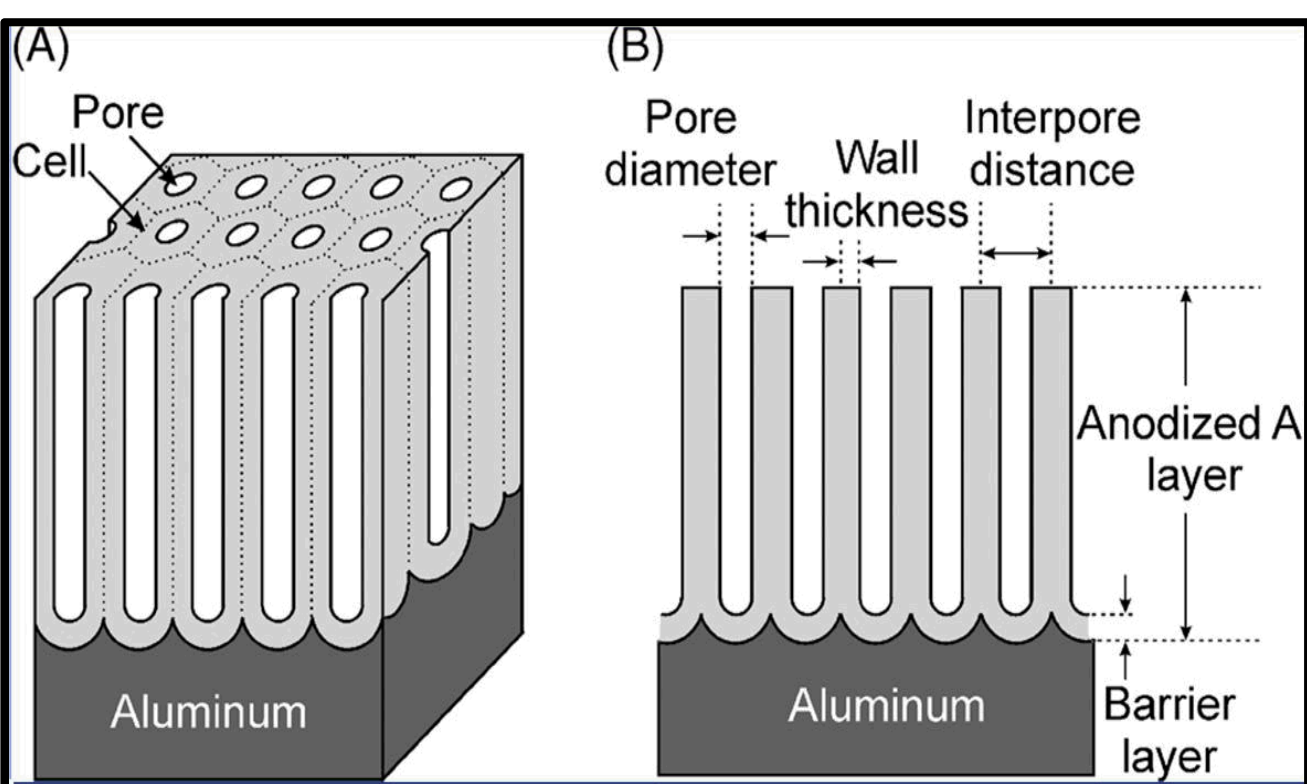


# Quantitative Evaluation of the Material Properties of Surface Treatments

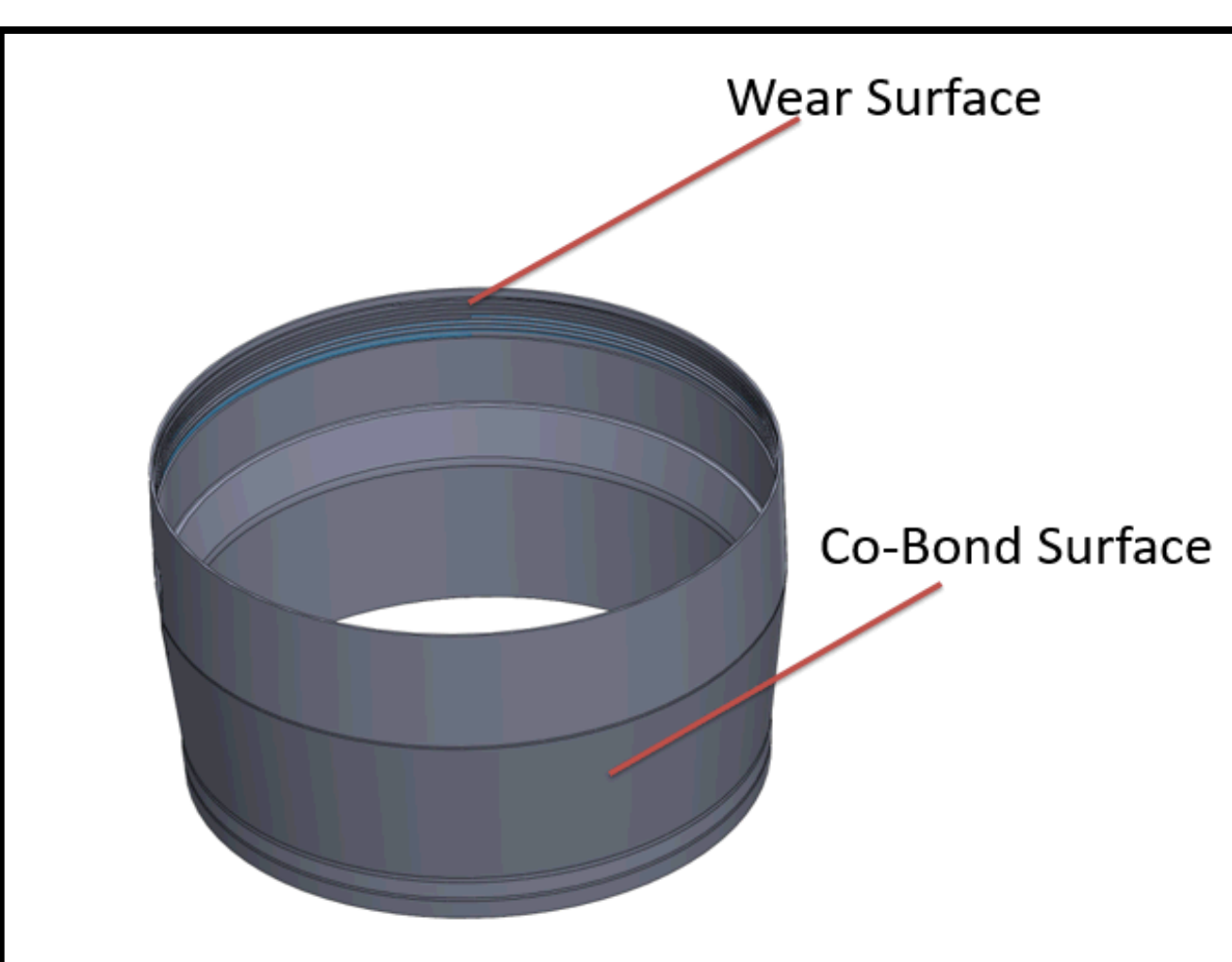
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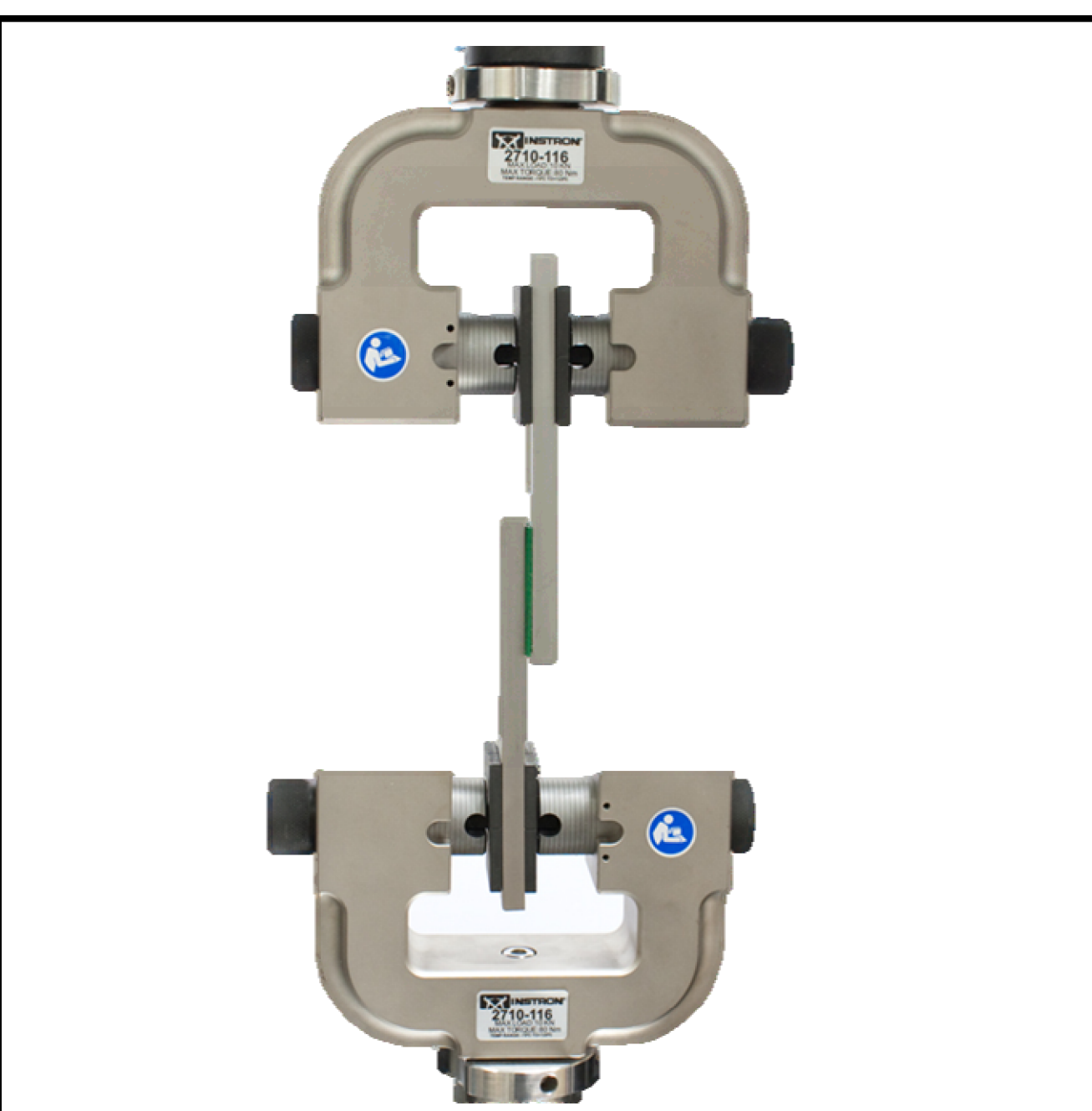
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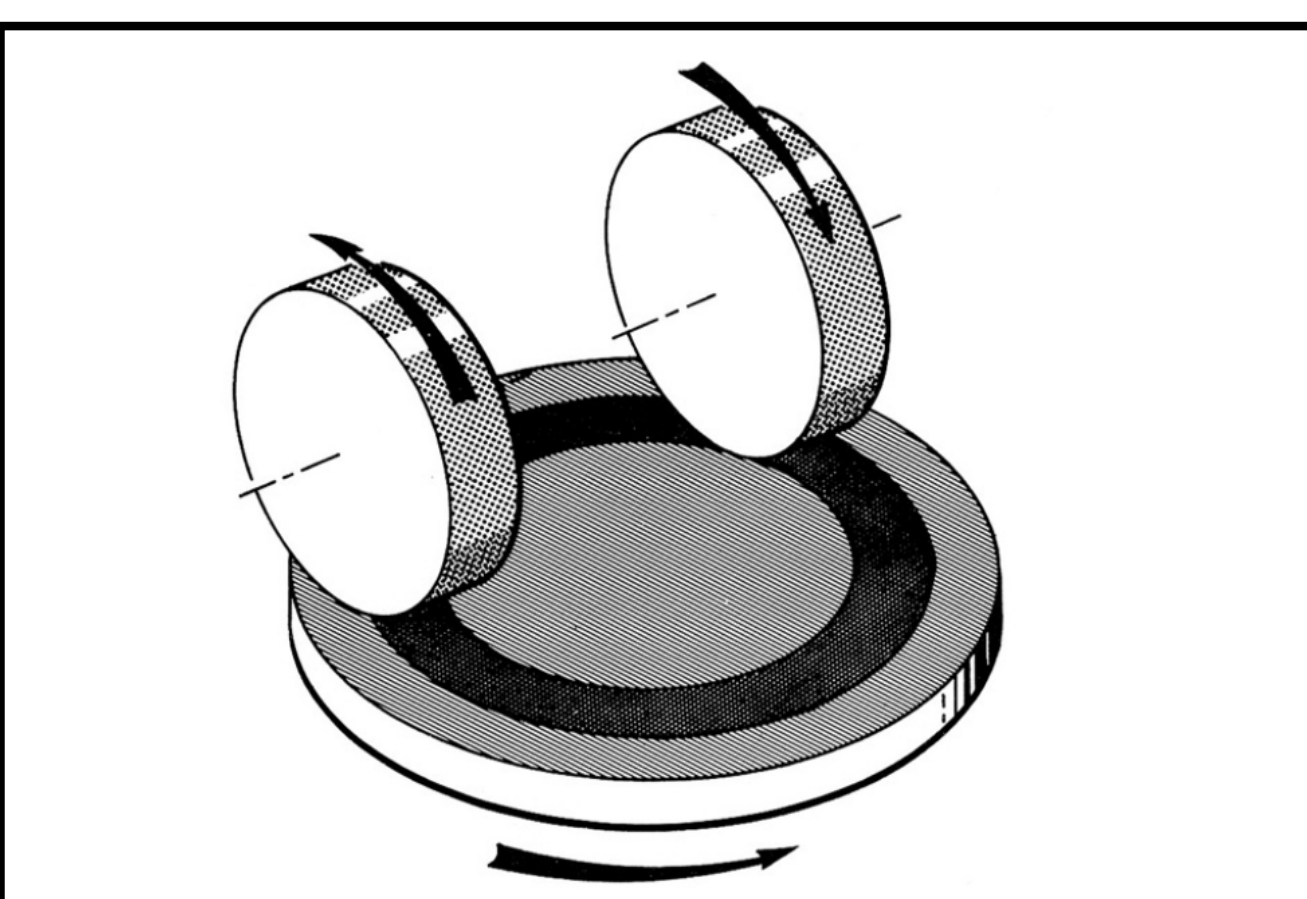
Pore structure of anodized aluminum



Piece part to be surface treated



Lap Shear test for adhesive bonding



Taber Abrasion test for wear resistance

**Background:** The piece parts of the warhead case have several different surfaces that require different material properties. To obtain the desired properties, the aluminum piece parts must be surface treated. These desired properties are wear/abrasion resistance, corrosion resistance, strong adhesion to a glass composite material, and low electrical resistance. There are various surface treatments that are currently used in industry, however there is no study that quantitatively compares the above mentioned properties across different surface treatments.

**Project Goals:** The goal of this study is to be able to quantitatively compare the wear, corrosion, adhesion, and electrical properties between different surface treatments. By creating this database of information, an informed decision can be made about which surface treatment(s) should be applied to the aluminum piece parts. The overall goal of this study is to be able to down select to a smaller subset of surface treatments for further "in service" testing based on quantitative comparisons between surface treatments, and to obtain a better general understanding of the properties of aluminum surface treatments.

## Surface Treatments Selected for Experimental Study:

**Anodization** – An electrochemical reaction is used to "convert" the surface of an aluminum substrate into aluminum oxide.

**Sulfuric Type II (Regular) Anodization** – Used for corrosion resistance, decorative purposes, and light wear.

**Phosphoric Anodization** – Used as a surface for adhesive bonding.

**Sulfuric Type III (Hardcoat) Anodization** – Used for heavy wear and corrosion resistance.

**Sealing Methods for Anodized Surfaces** – The pores of an anodized surface are sealed to increase corrosion resistance.

**Hot Water Seal** – Most commonly used sealing method.

**Trivalent Chromium (TCP-HF)** – "New" sealing method that may enhance material properties.

**Hot Water Seal + TCP(Duplex Seal)** – Combination of above sealing methods for better a seal.

**Electroless Nickel Plating** – A chemical reducing agent is used to deposit a layer of nickel and phosphorus onto a substrate.

**Mid Phosphorus (6-9%)** - High hardness, wear resistance, and low electrical resistance.

**High Phosphorus (11-12%)** – High hardness, wear resistance, corrosion resistance, and low electrical resistance.

**Heat Treatment for Electroless Nickel** – Since nickel deposit contains phosphate, it can be heat treated to change its properties.

**No heat treatment**

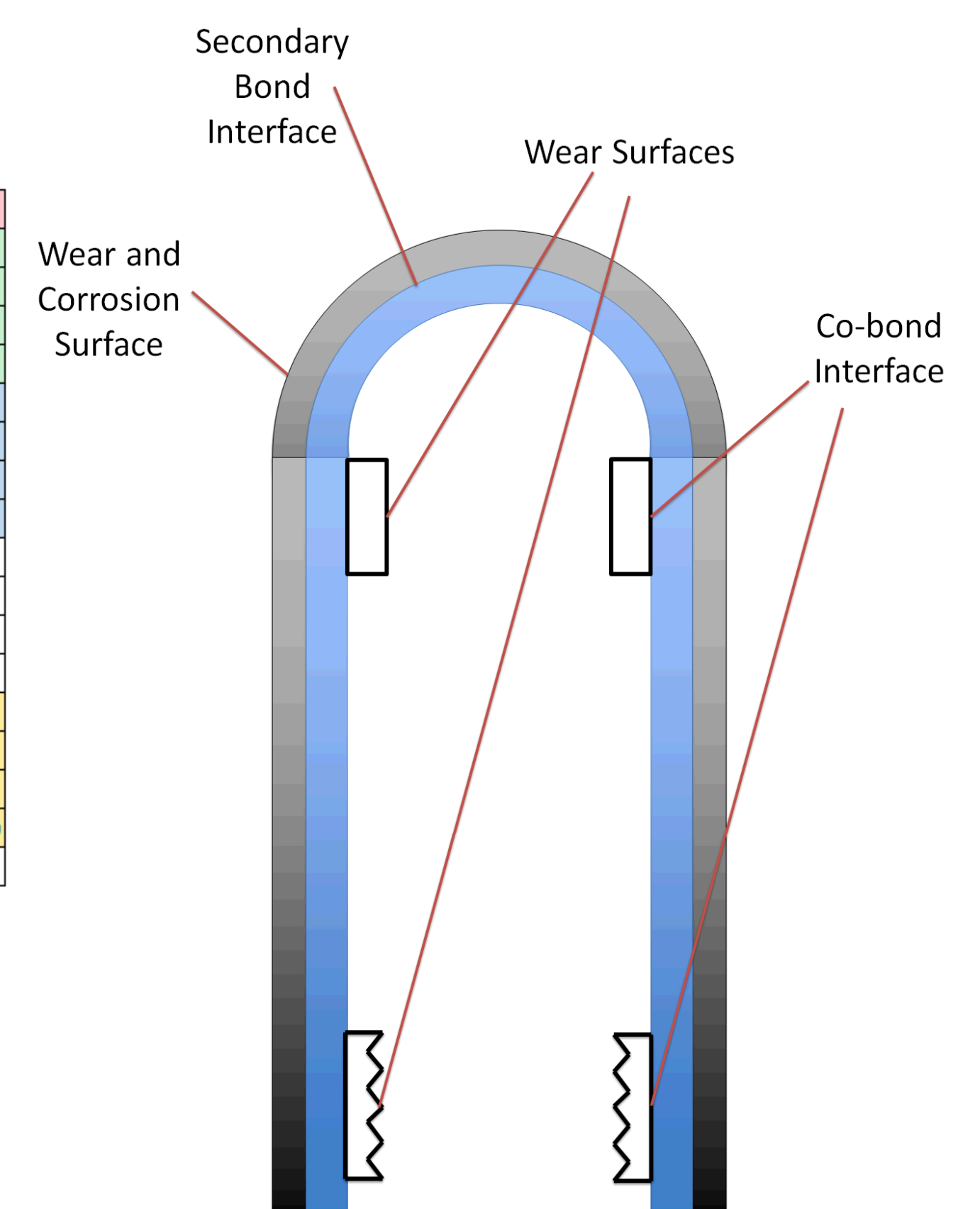
**Heat treatment at 375 F for 4 hours** – For increased adhesion between electroless nickel and aluminum.

## Experiments:

1. Taber Abrasion Test – Measures the depth of a wear surface caused by two abrasive wheels. (Wear/Abrasion test)
2. Lap Shear Test – Measures the load at which a lap joint made of aluminum and a glass composite fails. (Adhesion strength test)
3. Salt Spray Test – Measures the time until a specified failure condition in a chamber that produces a salt fog. (Corrosion test)
4. Electrical Resistance Test – Measures the current between two electrodes due to an applied voltage to determine electrical resistance.

## Test Matrix:

Test Samples - Wear/Abrasion, Corrosion, Electrical Resistance	Test Samples - Secondary Bond, and Co-bond
Sulfuric Type II Anodization+ No Seal	Sulfuric Type II Anodization+ No Seal + Hysol 2000
Sulfuric Type II Anodization + Hot Water Seal	Sulfuric Type II Anodization + Hot Water Seal + Hysol 2000
Sulfuric Type II Anodization + TCP-HF	Sulfuric Type II Anodization + TCP-HF + Hysol 2000
Sulfuric Type II Anodization + Hot Water Seal + TCP-HF	Sulfuric Type II Anodization + Hot Water Seal + TCP-HF + Hysol 2000
Phosphoric Anodization + No Seal	Phosphoric Anodization + No Seal + Hysol 2000
Phosphoric Anodization + Hot Water Seal	Phosphoric Anodization + Hot Water Seal + Hysol 2000
Phosphoric Anodization + TCP-HF	Phosphoric Anodization + TCP-HF + Hysol 2000
Phosphoric Anodization + Hot Water Seal + TCP-HF	Phosphoric Anodization + Hot Water Seal + TCP-HF + Hysol 2000
Sulfuric Type III Anodization + No Seal	Sulfuric Type III Anodization + No Seal + Hysol 2000
Sulfuric Type III Anodization + Hot Water Seal	Sulfuric Type III Anodization + Hot Water Seal + Hysol 2000
Sulfuric Type III Anodization + TCP-HF	Sulfuric Type III Anodization + TCP-HF + Hysol 2000
Sulfuric Type III Anodization + Hot Water Seal + TCP-HF	Sulfuric Type III Anodization + Hot Water Seal + TCP-HF + Hysol 2000
Electroless Nickel - Mid Phosphorus (6-9%) + No Heat Treatment	Electroless Nickel - Mid Phosphorus (6-9%) + No Heat Treatment + Hysol 2000
Electroless Nickel - Mid Phosphorus (6-9%) + Heat Treated for Adhesion	Electroless Nickel - Mid Phosphorus (6-9%) + Heat Treated for Adhesion + Hysol 2000
Electroless Nickel - High Phosphorus (11-12%) + No Heat Treatment	Electroless Nickel - High Phosphorus (11-12%) + No Heat Treatment + Hysol 2000
Electroless Nickel - High Phosphorus (11-12%) + Heat Treated for Adhesion	Electroless Nickel - High Phosphorus (11-12%) + Heat Treated for Adhesion + Hysol 2000
	Sulfuric Type II Anodization + Hot Water Seal + BR127



Section view of warhead case

## Further Work

Further testing in "real world" conditions will be done to ensure that the component will be able to last for 30 years. The results of this study will be used for down select to a smaller subset of surface treatments.

## Acknowledgements:

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Citations:  
 [1] Instron Lap Shear Test. (n.d.)  
 [2] Sulka, G. D. (n.d.). Highly Ordered Anodic Porous Alumina Formation by Self-Organized Anodizing.  
 [3] Taber Industries. (n.d.).