Definition: Extreme Wear Solutions
The manufacturing and repair methods used to produce custom, application-specific, superior performing parts.

Benefits of using Extreme Wear parts:
• Reduction of costly downtime with the use of superior performing Extreme Wear parts
• Reduced part replacement or repair costs
• Reduction of maintenance & operating costs due to longer service cycles with Extreme Wear parts

Hard Chrome Plating vs. HVOF

Why the Technology?
• Used for fluid power hydraulic repairs in cylinders and corner groups
• Provides long-term robust repair for hydraulic and fluid power components
• Cutting edge environmentally friendly technology
• Provides a safe working environment for associates to do repairs

Hard Chrome Plating
Chrome was discovered in 1798, first successful electrolytic plating in 1856, with commercial utilization in the late 1920’s

Advantages
• Resists most chemicals, oxygen, and moisture in air
• Does not tend to seize, gall, or cold weld
• Hard surface typical 69 Rc, 0.003-0.015” typical thickness
• Simple technology
• Excellent wear resistance
• Historically relatively inexpensive

Issues with hard chrome plating
• The process produces large amounts of hydrogen gas in the gas bubbles burst throwing hexavalent chrome solution into the air as fine mist. Hexavalent chrome is a know carcinogen.
• The process produces large volumes of toxic waste.
• EPA and OSHA have mandated more stringent stack emission levels and lowering of permissible exposure limits for workers.
• This results in increased costs and business risks.
Alternatives to Hard Chrome Plating Sought

- The Hard Chrome Alternatives Team (HCAT) formed during the 1990’s
- HCAT is a bi-national team comprised of Dept of Defense, US airlines, Canadian military and airline industries, support manufacturers
- Methods evaluated were Arc Spraying, Plasma Spraying, Flame Spraying, and High Velocity Oxy-Fuel (HVOF)

The BEST Alternative

- The best clean alternative method determined by HCAT was HVOF thermal spray for Hydraulic Actuators (Cylinder Rods)
- The HVOF process utilizes a material in powder form injected into a flame of supersonic gas
- The material softens in the flame and forms a dense coating on the substrate.

HVOF

- The fuel for the flame is a gas such as hydrogen, acetylene, propylene, or a liquid such as kerosene
- The coating material is usually a metal alloy such as chrome carbide
- Typical deposit coating layers range from 0.003-0.015” in thickness

HVOF Spray Gun Cutaway
HVOF

- The part to be coated must have chrome removed by stripping electrolytically or grinding
- If the surface has been previously HVOF coated, the surface must be ground to remove any imperfections
- Any area not to be coated must be masked off
- The surface to be coated must be thoroughly grit blasted using aluminum oxide material-36 grit-the prepared surface must be kept clean from this point on
- The work piece is put into the HVOF thermal spray cabinet.
- During the spray process the work piece rotates at 300 surface feet per minute
- Each pass applies 0.001”of coating
- The work piece temperature is not allowed to exceed 350 F, the spray process can be stopped and started to limit this temperature HVOF
- Final surface finishing requires use of either diamond belts or diamond grinding wheels
- It is necessary to not only grind but also superfinish
- The finished surface is measured and documented
- The bond strength is >10,000 PSI

Comparison of Hard Chrome Plating to HVOF

<table>
<thead>
<tr>
<th></th>
<th>Hard Chrome Plating</th>
<th>HVOF</th>
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<tbody>
<tr>
<td><strong>Surface Hardness</strong></td>
<td>69 Rc</td>
<td>71 Rc</td>
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<tr>
<td><strong>Time required to coat</strong></td>
<td>7 hours (0.002” per hour to get 0.007”/side)</td>
<td>1 hour (12lbs at 12lbs/hr to get 0.007”/side)</td>
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<tr>
<td><strong>Komatsu 830E first stage</strong></td>
<td>145F</td>
<td>300-350F</td>
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<tr>
<td><strong>Work Piece Temp</strong></td>
<td>5000 F</td>
<td>5600 F</td>
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<tr>
<td><strong>Post Plate H2 Relive</strong></td>
<td>Mach 1</td>
<td>Mach 2+ (3300-3900 ft. / second)</td>
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<tr>
<td><strong>Temperature</strong></td>
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• At the bottom of each photo is the substrate material which is being coated

Benefits of HVOF Coatings
• High density, low porosity
• Improved corrosion barrier
• Higher hardness ratings
• Improved wear resistance
• High bond strength
• Thick coatings
• Smoother as-sprayed surfaces

Summation
• Hard chrome has the advantage that it is a single material and deposition method that can be used for a wide variety of applications
• HVOF is a single technology, with a wide variety of materials that can be used to achieve the right combination of properties for many purposes.

Hazardous Environment Changes
• Provides a safer work environment for our people
• 80% reduction in hazardous waste
• Waste produced is considerably less hazardous than Hard Chrome Plating