Marine Applications of Thermal Spray Technology
Hard Chrome Alternatives Team Meeting
San Diego, CA    25 January 2006

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**Report Documentation Page**

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<td>Thermal Spray and Machine, Inc, 2400 Hampton Boulevard, Suite B, Norfolk, VA, 23517</td>
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13. SUPPLEMENTARY NOTES

26th Replacement of Hard Chrome and Cadmium Plating Program Review Meeting, January 24-26, 2006, San Diego, CA. Sponsored by SERDP/ESTCP.

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CUSTOMER BASE

• Approx. 40-45% of Overall Sales Volume – U.S. Military
  Navy – Army – Coast Guard – Military Sealift Command

• Support Center For Shipyards, Manufacturing Plants,
  Electrical, Hydraulic, and Mechanical Repair Facilities
  and Original Equipment Manufacturers

• Commercial Customers
  Anheuser-Busch – Dupont – Weyerhaeuser – Alcoa
  Georgia Pacific - International Paper - Phillip Morris
  Honeywell Performance Fibers … and a host of others..! !
Thermal Spray & Machine, Inc. - CERTIFICATIONS

1. SUPERVISOR OF SHIPBUILDING, CONVERSION & REPAIR, US NAVY, PORTSMOUTH, VA
   Certification of Facilities in accordance with NAVSEA MIL-STD 1687A

2. COMMANDER NAVAL SEA SYSTEMS COMMAND (SEA 05M2)
   Approval of TSM’s Thermal Spray Coating Procedure FP-WC-01 for HVOF Application of Tungsten Carbide

3. COMMANDER NAVAL SEA SYSTEMS COMMAND (SEA 05M2)
   Approval of TSM’s Thermal Spray Coating Procedure for HVOF Application of Alloy 625

4. NAVAL SURFACE WARFARE CENTER, CRANE DIVISION
   Certification of Facility IAW NAVSEA S9320-AM-PRO-030/MLDG Rev 02, Vol. III

5. COMMANDING OFFICER, SUBMEPP
   NAVSEA Qualification to Manufacture MIL-C-24231 Connector Plugs for Submarine Cables

6. AMERICAN BUREAU OF SHIPPING
   Certificate of Type Approval No. NN498634 of TSM’s Thermal Spray Coatings Including Main Propulsion Shafting Applications

7. AMERICAN BUREAU OF SHIPPING
   Certificate of Design Assessment No. 04-HS410093/2-PDA of TSM’s Process F/P WC-01 for Repair and Restoration of Marine Machinery Components

8. AMERICAN BUREAU OF SHIPPING
   Certificate of Manufacturing Assessment No. NN498634 of TSM’s Facilities and Associated Quality Procedures to Apply Coatings That Meet ABS Designated Standards

9. LLOYD’S REGISTER
   Certificate of Approval No. MNDE/REP/0001/01 of TSM’s Arc Spraying and HVOF Spraying Procedures
DoD Issues Green Procurement Policy

The Department of Defense today announced an important step forward in its efforts to align mission and environmental stewardship by issuing a new “green procurement” policy. The policy affirms a goal of 100 percent compliance with federal laws and executive orders requiring purchase of environmentally friendly, or “green” products and services.

Thermal Spray Process And Coatings Comply With DoD Green Procurement Policy…

• **NO** Hexavalent Chrome !  • **NO** Phosphates !
• **NO** Cadmium !  • **NO** Halogens !
• **NO** Lead !  • **NO** Volatile Organic Compounds (VOC’s) !
Applications of HVOF Thermal Spray

- Bearing & Seal Journals
- Manufacturing Rolls
- Compressor Parts
- Pump Shafts
- Blower Shafts
- Armature Shafts
- Hydraulic Rods
- Gear Fits
- Pump Casings
- Impellers
- Centrifuges
- Turbine Shafts
- Sleeves

- Axle Shafts
- Camshaft Journals
- Pistons/Piston Rods
- Crankshafts
- Bow Thruster Shafts
- Bearing Fits
- Propeller Shafts
- Rudder Posts
- Valve Stems
- Main Propulsion Shafts
- Plungers
- Mandrels
- Packing Glands
MARINE APPLICATIONS

INNOVATION! EXPERIENCE! QUALITY!
HARD CHROME REPLACEMENT

INNOVATION!  EXPERIENCE!  QUALITY!
HYDRAULIC CYLINDER ROD
Shaft Coated With HVOF Applied Tungsten Carbide

HVOF Applied Tungsten Carbide Coatings Are An Approved Alternative For Hard Chrome Replacement !!

These coatings are hard, dense, well bonded, wear resistant, seal friendly, and protect against corrosion !
HYDRAULIC CYLINDER ROD
Shaft Coated With HVOF Applied Tungsten Carbide

HVOF Applied Tungsten Carbide Coatings Are An Approved Alternative For Hard Chrome Replacement ! !

These coatings are hard, dense, well bonded, wear resistant, seal friendly, and protect against corrosion !
WEAPONS ELEVATOR CYLINDER ROD – USS WASP

Entire Rod Repaired With HVOF Applied Tungsten Carbide As Hard Chrome Replacement

OVERALL ROD DIMENSIONS
10” Diameter X 24’ Long

Custom Designed TSM “Superfinisher” In Action

Superfinished to Customer Specifications of 6 Ra

HVOF Applied Tungsten Carbide Coatings Are An Approved Alternative For Hard Chrome Replacement ! !
USS BOONE (FFG-25) – STEERING ENGINE RUDDER RAM REPAIRED WITH TUNGSTEN CARBIDE-COBALT REPLACING THE ORIGINAL HARD CHROME

AS DELIVERED

AS RECEIVED
STERN GATE HYDRAULIC CYLINDER ROD - USS ASHLAND

Entire Rod Coated With HVOF Applied Tungsten Carbide As Hard Chrome Replacement

OVERALL ROD DIMENSIONS
6” Diameter X 13’ Long

HVOF Applied Tungsten Carbide Coatings Are An Approved Alternative For Hard Chrome Replacement ! !
**LIFT FAN SHAFTS**

We have coated the bearing journals on more than 600 LCAC lift fan shafts extending the service life from 100 hours (1 Year) to over 700 hours (7 Years) and still counting !!

**PROJECTED SAVINGS:** $20.1M Over 15 Year Service Life !
HVOF Applied Tungsten Carbide Cobalt/Nickel Coatings
(TSM-0010)

Thermal Spray Coating (TSM-0010) not only increases corrosion protection but also increases surface hardiness resulting in a substantial increase in material life. Normal carbon steel hardness is 22 on the Rockwell C Scale, by coating with Tungsten Carbide the hardness is increased to 64, almost three (3) times the hardness of the original material.

AIRCRAFT CARRIER ELEVATOR STANCHIONS

BEFORE

AFTER
AIRCRAFT CARRIER FLIGHT DECK ELEVATOR LOCKING PIN
Coated With HVOF Applied Tungsten Carbide For Increased Wear Resistance
USS Detroit - 63 Ton Rudder Post
Bearing and Seal Areas Repaired with HVOF Applied Inconel 625

Yes, that was 63 TONS (126,000 lbs.) !!

Saved the customer $193,000.00 and 25 schedule days
USS KENNEDY – MAIN FEED PUMP TURBINE
Bearing and Seal Areas Repaired With HVOF Applied Tungsten Carbide
USS KENNEDY – SHIP’S SERVICE TURBINE GENERATOR

BEFORE

Bearing Areas Repaired with HVOF Applied Tungsten Carbide

AFTER
USS NASHVILLE – SHIP’S SERVICE TURBINE GENERATOR ROTOR
Bearing Area Repaired With HVOF Applied Tungsten Carbide And Collector Rings Dressed

SHIP’S SERVICE TURBINE GENERATOR ROTOR AFTER REPAIR
CONTROL ARM LEVER
SHIP’S SERVICE TURBINE GENERATOR – USS NASHVILLE (LPD-14)

BEARING AREAS REPAIRED WITH HVOF APPLIED TUNGSTEN CARBIDE

BEARING AREAS – AFTER REPAIR
USS PONCE (LPD-15)
TURBINE GENERATOR REDUCTION GEAR AND DRIVESHAFT

Bearing Areas Repaired With HVOF Applied Tungsten Carbide

REDUCTION GEAR

CLOSE-UP OF BEARING AREA AFTER REPAIR

DRIVESHAFT – AFTER REPAIR
SUBMARINE ELECTRIC MOTOR ROTOR

Bearing Areas Repaired With HVOF Applied Tungsten Carbide

NOTE: This Is A Special Rotor Designed For Submarine Applications And The Finished Machining Tolerance Was .0002” Over The Entire Length Of The Shaft For Noise Reduction.
U.S. COAST GUARD – 110 CLASS RUDDER AND POST

Packing, Bearing, and Seal Areas Repaired With HVOF Applied Tungsten Carbide
Submarine Vacuum Pump Shaft
Bearing Area Repaired with HVOF Applied WCCo/NI
USS WASP - STEERING ENGINE RUDDER RAM TUNGSTEN CARBIDE COBALT/NICKEL COATING

BEFORE

AFTER
FIN STABILIZER SHAFT
Bearing and Seal Area Repaired With HVOF Applied Tungsten Carbide

BEFORE REPAIR – NOTE SCORING

BEARING AND SEAL AREA AFTER REPAIR
COAST GUARD ANCHOR WINDLASS DRUM
Seal Areas Repaired With HVOF Applied Tungsten Carbide
NUCLEAR SUBMARINE SNORKEL INNER PIPE
Entire Snorkel Surface Repaired with HVOF Applied Tungsten Carbide Coating

CLOSE-UP OF WORN AREA
BEFORE

AFTER
Restored bearing area completed 400 hour wear test by NUWC, Newport with no measurable wear. NUWC plans to restore all worn TAHE with HVOF applied tungsten carbide.

SUBMARINE SHAFT FOR TOWED ARRAY HANDLING EQUIPMENT
Bearing Area Restored With HVOF Applied Tungsten Carbide for Increased Wear Resistance for Naval Undersea Warfare Center, Newport Division
U.S. NAVY - PATROL COASTAL CRAFT

MAIN PROPULSION SHAFTS

Bearing Journals Repaired With HVOF Applied Tungsten Carbide

U.S. Navy – Patrol Coastal Craft

PC-1 Class - Length 170 Feet

Main Propulsion Shafts Installed In Strut
Bearings After Repair
Z – DRIVE SEAL LINER
Military Sealift Command – Cable Laying Ship
Repaired With HVOF Applied Tungsten Carbide

AFTER REPAIR – 26” Diameter Ring
GATE VALVE – 12”
Seat Surface Repaired With HVOF Applied Tungsten Carbide
COMMERCIAL
HIGH VELOCITY OXY-FUEL
(HVOF) APPLICATIONS

INNOVATION!  EXPERIENCE!  QUALITY!
BOW THRUSTER YOKE
Alignment Fit Repaired With HVOF Applied Tungsten Carbide

BEFORE REPAIR
NOTE: DEEP LATERAL SCORING

AFTER REPAIR

CLOSE-UP OF REPAIRED AREA
CSX Lines - Bow Thruster Shaft
Bearing Journal and Seal Repaired with HVOF Applied WCCo/NI
Adjacent Flange Coated for Corrosion Prevention
LINE WINCH DRIVE SHAFT

Seal Area Repaired With HVOF Applied Tungsten Carbide
DIESEL ENGINE TURBO BLOWER
Bearing Areas Repaired With HVOF Applied Tungsten Carbide
PINION GEAR – TUGBOAT GEARBOX DRIVE
Bearing And Seal Area Repaired With HVOF Applied Tungsten Carbide
Z-DRIVE SEAL LINERS
Both Seal Liners Put Into Operation at the Same Time.
After One Year of Operation……

The Un-Coated Liner Has (2) 1/8” Grooves Worn by the Seal!
The Coated Liner Showed NO Signs of Wear!*
(only a slight discoloring of the coating in the seal area)

COATED SEAL LINER
HVOF Applied Tungsten Carbide

UNCOATED SEAL LINER
1/8” Grooves Worn by Seal
TUGBOAT Z-DRIVE SEAL LINER
Seal Area Coated With HVOF Applied Tungsten Carbide

NEW SEAL LINER COATED WITH HVOF APPLIED TUNGSTEN CARBIDE FOR INCREASED WEAR RESISTANCE!
STEERING DRIVE SEAL RINGS

Wear Areas Coated With HVOF Applied Tungsten Carbide

Increased Wear Resistance Provides Longer Service Life!
OIL DISTRIBUTION BOX SHAFT
FOR CHANGEABLE PITCH PROPELLER
Bearing And Seal Areas Repaired With HVOF Applied Tungsten Carbide

BEFORE

AFTER
BUTTERFLY VALVE STEM
New Shaft Coated With HVOF Applied Tungsten Carbide To Prevent Wear
NAVY and COAST GUARD
ELECTRIC ARC
APPLICATIONS

INNOVATION! EXPERIENCE! QUALITY!
USS Halyburton – Rudder Post

Seal Area Repaired with Arc Wire Al/Br
Bearing Area Repaired with Arc Wire SS
Worn Groove Repaired with Arc-Wire Applied Inconel 625

Worn Area

Wear Groove is .150” Deep, 5/8” Wide, and 28” Long

One-Half of Coupling Before Repair

Close-Up of Wear Area Before Repair

As-Sprayed

After Repair

Note: Coupling Half is Inverted
AIRCRAFT CARRIER HANGAR BAY DOOR ROLLERS

Roller Surface Area Coated With Arc-Wire Applied

Pseudo-alloy AlBr-Mo
Submarine Bow Plane Housing Mating Flanges Repaired with Arc Wire Molybdenum
PLUG FOR DUPLEX STRAINER
Repaired Plug With Arc-Wire Applied AlBr And Machined to Fit
U.S. Coast Guard - CHANGEABLE PITCH PROPELLER HUB

Damaged O-Ring Seal Areas Repaired With Arc-Wire Applied Bronze
ELECTRIC MOTOR GENERATOR ROTOR

Thrust Bearing Areas Repaired With Arc-Wire Applied Inconel 625

AFTER REPAIR

AFTER REPAIR
INNOVATION! EXPERIENCE! QUALITY!

COMMERCIAL ELECTRIC ARC SPRAYED APPLICATIONS
MV OCEAN BREEZE - Main Propulsion Shaft
Repaired with Arc Wire Al/Br and Finished with WCCo/Ni

Shaft Worn 1 ¼” on Diameter – Repaired in Less Than 24 Hours!

TSM saved this Customer over $200,000 and more than 2 weeks downtime!
MAIN ENGINE COUPLING HUB - TUGBOAT

I.D. Of Hub Repaired With Arc-Wire Applied Carbon Steel

AFTER REPAIR
LOW PRESSURE CHAMBER FOR OIL DISTRIBUTION SYSTEM FOR CHANGEABLE PITCH PROPELLER

I.D. Areas (Corrosion) Repaired With Arc Wire Applied High Carbon Steel
GEARBOX CASING
Bearing Area Repaired With Arc-Wire Applied Inconel 625 And Line Bored
ELECTRIC MOTOR SHAFT

Impeller Fit Area Repaired With Arc-Wire Applied CrSS
PLASMA APPLIED
NON-CONDUCTIVE COATING

INNOVATION! EXPERIENCE! QUALITY!
SUBMARINE CABLE CONNECTORS
Connector Bodies Coated With Plasma Applied NCC Ceramic Coating To Prevent Corrosion Caused By Surface Electrical Currents On The Connectors. This Corrosion Would Cause The Polyurethane Coating To Separate Resulting In Failure.

SUCCESS STORY
Since TSM has started applying NCC coating to submarine cable connectors, there has not been one documented failure!

TSM HAS COATED MORE THAN 25,000 CONNECTORS!
SSN SPECIAL PURPOSE MOTOR LEAD CONNECTOR

Connector Body Coated With Plasma Applied Non-Conductive Ceramic Coating To Prevent Corrosion By Galvanic Action

UNCOATED

COATED
SUBMARINE ELECTRONICS ENCLOSURE
Interior Of Enclosure NCC Coated
SUBMARINE AIR INTAKE FLAPPER VALVE

Valve Flapper Coated With Plasma Applied Non-Conductive Ceramic Coating To Prevent Corrosion By Galvanic Action
SUBMARINE AIR INTAKE VALVE FLAPPER ARM
Valve Arm Coated With Plasma Applied Non-Conductive Ceramic Coating To Prevent Corrosion By Galvanic Action
SUBMARINE SONAR TRANSDUCER PLATE

Surface Coated With Plasma Applied Non-Conductive Ceramic Coating (NCC) To Resist Corrosion From Galvanic Action
NON-CONDUCTIVE COATING DIVISION

- Spray Booth
- Cleaning & Sealing
- Receiving & Prep
- Q.A. & Shipping

**NCC DIVISION**
A Segregated, Independent Production Cell
U.S. ARMY HELLFIRE MISSILE EXHAUST DIFFUSER

Protected By Plasma Applied Thermal Barrier Coating Of Yttria Stabilized Zirconium Oxide To Deflect Intense Heat Of Missile Exhaust Away From Helicopter

Diffusers Used On U.S. Army Blackhawk Helicopters

Success Story! 629 Diffusers Coated By TSM For U.S. Army!