WEAR REDUCING TECHNOLOGY NEWLY APPLIED TO SEVERE PUMPING SERVICES

TAMU Case Study 2011

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ABSTRACT

- A U.S. Gulf Coast refinery had experienced accelerated internal wear of FCCU cycle oil pumps, often requiring entire case replacements. Compared to typical industry pump performance, run lengths were shorter, and cost per installed was higher. The application requires pumps capable of withstanding significant catalyst fines.
- Several wear resistant products have been used in pumps. However, all are limited due to the nature of the technologies. Thermal spray coatings and weld overlays can be used in “line of sight” applications, but not for small interior surfaces. Thermal sprays suffer from failures of the mechanical bond. There is preferential erosion of the soft matrix between the hard particles in weld overlays. Hard diffusion coatings (boronizing) are very thin and can be punctured by large abrasive particles.
- Infiltration brazed tungsten carbide cladding (IBTCC) solves many of these issues. IBTCC was developed for extreme wear applications with difficult geometries such as downhole drilling tools and coal fired power plants. IBTCC combines a true metallurgical bond and a dense, uniform distribution of tungsten carbide particles throughout the coating, to create excellent erosion resistance and toughness in complex geometries.
- After 13 months in service, an IBTCC cycle oil pump showed no significant signs of internal erosion. This technology has also been applied to FCCU fractionator bottoms and debutanizer reboiler services, with no signs to date of increased vibration or loss of hydraulic performance.
- The case study will show how internal material changes can improve pump longevity and produce maintenance cost savings.

Introduction

- **Current Hardware**
  - P-8A/B, P-9A/B overhung API pumps
  - P-3A/B, P-518A/B between bearings, top suction API pumps

- **Previous Run Lengths, MTBRs**
  - P-8A/B, P-9A/B with 12% chrome case average life was 1 month, with tungsten carbide HVOF averaged 8-12 months.
  - P-3 A/B with WC HVOF would run for about 2.5-3 years before complete failure, 4.5-5 years with Boron Diffusion.
  - P-518 A/B developed severe vane pass vibration in 1 – 1.5 years. Lasted 3 years maximum before total loss of impeller and case.

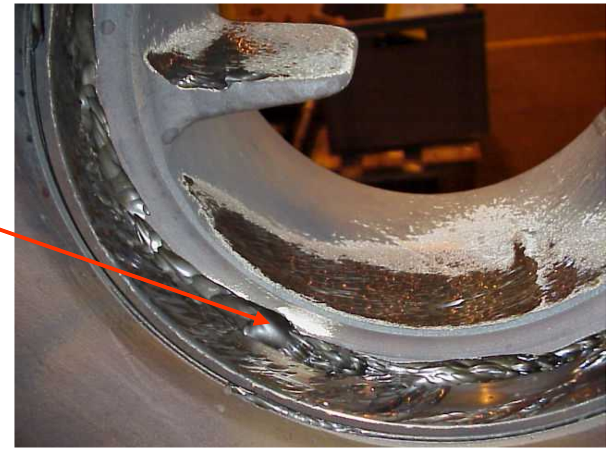
- **Pump Operating Conditions**
  - P-8, P-9 FCCU Cycle Oil Pumps
  - Clarified Oil at 650 F, 0.75 SG, with significant catalyst fines – like sand, but very fine
  - 30 psig suction, 400 gpm, 350 feet of head
  - 4x3-10.5 pumps at 3600 rpm – small size/high speed not ideal for erosive service

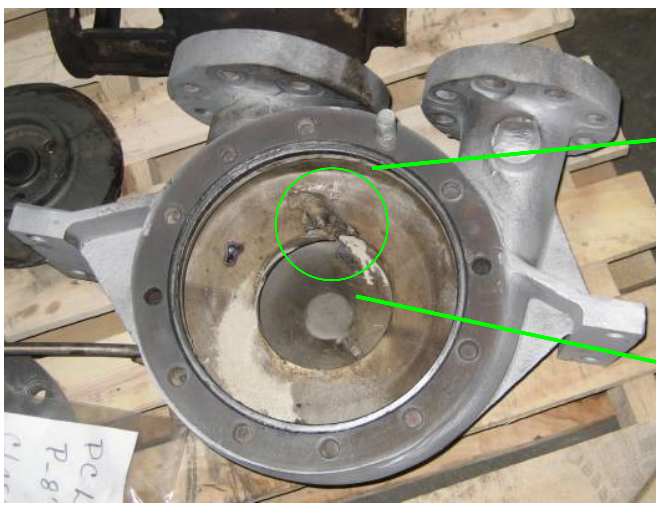
  - P-3 FCCU Fractionator Bottoms Pumps
  - FCCU Catalyst Slurry at 680 F, 0.87 SG, with 0.1 to 0.3 wt% solids
  - 25 psig suction, 3500 gpm 440 feet of head, 5000 gpm 400 feet of head
  - 16x12-20 pumps at 1800 rpm

  - P-518 Cat Light Ends Debutanizer Bottoms Pumps
  - Cat Naptha (Butane) mix at 460 F, ~0.55 SG, with significant catalyst fines
  - 195 psig suction, 2950 gpm, 419 feet of head
  - 12x8-23 pumps at 1800 rpm

Problem Description

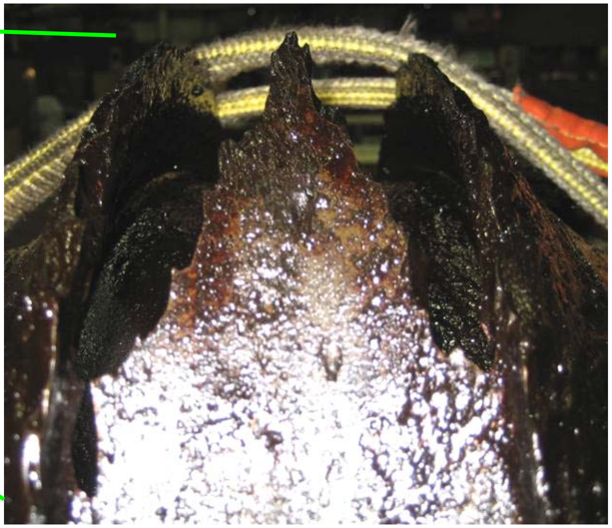
- P-8 case wear ring after 10 months
  - May 2005
- P-8 case gouge after 8 months
  - Oct 2008
- 1 unit shutdown, lost both pumps





Problem Description

- Shredded P-3 wear plate
  - December 2007
  - Spare strategy left unit vulnerability
  - Unable to maintain top rate
- P-3 impeller, cut to ribbons
  - May 2009



Existing Technology – Erosion Resistance for Pumps

- Tungsten Carbide (WC) Spray, HVOF
  - Line of site process
  - Low bond strength (10,000 – 12,000 psi) – easily undermined
- Boron Diffusion (BD)
  - Only 0.008-0.010” thickness on carbon steel
  - Even thinner ~0.003” on 12-chrome
  - Large abrasive particles can puncture the coating
  - Once thin coating punctured, the substrate is left without wear protection
- Weld Overlay
  - Soft binder holding carbide particles
  - Uneven carbide distribution in the matrix – Preferential erosion path
- Solid Stellite impellers
  - Difficult to source consistent castings
- Welded Stellite
  - Delayed cracking potential
  - Low carbide content (12%-15%) – Not optimum protection for erosion wear

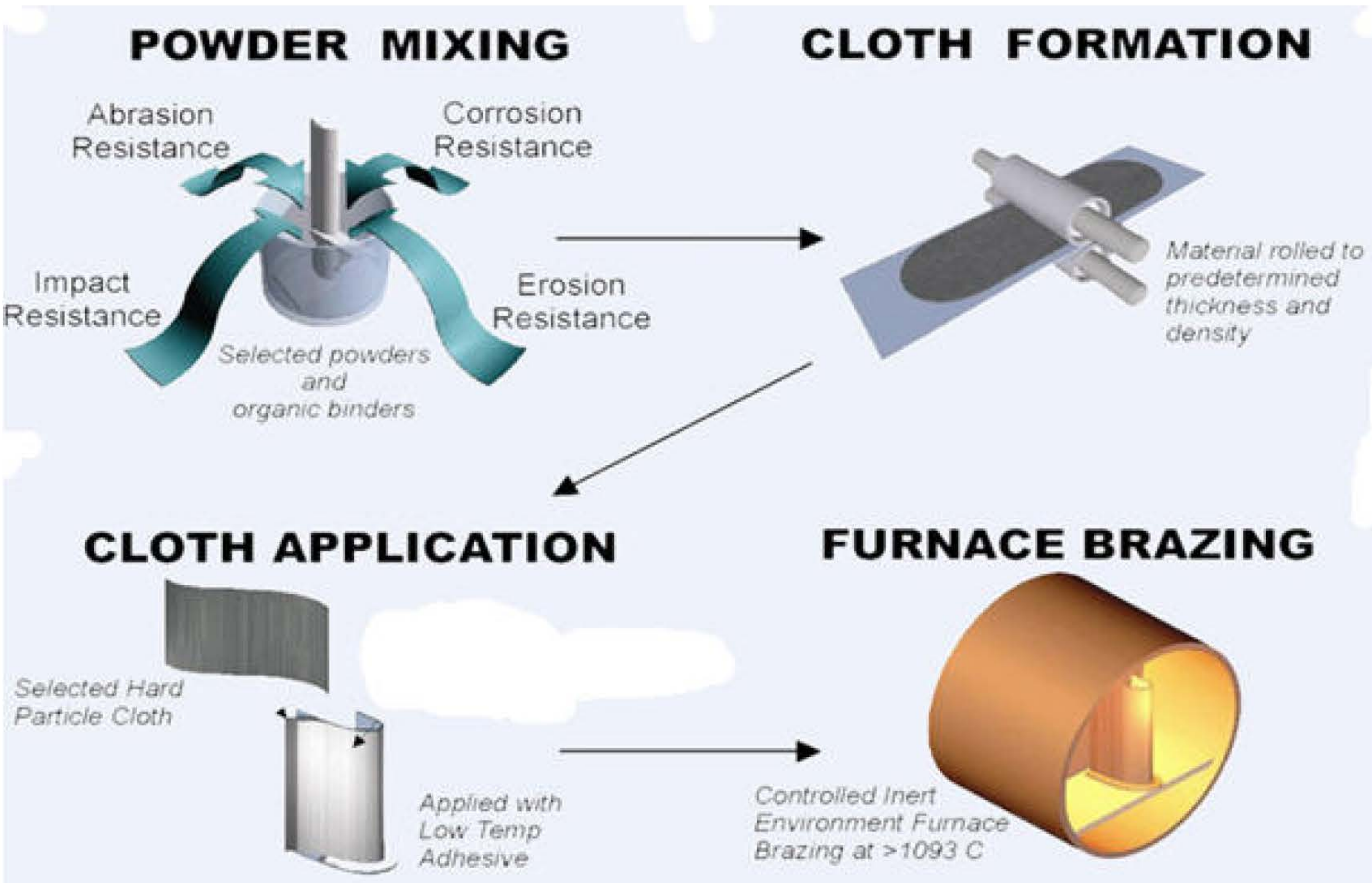
Infiltration Brazed Tungsten Carbide Cladding Technology

Flexible Tungsten Carbide cloth can conform to complex geometries.

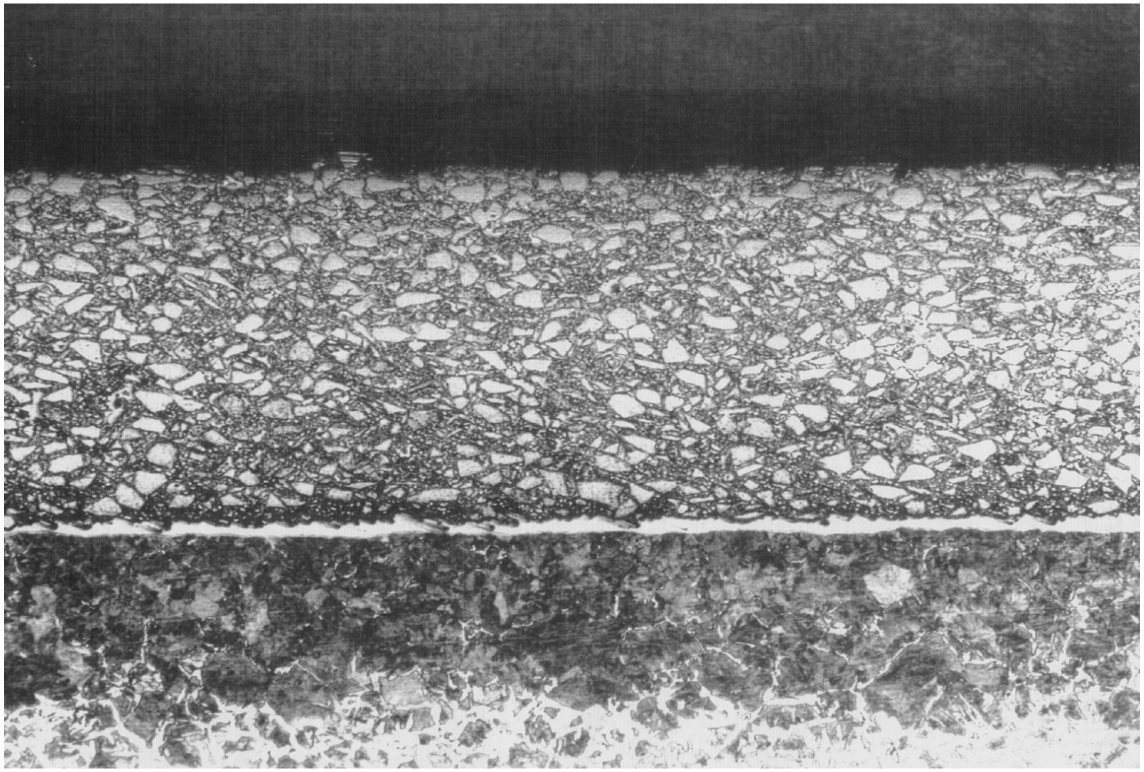
Provides premium wear protection in previously difficult to reach locations.

Not limited by “line of sight” application.

Infiltration Brazed Tungsten Carbide Cladding Process



Infiltration Brazed Tungsten Carbide Cladding Characteristics



WC Cladding

Metallurgical Bond Line

Diffusion Zone

Metallic Substrate

*Can be applied to most steels: Carbon, Stainless, Nickel Alloys

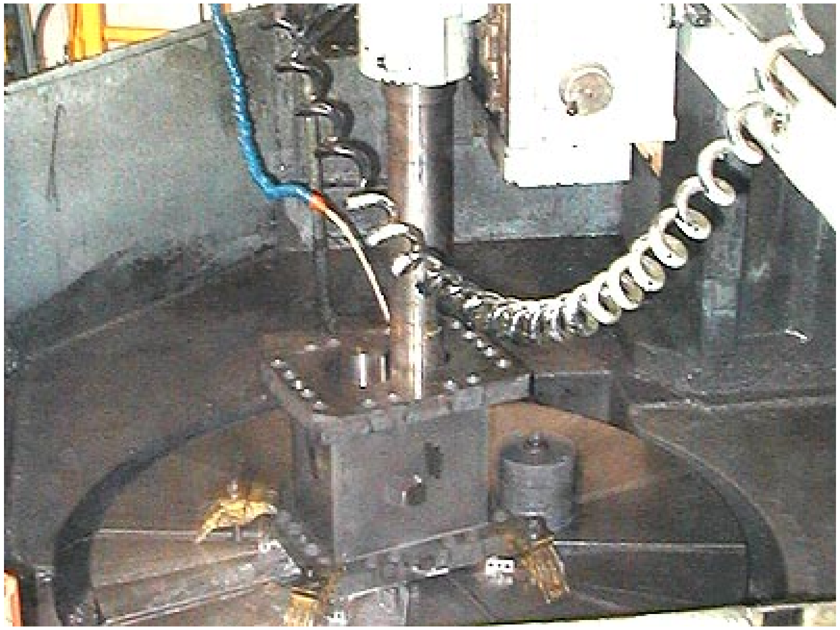
*0.030” to 0.060” thickness	*Metallurgical Bond (70 KSI + bond strength)
*Hardness up to 70 HRc	*High Tungsten Carbide Loading (70% by wt.)
*High Inter-Particle Bond Strength	*Uniform Carbide Distribution & Microstructure
*Controlled Cladding Thickness	*No Oxide Contamination
*Minimal Dilution from substrate	*Minimal Porosity

Finishing

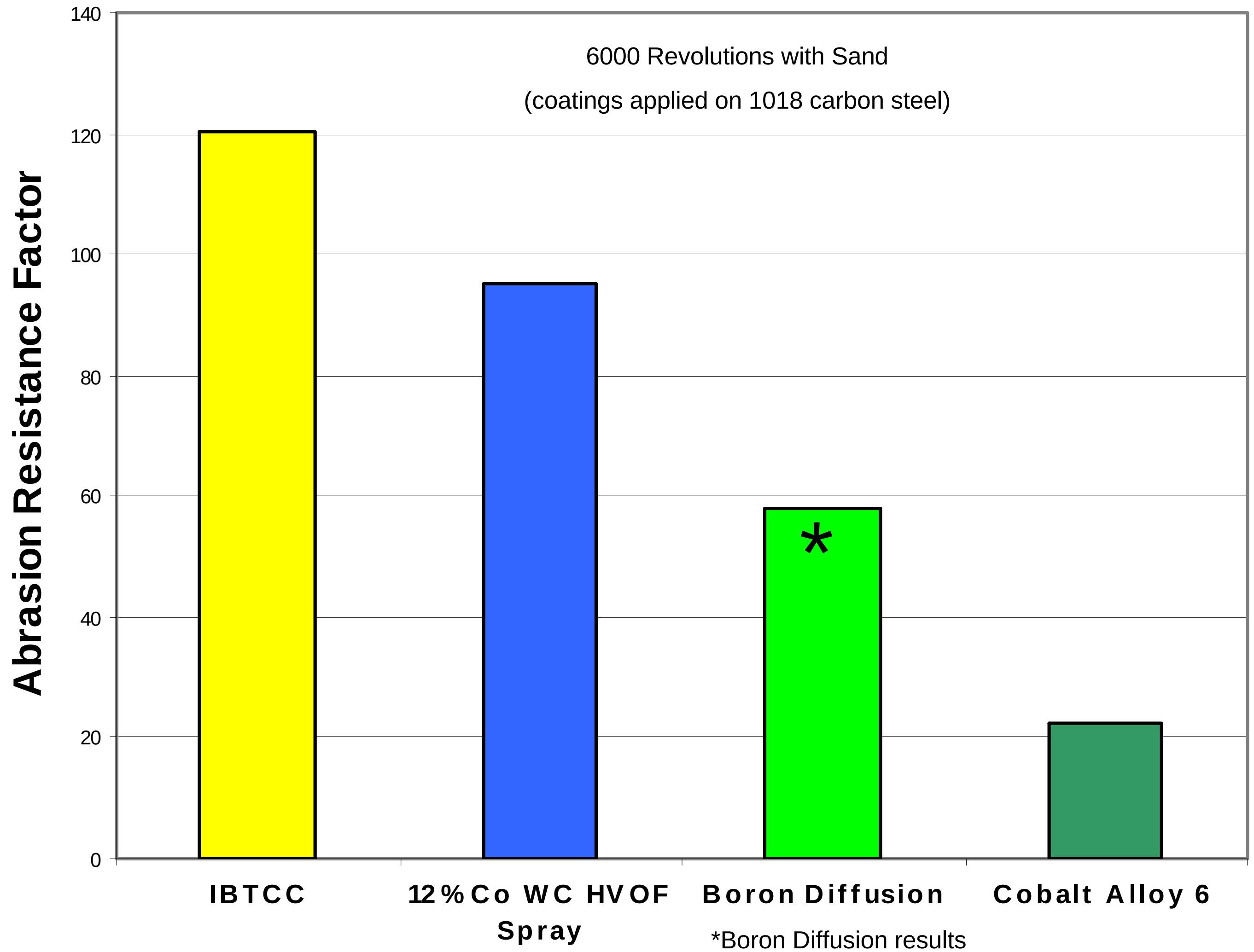
- Parts should not be finished prior to cladding, due to distortion during brazing process.

•0.125-0.25” Extra material needs to be left for important features (head & wear ring fits, etc.) to be finished after cladding.

- Ultra tight tolerances and fine finishes are possible with CNC machining centers and vertical grinders.



Abrasion Resistance (ASTM G-65)



*Boron Diffusion results extrapolated from 1000 revolution test due to coating thinness

Erosion Resistance

Erosion

- If high erosion-resistant particles exist in low erosion resistant or soft matrix, the impacting particles can undercut and remove portions of the material (Figure 1).

- However, if the high erosion resistant particles such as tungsten carbide are densely packed in a matrix material that causes the impacting particles to impinge on a greater percent of the hard particle, the erosion resistance increases dramatically (Figure 2).

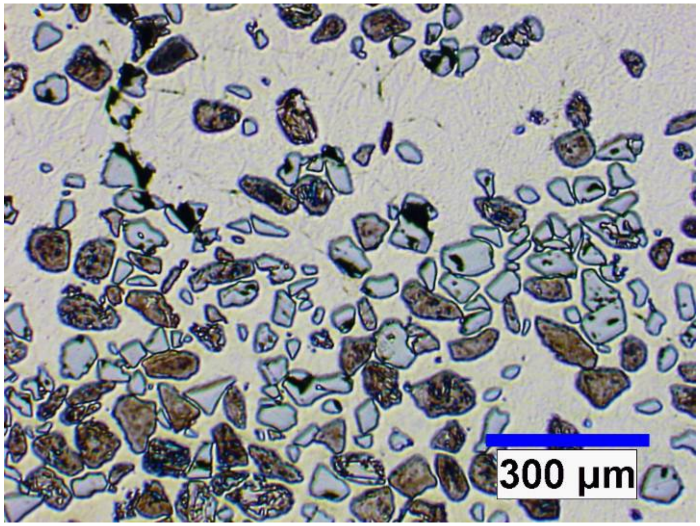


Fig 1

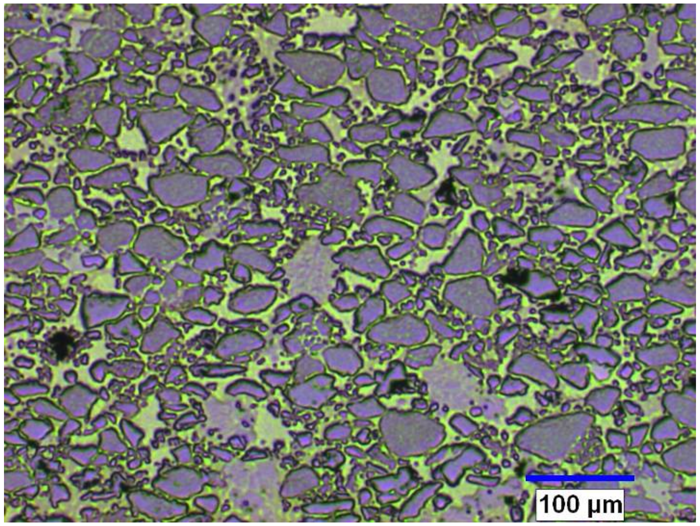
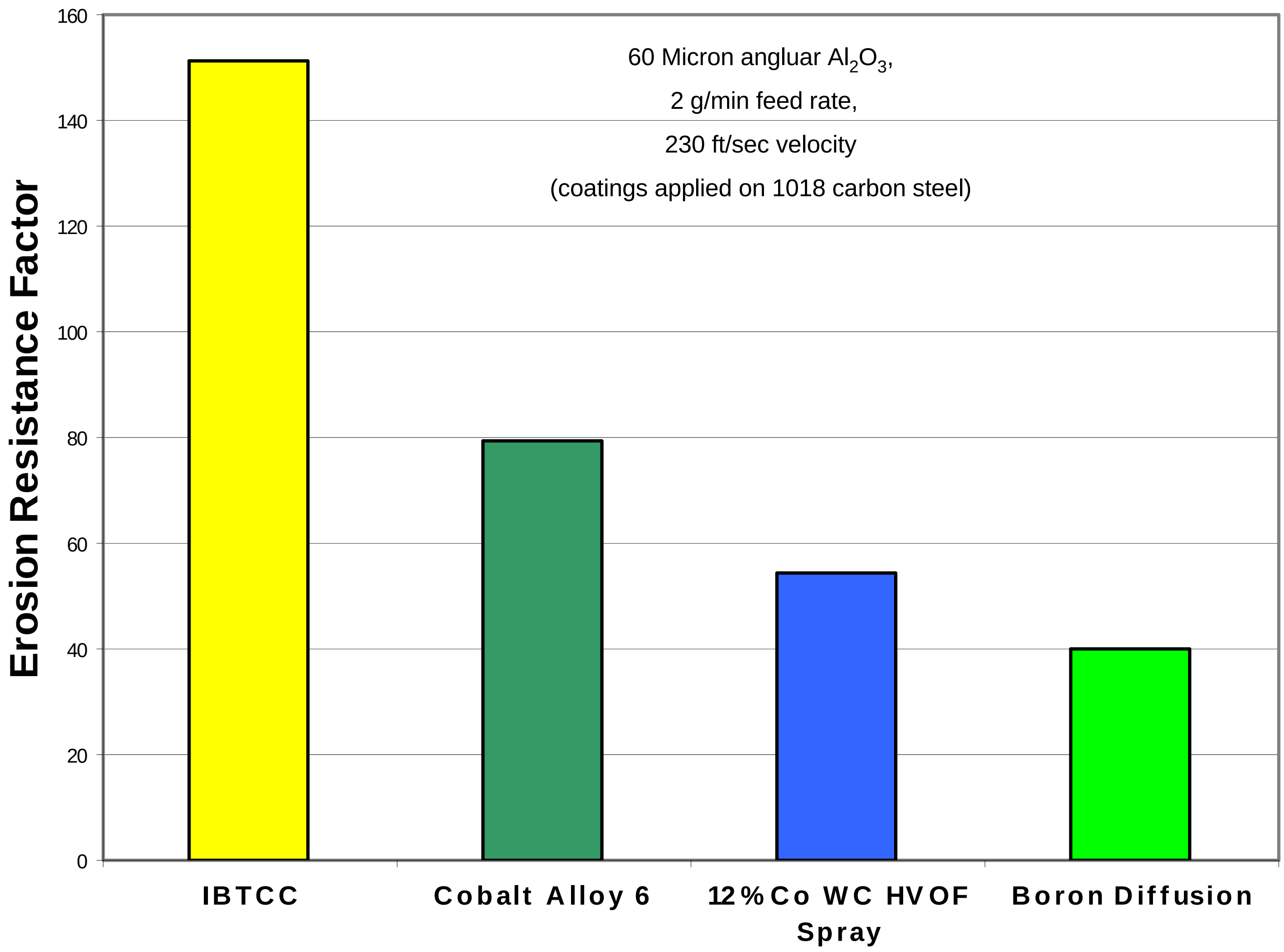


Fig 2

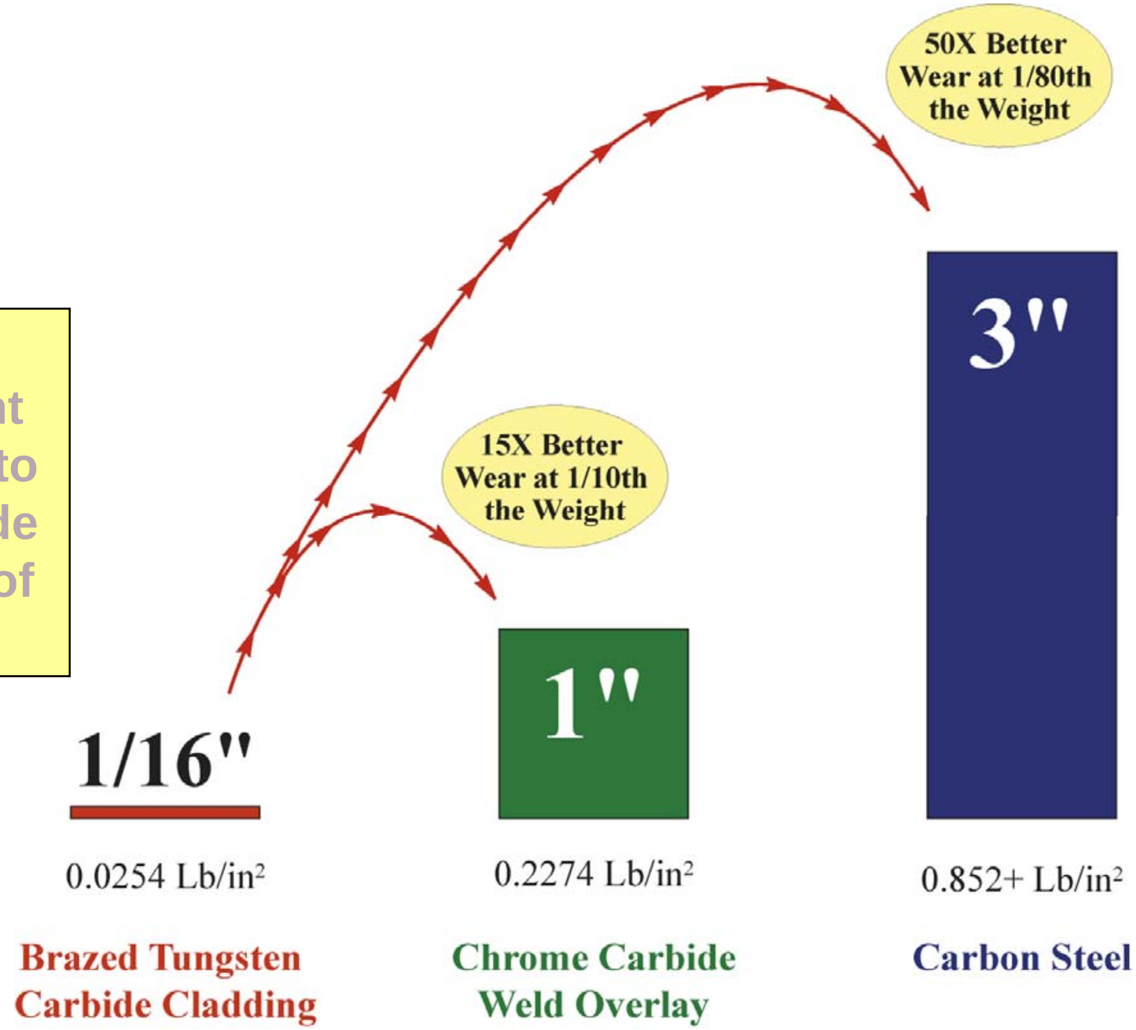
Hard particle density key to erosion resistance

Erosion Resistance (ASTM G76)



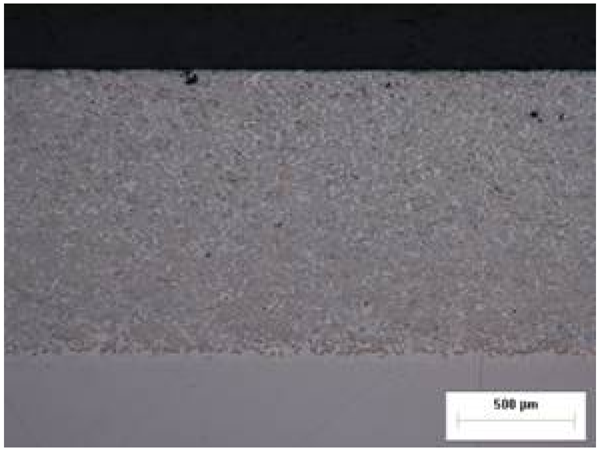
Erosion Resistance

1/16” of IBTCC provides equivalent erosion protection to 1” of chrome carbide weld overlay or 3” of carbon steel.

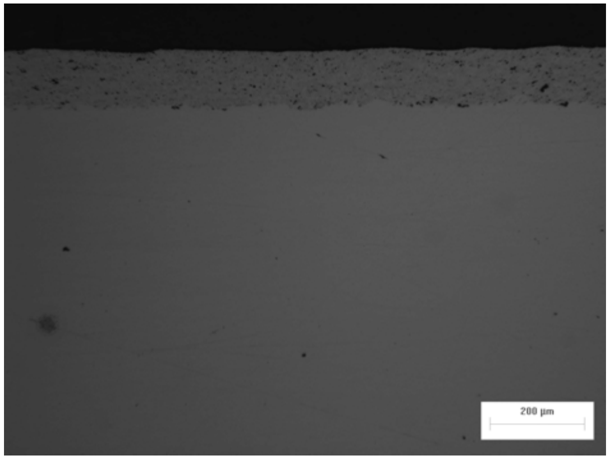


Comparative Microstructures

IBTCC (reference = 500 μm)

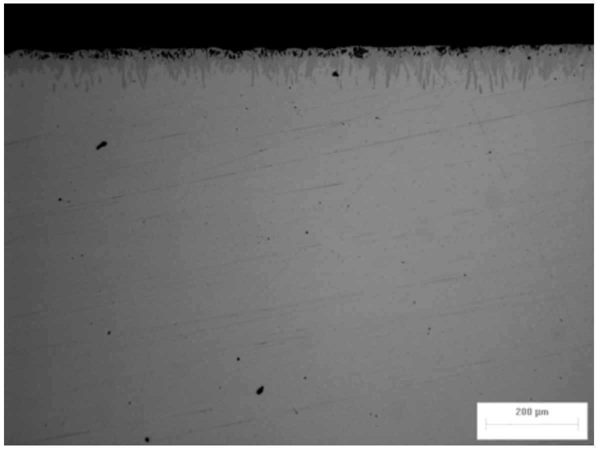


12% Co WC HVOF Spray
(reference = 200 μm)

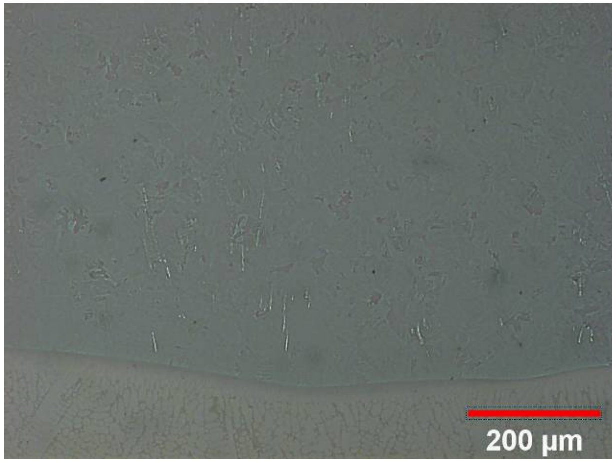


Boron Diffusion

(reference = 200 μm)

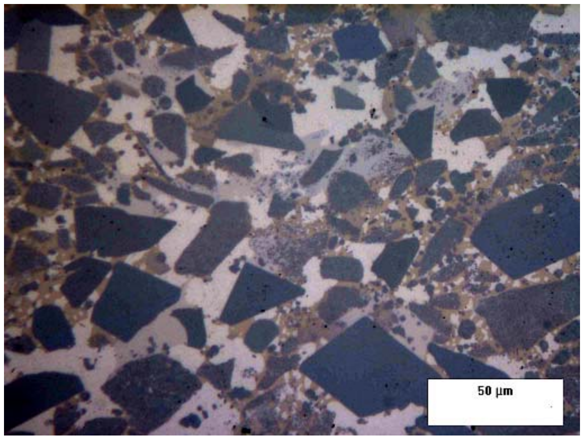


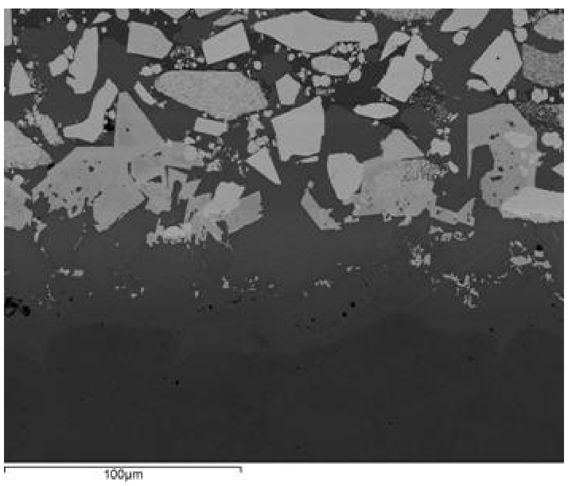
Cobalt Alloy



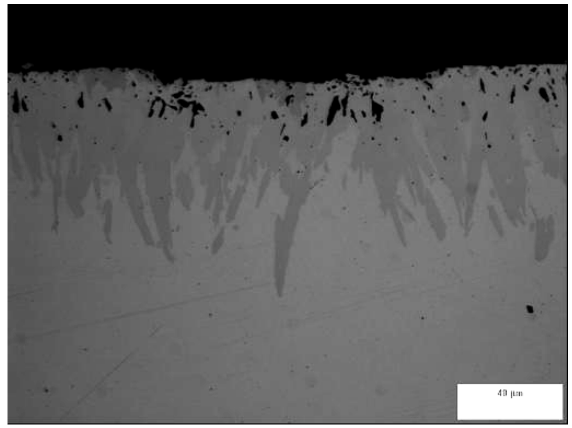
Comparative Microstructures

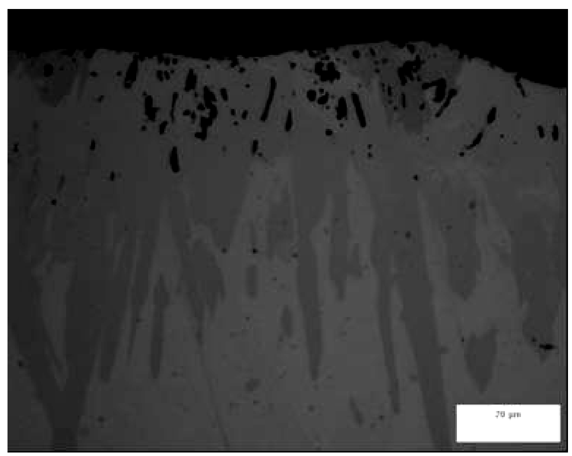
IBTCC 50 μm and 100 μm





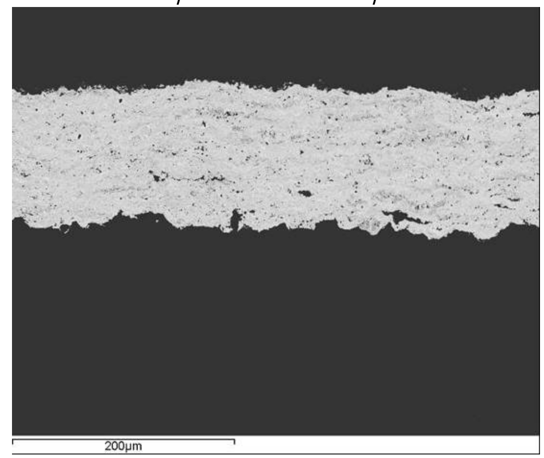
Boron Diffusion
40 μm and 20 μm

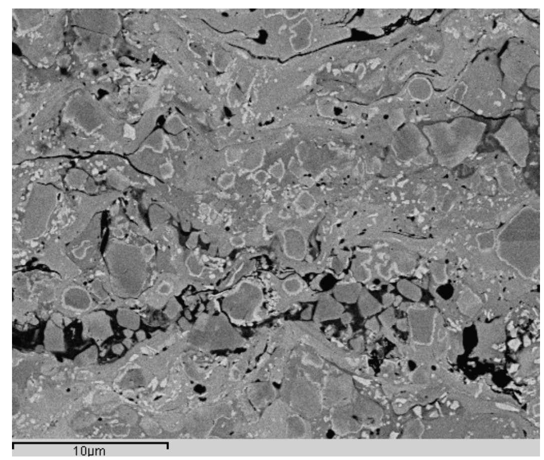




12% Co WC HVOF Spray

200 μm and 10 μm





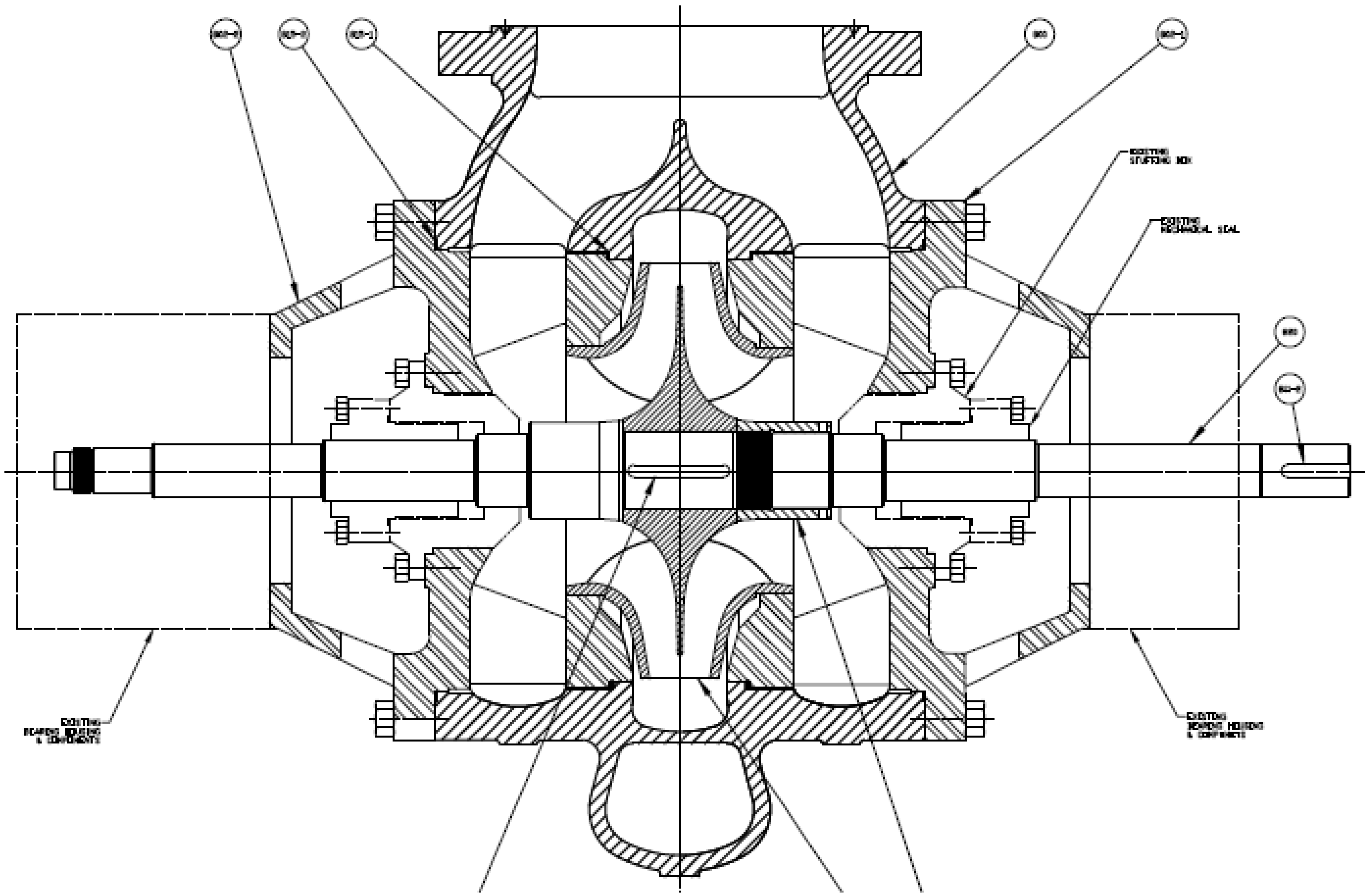
Improvement Projects

- IBTCC applied to new P-3 cases, heads, impellers, wear plates.

- Manufacturing Considerations: To machine or grind
- Areas to be clad need generous radii underneath, prefer 1/8” min.
- Weld balance pads on impellers or extra layer all around
- Build up to-be-ground areas to 0.06-0.08”, leave nominal 0.030”
- Adjust casting patterns for more axial clearance
- Coating thickness – not much effect on large pump efficiency

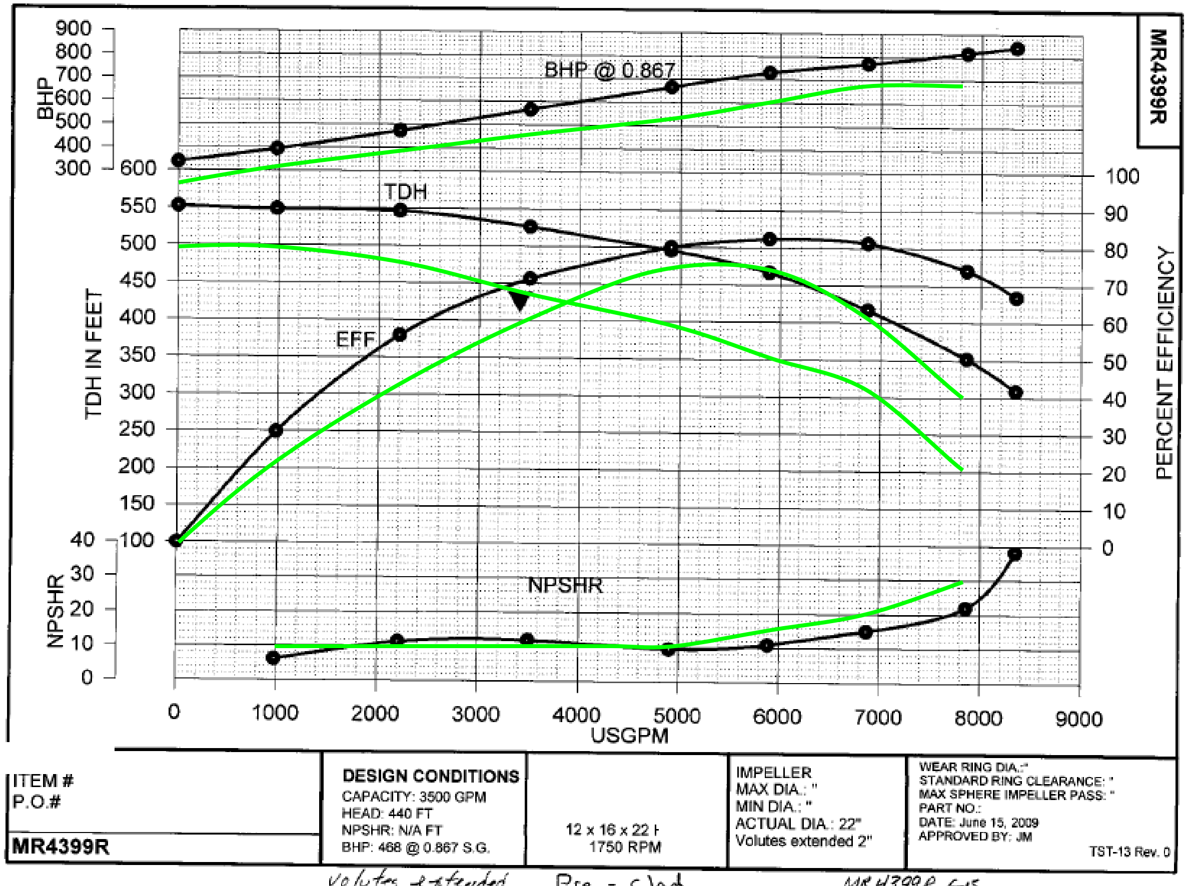
Improvement Projects

- New P-3 “drop-in” pumps with IBTCC internals on all wetted parts - case, heads, impeller, and wear plate surfaces. Integral wear rings.
- Adds ~8 weeks to lead time. Slightly more expensive than BD.



Hydraulic Performance

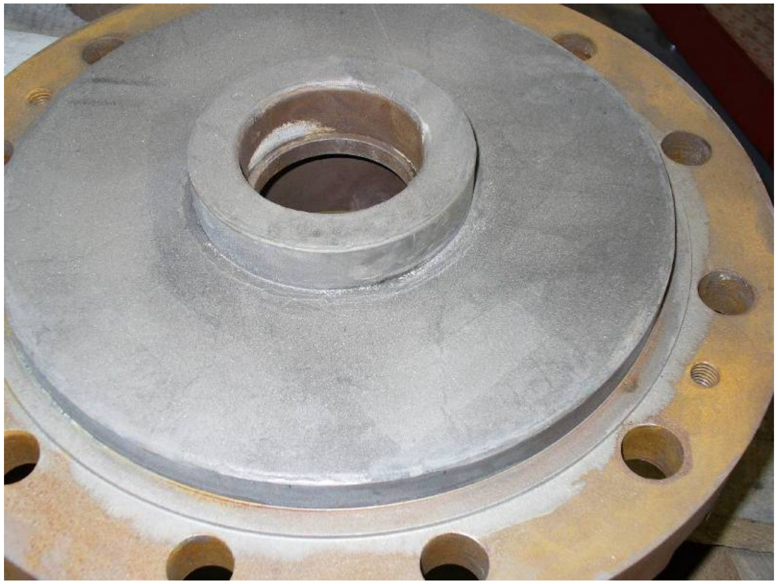
- **OEM original 22" impeller** vs. **IBTCC with 20.625" impeller**
- Measured thickness applied to various components 0.030-0.060", falls within typical casting tolerances.

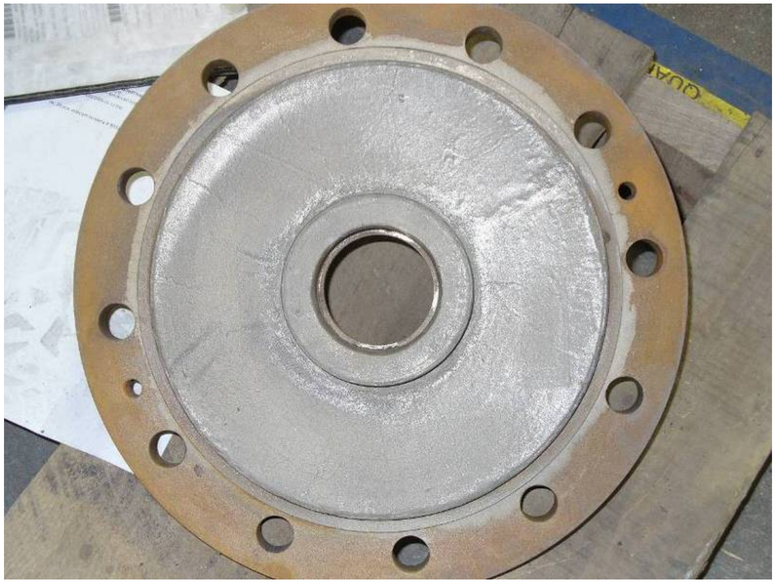


- No signs of performance or mechanical degradation so far, ~1 and ~2 year ongoing run lengths

Mechanical Performance

- Can balance to common specifications: 4W/N, ISO G2.5, etc.
- P-8 Clarified oil pump after one year of service with infiltration brazed tungsten carbide cladding, 0.004-0.008” at most material loss. See below. Did a slight cladding repair.
- Projected life extended to 3-4 years, from ~12 month max run with WC HVOF.
- Pump pulled due to strainer plugging. Impeller ran 3 months on the key alone, metal/metal against case. Could have reused except for oversize impeller bore.

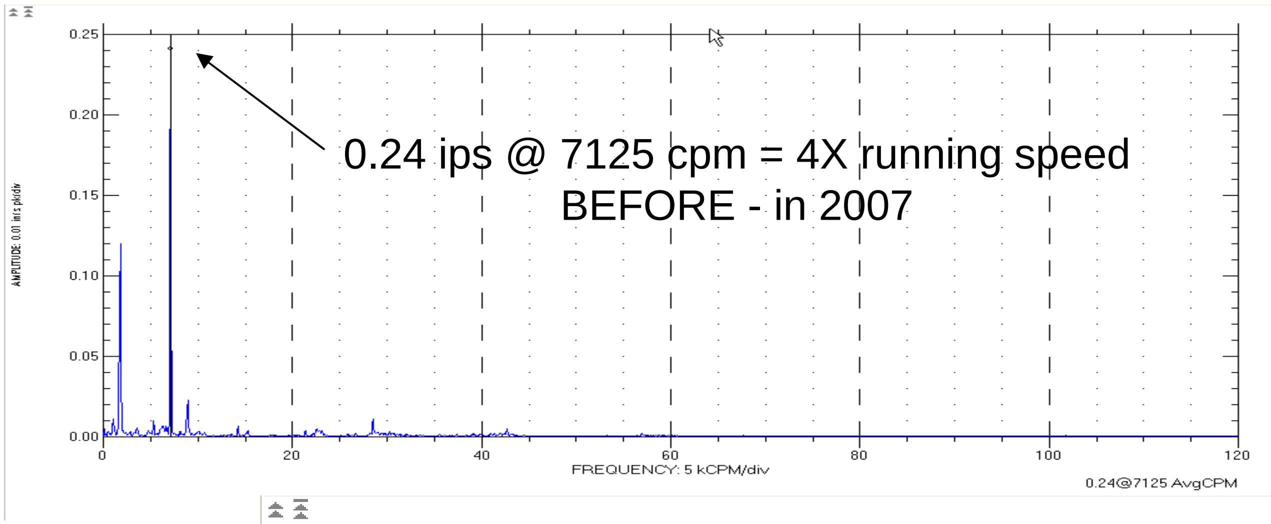


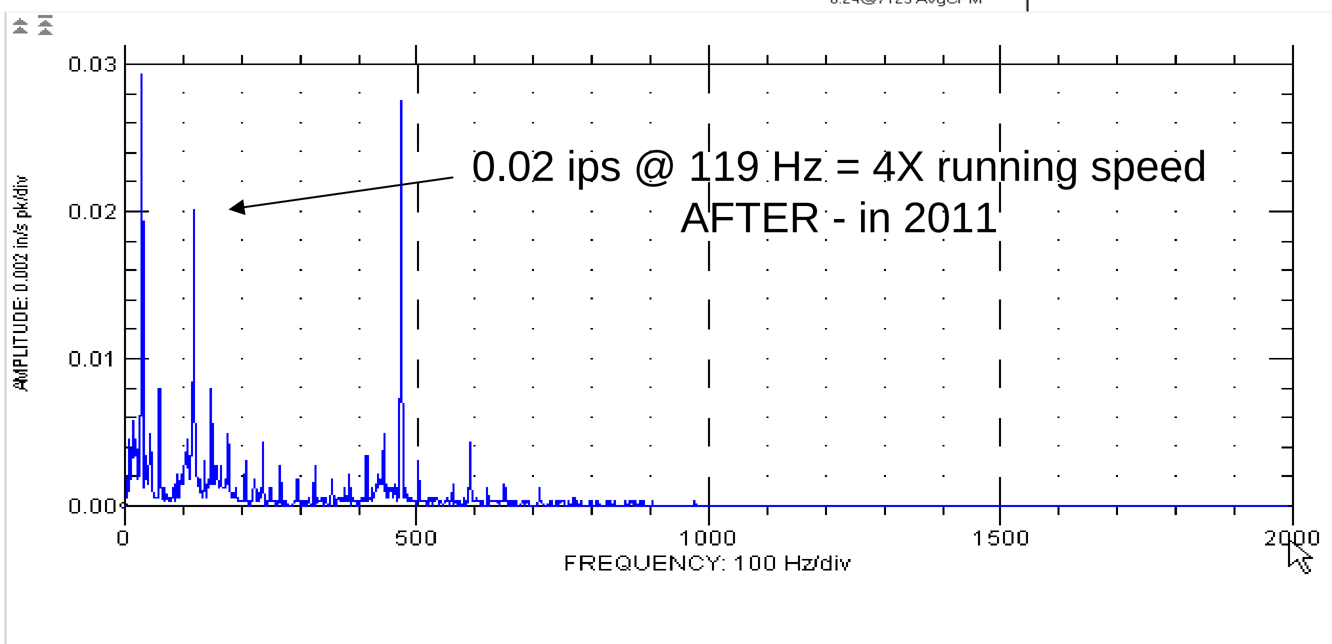


- Separate Houston area Olefins plant applied IBTCC inside a tar pump. Internal inspection showed no wear after 5 months. The pump required repair every 4-6 months with previous coatings.

Mechanical Performance

- Both P-518A/B IBTCC cases running ~4 years -no signs of vane pass vibration yet.

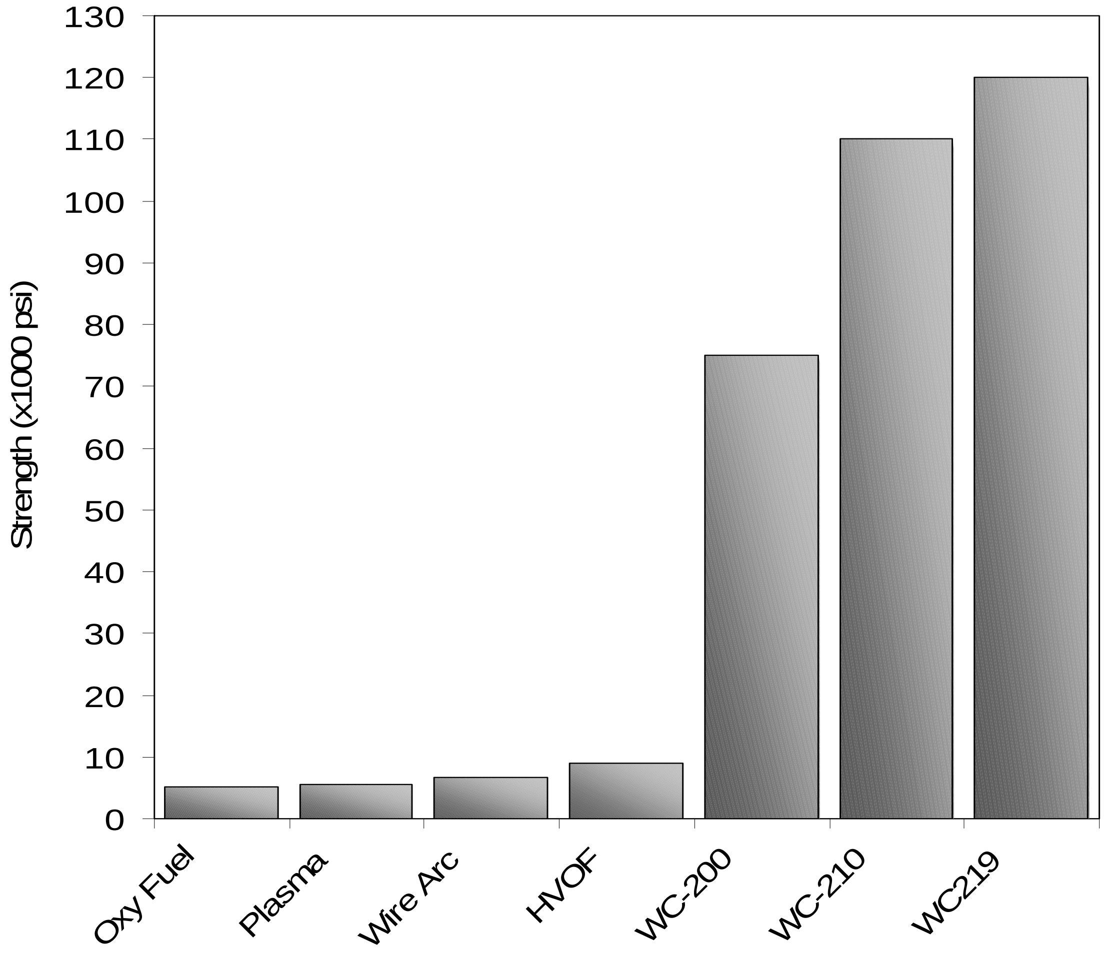




Comments and Questions?

Backup Material

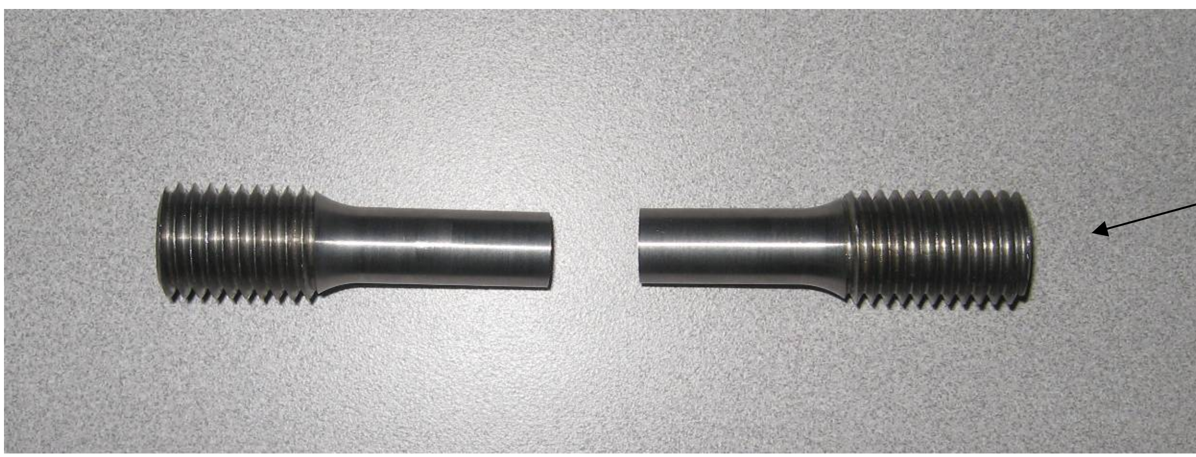
Bond Strength



Reported bond strengths of flame spray processes compared to brazed claddings.

Bond Strength Evaluation

Threaded tensile specimens were made from hardened 4140. The “halves” were brazed together using the braze alloy and typical brazing cycle.



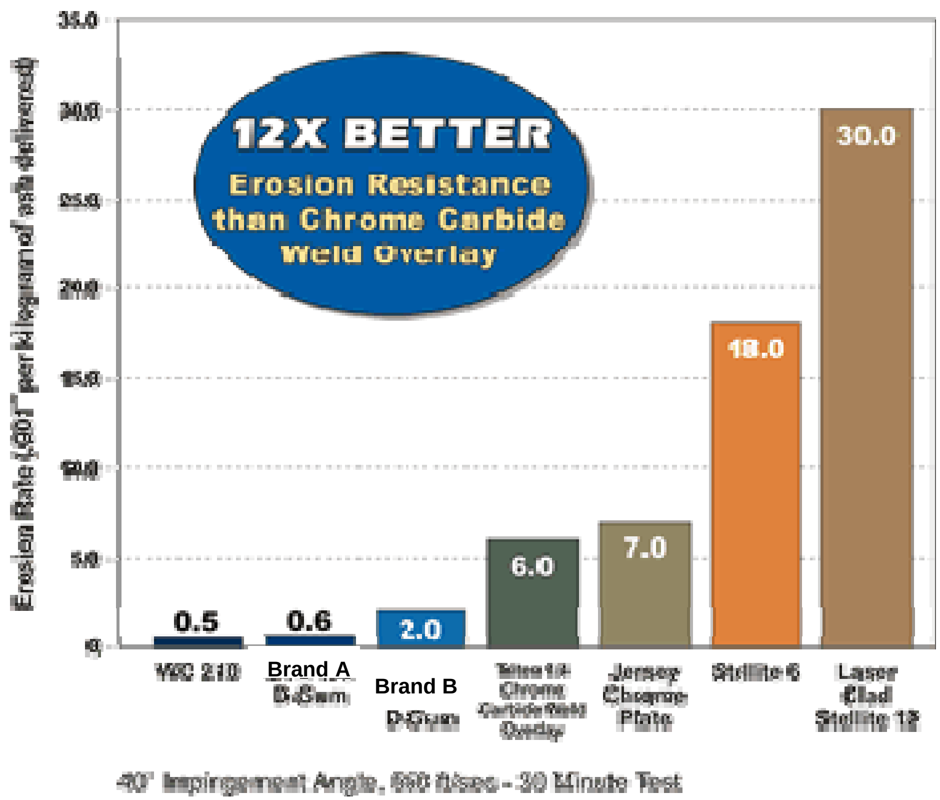
Specimens were tensile tested by an outside lab. All samples broke at the braze joint (as was intended). The average tensile strength from 26 pieces was 72,000 psi.

Erosion Resistance

Fly Ash Erosion Test

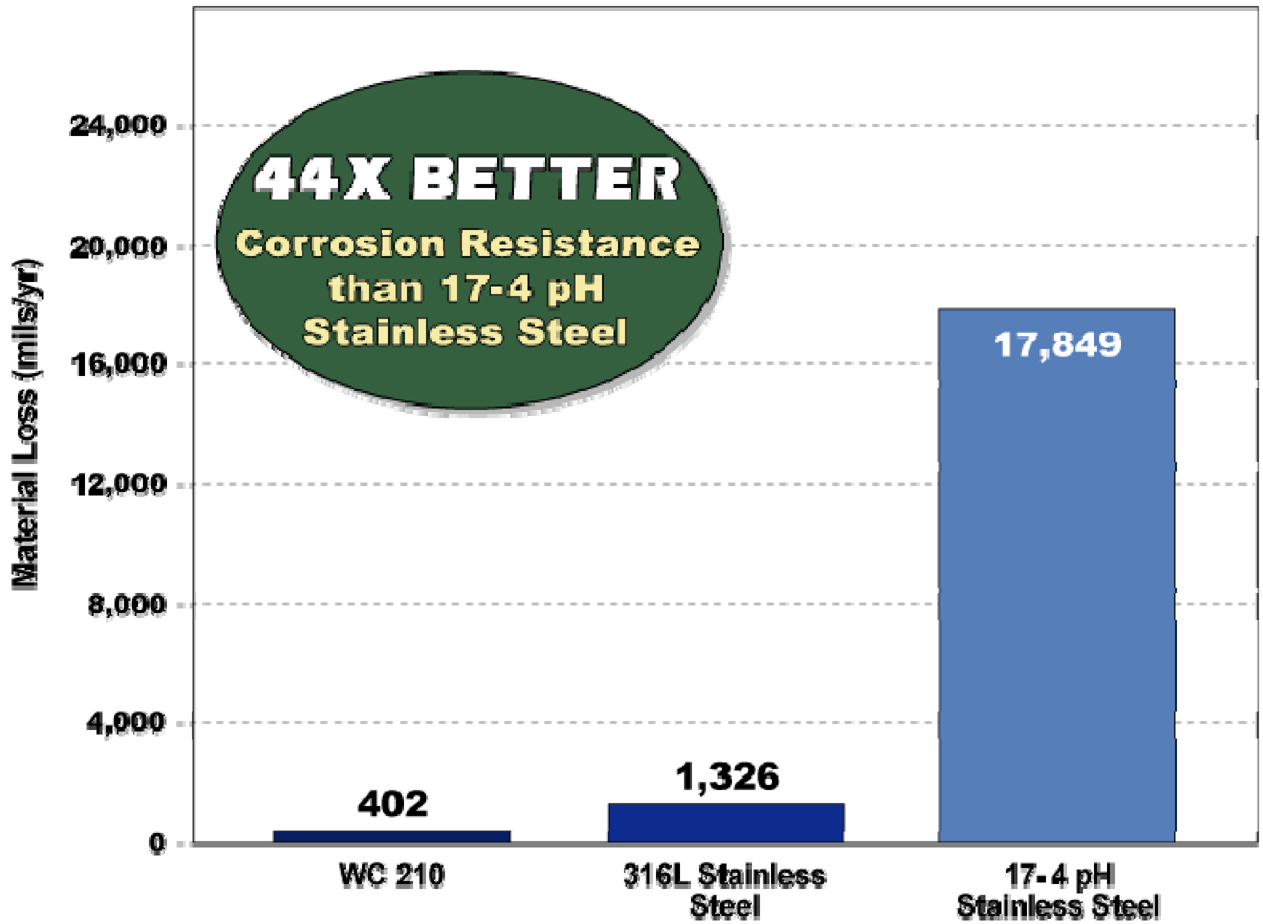
EPRI (Electric Power Research Institute) testing found that IBTCC WC 210 provides superior erosion protection for power boiler fan blades exposed to high-velocity bituminous coal fly ash.

EPRI CS - 6068, Project 1649-4



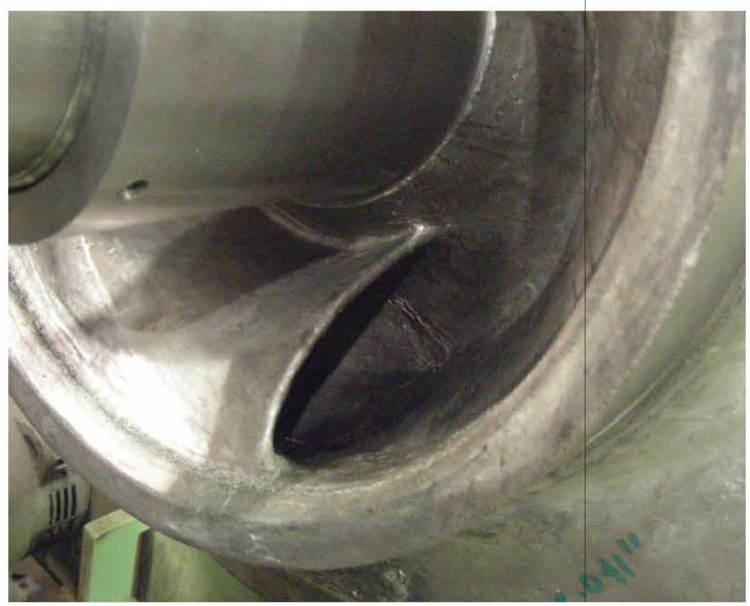
Corrosion Resistance

Laboratory Testing, ASTM G31 Standards



10% Sulfuric Acid at 212˚F (100˚C)

New IBTCC P-3 Pump



Damage to Previous Pumps

Boron Diffusion worn through
(wear plate closeup)

25 Chrome iron impeller
tip wear