Bear the Wear

Optimizing ESP efficiency and run life with technical ceramic bearing systems

CoorsTek

Disclaimer

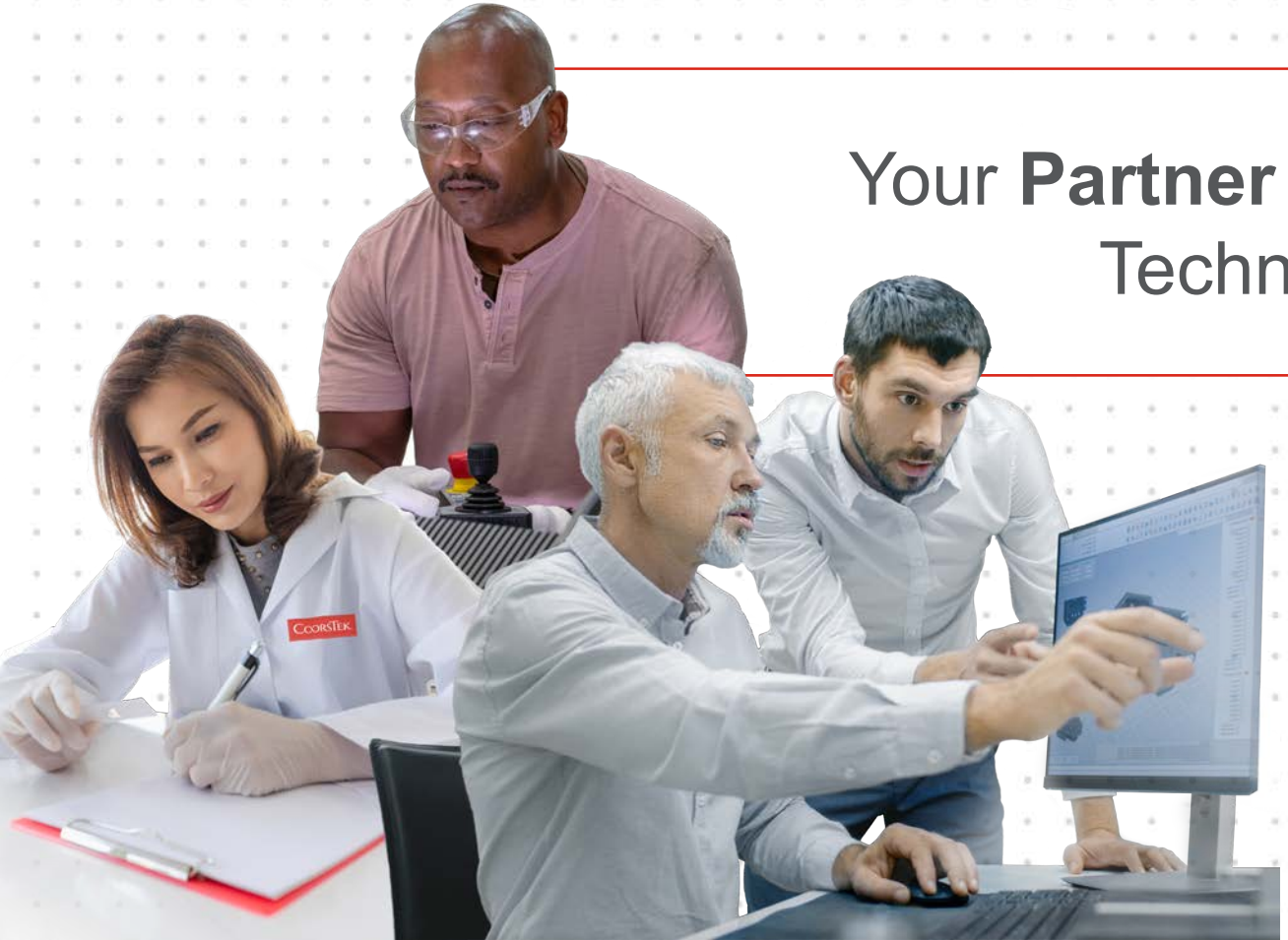
The figures herein are generalized information and for illustrative purposes only.

The charts are intended to illustrate typical properties. Property values vary with method of manufacture, size, shape of part, and test method. Data contained herein is not to be construed as absolute and does not constitute a representation or warranty for which CoorsTek assumes legal responsibility.

References cited and/or used are listed at the end.

Topics

- CoorsTek Overview
- ESP Wells and Wear
- Pump Bearing Systems & Materials



Your **Partner of Choice** for Technical Ceramics

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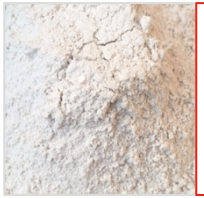
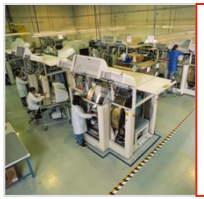
TECHNICAL CERAMICS LEADER



MATERIALS
400+ Vertically Integrated Ceramic Solutions



CAPACITY
500,000 m^2 Ceramic Manufacturing Space

EXPERTISE
6,000+ Team Members Worldwide

400+

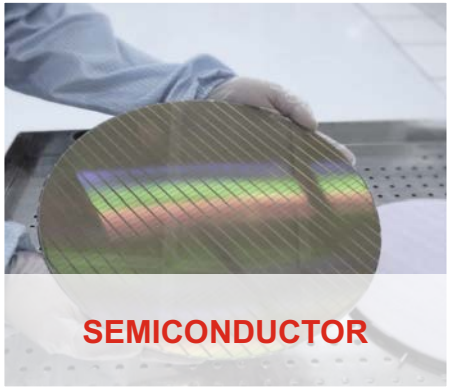
Ct

CoorsTek

6000+

VISION | We Make the World Measurably Better

WHERE DO YOU FIND TECHNICAL CERAMICS?



DIVERSE OFFERINGS IN GLOBAL MARKETS

ESP Wells and Wear

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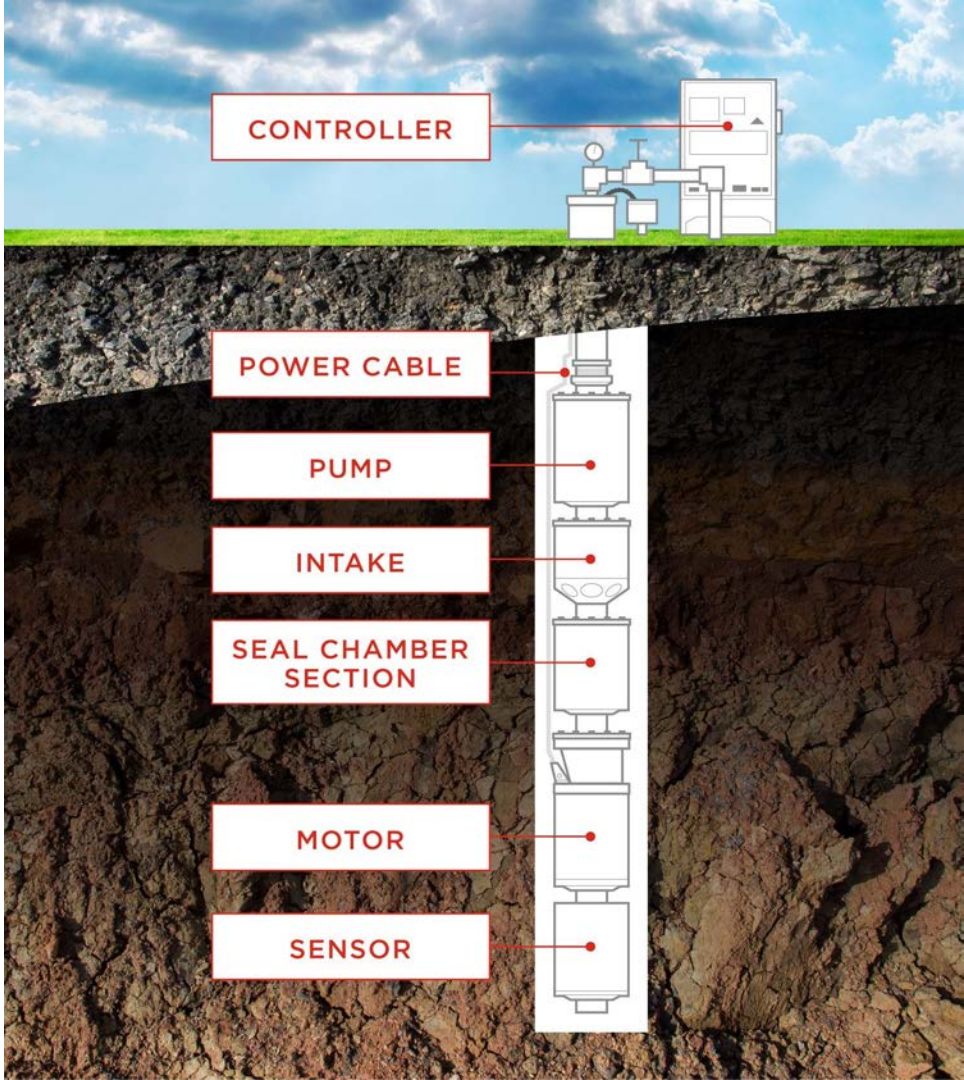
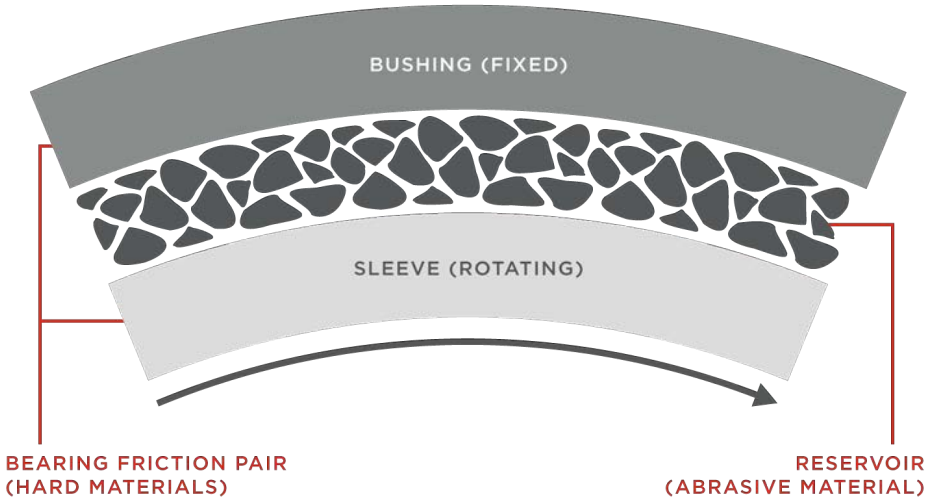
ESP Systems

- The first pump made in Bartlesville was installed in 1927 near Russell Kansas
- Today's systems have a small environmental footprint that are optimized for power utilization, high reliability, and minimal stoppages and waste streams
- Intake and Pump internal components directly exposed to well fluids
- Bearings in multistage centrifugal Pump are critical to run-life



ESP Wells and Wear

- Mature/Shale oil wells have challenges
- Abrasive solids cause three body wear (Wilson, 1990) to:
  - Pump's radial bearings
  - Impeller-Diffuser seal areas
  - Thrust bearings (Beck, et.al. 2019)
- Increased clearance causes shaft instability
- Shaft instability compromises mechanical seal in Seal Chamber Section
- Seal failure allows well fluids to enter Motor causing an electrical failure



Bearing Systems and Wear

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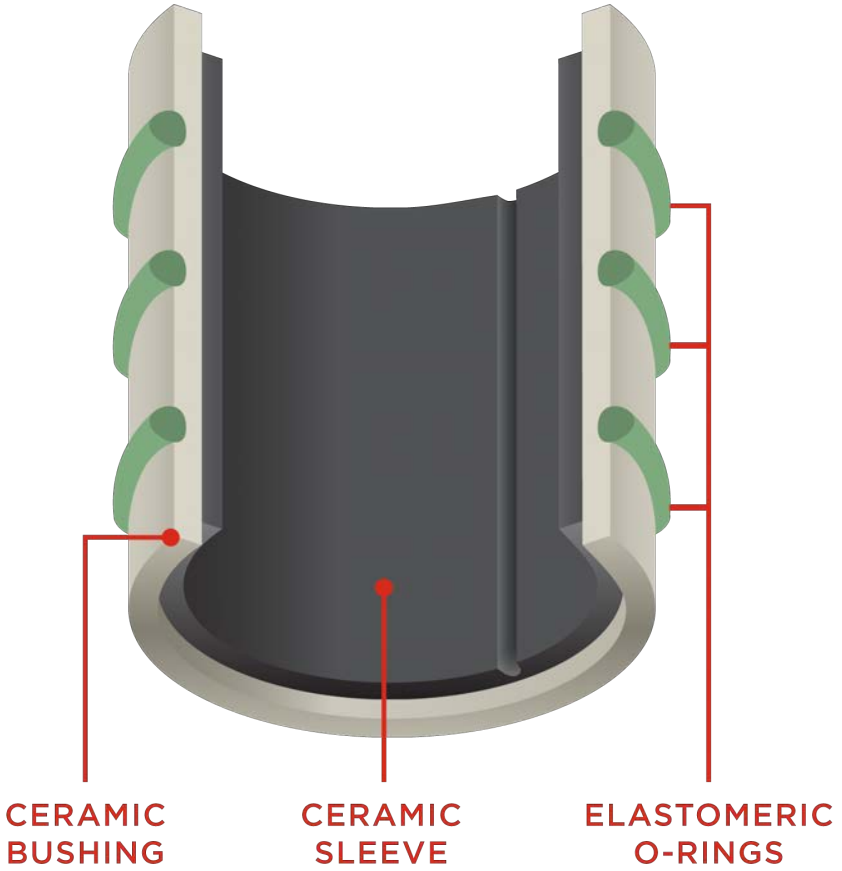
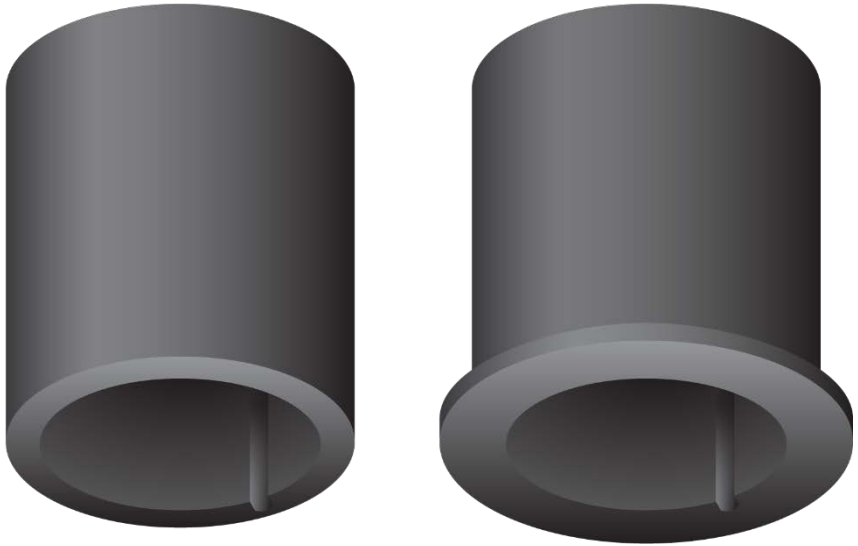
Radial Bearings

- Sleeve – keyed to rotating shaft
- Bushing – held inside Housing or Diffuser, with two styles
  - Compliant (shown here on right)
    - Usually has retention means
    - O-rings minimize vibration, compensate for thermal expansion, and enhance alignment (Pastre et al., 2017)
  - Interference fit
    - Press fit or thermal heat shrink
    - Bushing can migrate out of Diffuser (Nowitzki et al., 2018)



Sleeves

- Two Designs
  - Keyed – two styles (shown here on right)
    - Simple cylinder with ID keyway, shaft has free axial movement
    - Flanged – in compression pumps, imparts Impeller's axial loads to Thrust Bearing in Seal Chamber Section
  - Keyless – eliminates keyway stress concentration in keyed design Sleeve (Pastre et al., 2017)
- Bearing Material Combinations
- Bearings per Pump Configuration (Pastre et al., 2017)



Bearing Materials

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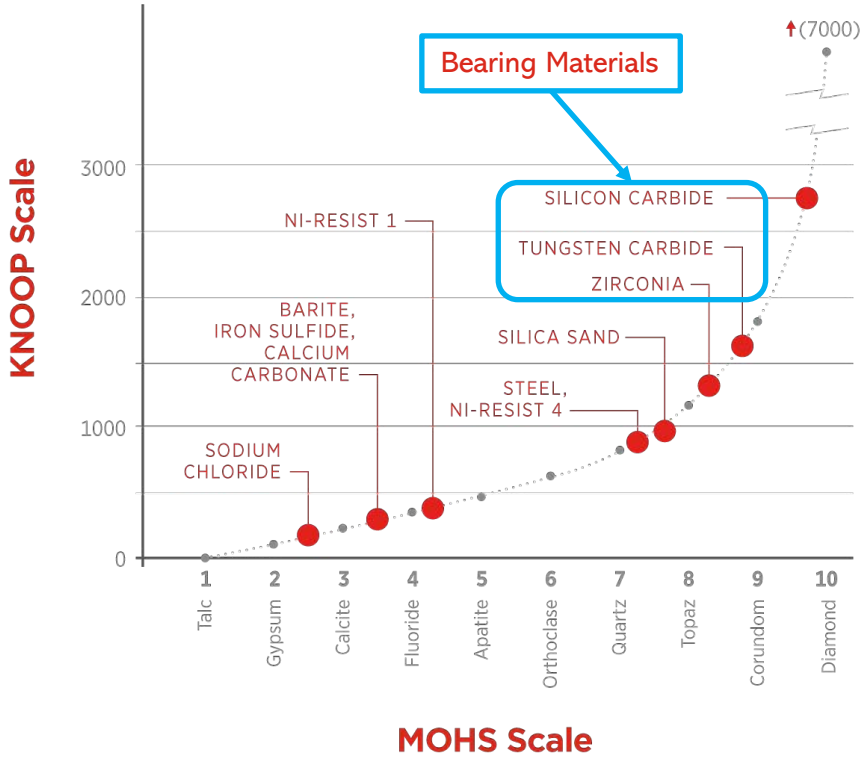
Hardness and Wear

- Mohs' scale shows hardness of minerals compared with the Knoop scale
- The chart shows all bearing materials are harder than oil well solids
- In most cases, softer materials do not wear a harder material
- ESP Bearing systems experience more complex grinding abrasion
- Hardness, surface ductility, size, shape, and toughness influence rate of material removal (Wilson, 1990)



Material Properties

Properties	Units	Magnesia Partially Stabilized Zirconia	Tungsten Carbide YG6X grade	Direct Sintered Silicon Carbide	Steel
Hardness	kg/mm^2	1200 (Knoop 1000 gm)	1740 (HV30)	2800 (Knoop 100 gm)	650-900 (Knoop 1000 gm)
Fracture Toughness K(I c)	Mpa $m^{1/2}$	11	6	4	50-80
Maximum Use Temperature	˚C	500	-	1600	800
Thermal Shock Resistance ΔTc	˚C	350	-	300	-
Coefficient of Thermal Expansion	10^{-6}/˚C	10.2	5.1	4.4	12
Thermal Conductivity	W/m ˚K	2.2	-	150	35-55
Chemical Resistance					

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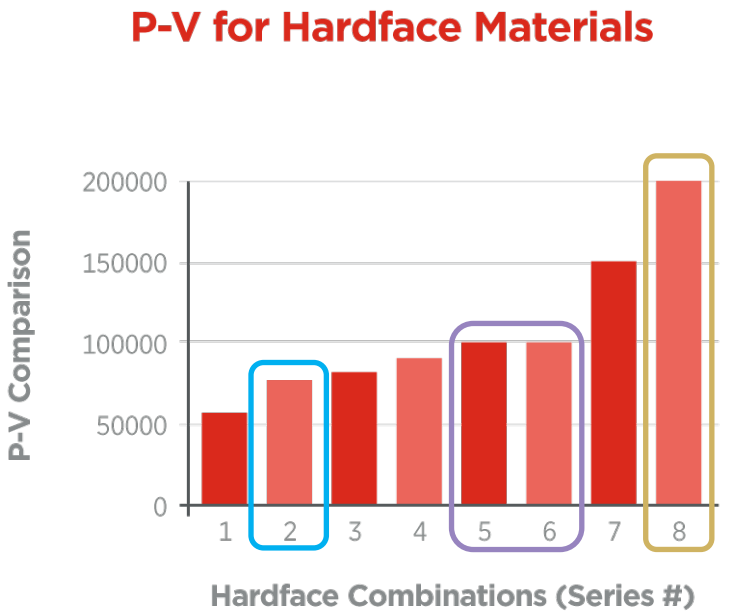
Wear Rate Tests

- P-V test is a sliding contact test for engineered surfaces
- Rotating ring on washer (flat-on-flat) and all conditions controlled except varying rotational speeds and applied loads (ASTM D3702-94)
- Values predict wear and service life
- Charted materials and surface finishes (shown on right) provide relative wear indexes

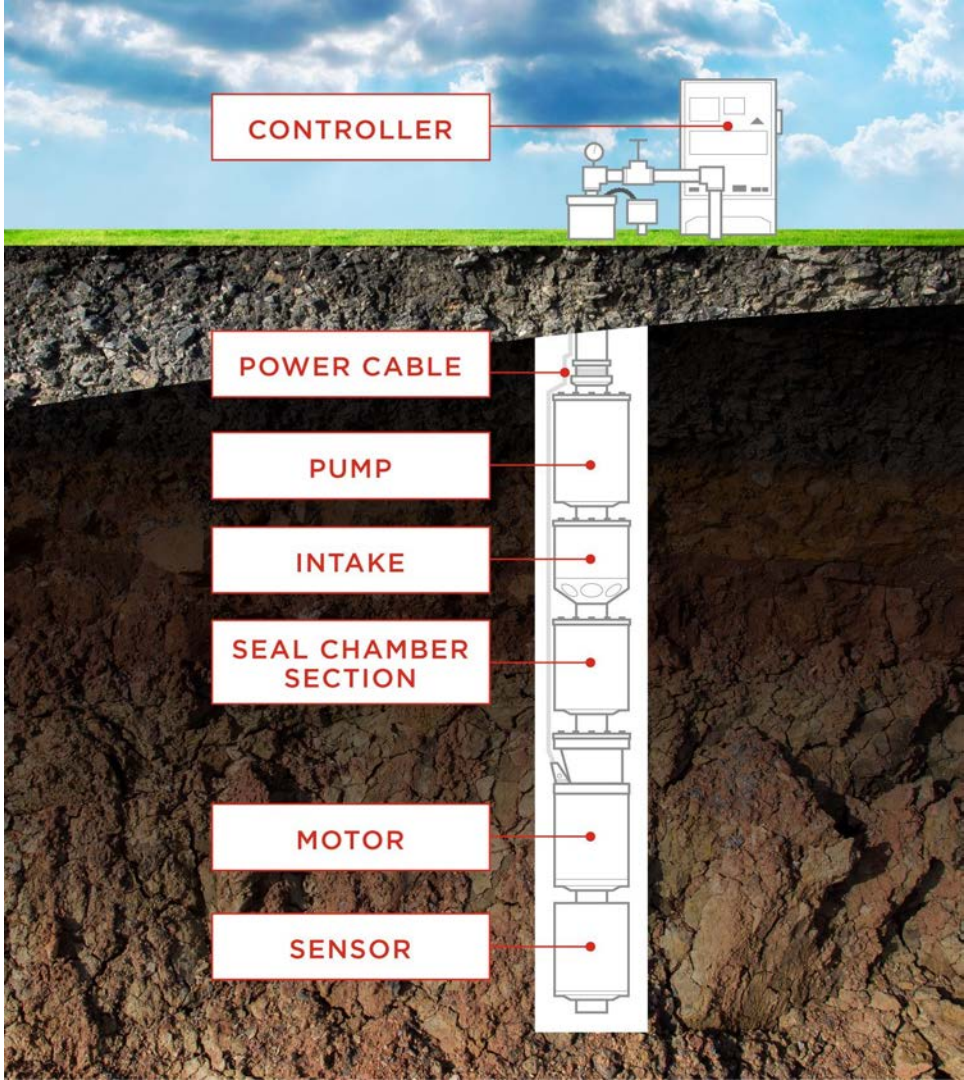


Legend for Hardface Material Combinations

Series 1—Alumina vs. Alumina
Series 2—TC vs. TC
Series 3—SiC1 vs. SiC1
Series 4—SiC2 vs. SiC2
Series 5—Polish vs. Matte
Series 6—Matte vs. Matte
Series 7—SiC3 vs. SiC4
Series 8—SiC3 vs SiC3

Rotating Applications for Technical Ceramics

- Pump and Intake: Radial Bearings (discussed in detail previously)
- Seal Chamber Section: Mechanical Seal and Thrust Pad and Runner
- Motor: Thrust and Rotor Bearings



Closing Remarks

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2. Beck, D., Nowitzki, W., and Shrum, J., “Electric Submersible Pump ESP Vibration Characteristics Under Wear,” presented at SPE Gulf Coast ESP Symposium, The Woodlands, Texas, May 13-17, 2019, SPE-174388.

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Questions

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