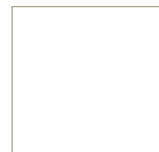


### **DiamondFaces®**

The new dimension  
in mechanical seal technology



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# Introduction

Any system can only be as functional as the lifespan of its weakest component.

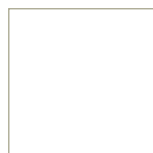
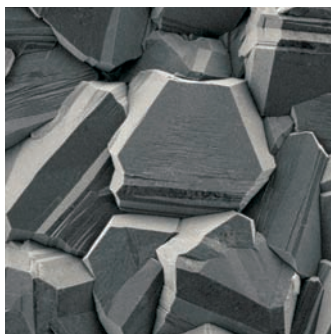
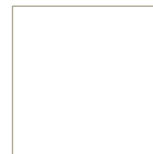
This rule applies to all products in general – and to mechanical seals in particular. Investigations have shown that the mechanical seal is a critical component in pumps. The most frequent cause of damage to mechanical seals is still the damage to the sliding faces due to inadequate lubrication which results dry-running.

**This is precisely where the DiamondFaces® innovation comes in.**

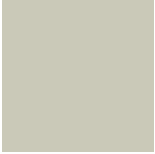
EagleBurgmann has designed the innovative DiamondFaces® microcrystalline diamond coating for mechanical seals especially to counter this operating conditions. Through intense collaboration with our customers, suppliers and in this case especially with the Fraunhofer IST in Braunschweig, we have now developed this manufacturing technology for mass production.

With DiamondFaces®, EagleBurgmann has launched a development on the market to provide outstanding wear protection in conditions of dry-running, mixed friction and abrasive media. As a result, the service life of mechanical seals has been increased many times over for a large number of applications, the maintenance intervals correspondingly extended and the life cycle costs significantly reduced.

**DiamondFaces® from EagleBurgmann – the innovation for longer running times and greater reliability for your pumps and mixers.**



# Applications



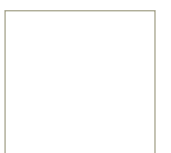
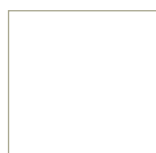
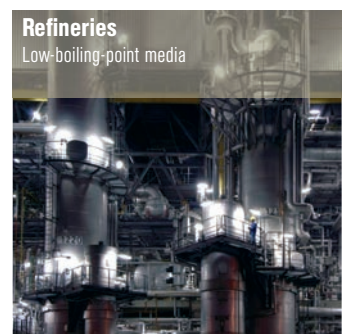
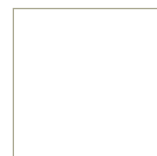
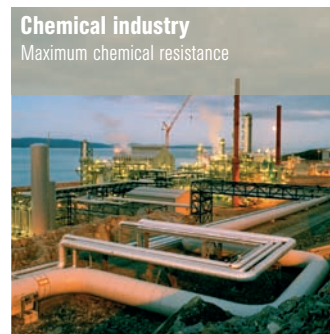
Mechanical seals from EagleBurgmann cover an extremely wide range of applications in numerous industrial sectors. They are used as shaft seals in pumps, agitators, compressors and other rotary machines which handle liquid and gaseous media. Mechanical seals are usually safe and reliable components which, when working correctly, generally operate wear-free.

But, when lubrication is insufficient or when the seals are running dry, the sliding faces become extremely hot within a short time, leading to their destruction and total breakdown.

The DiamondFaces® innovation comes into its own when it is the reliability of pumps and mixers that matters. The specially developed crystalline diamond

coating offers the same advantages as natural diamond and is eminently suitable for applications in the oil and gas industries, the chemical and pharmaceutical industries, refineries, building services and slurry applications.

## Recommended applications



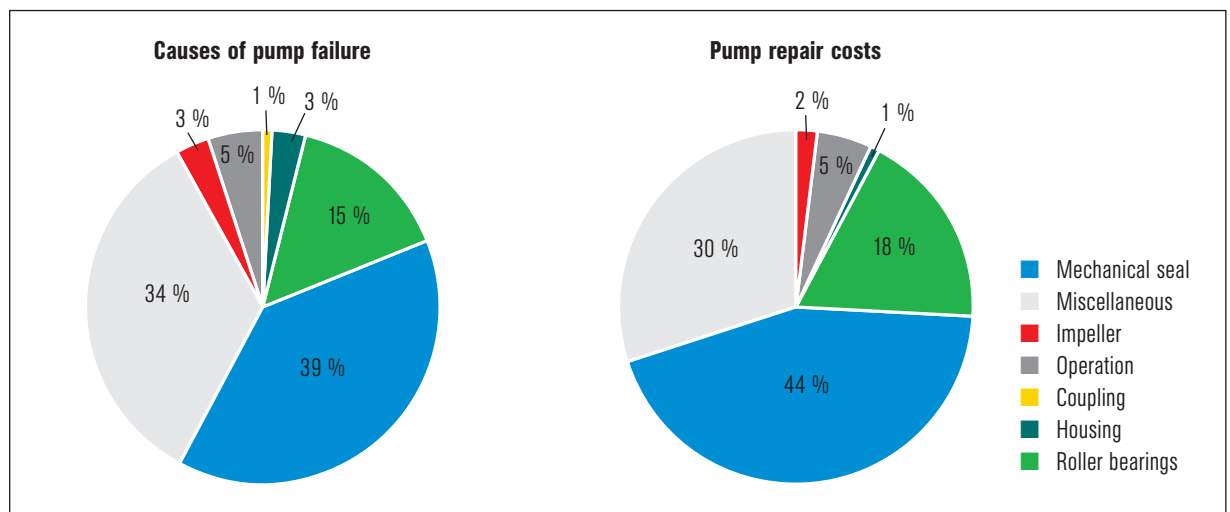
# Main causes of pump damage

The problem-free operation of pumps is an essential requirement for cost-effective and reliable operation of plants and systems.

Out of the key components of a pump, the mechanical seal has so far been the one with the shortest average service life. It therefore has a major influence on the MTBF/MTBR values of the system as a whole.

The primary aim of all operators must be to significantly improve the MTBF/MTBR values of the pump/system and minimize the process downtime costs which result from unplanned interruptions.

International analyses have clearly shown that mechanical seals are responsible for 39 % of the damage to pumps and are therefore the most frequent cause. A breakdown of the costs accounted for by pump repairs also clearly shows that mechanical seals represent the largest single factor at 44 %.



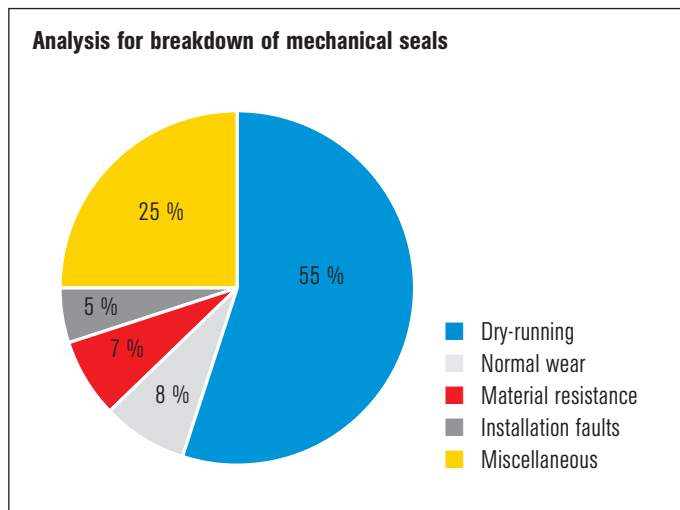
Source: OMV AG, Pumps in Process Engineering, 2002

The pairing of sliding faces remains the most critical part of a mechanical seal. Insufficient lubrication and the associated dry-running will cause immediate destruction of the sliding faces if two hard materials are paired together. This risk can be reduced to some degree by pairing a soft material with a hard material (carbon-SiC) but, in this case, the carbon wear significantly compromises the service life of the component.

Damage analyses carried out by EagleBurgmann have shown that 55 % of all mechanical seal damages are caused by dry-running. Thus, approximately 21 % of all pump damages are caused by dry-running of the mechanical seal.

The analyses performed by Grundfos, who (according to their own publications) examined the causes of around 1.3 million pump failures, concluded that dry-running the seal was responsible for 18 % of the overall malfunctions.

**DiamondFaces® can increase the service life of mechanical seals many times over for a large number of applications because of the excellent wear protection this innovation provides where dry-running, mixed friction or abrasive media are concerned – and therefore considerably extend the maintenance intervals.**



Source: EagleBurgmann, damage analysis, 2006

# DiamondFaces® technology

DiamondFaces® is a synthetically manufactured, ultrapure diamond with the same outstanding properties as the natural stone. A microcrystalline coating of 8 µm thickness on silicon carbide seal faces which is capable of performances previously unheard of for mechanical seals.

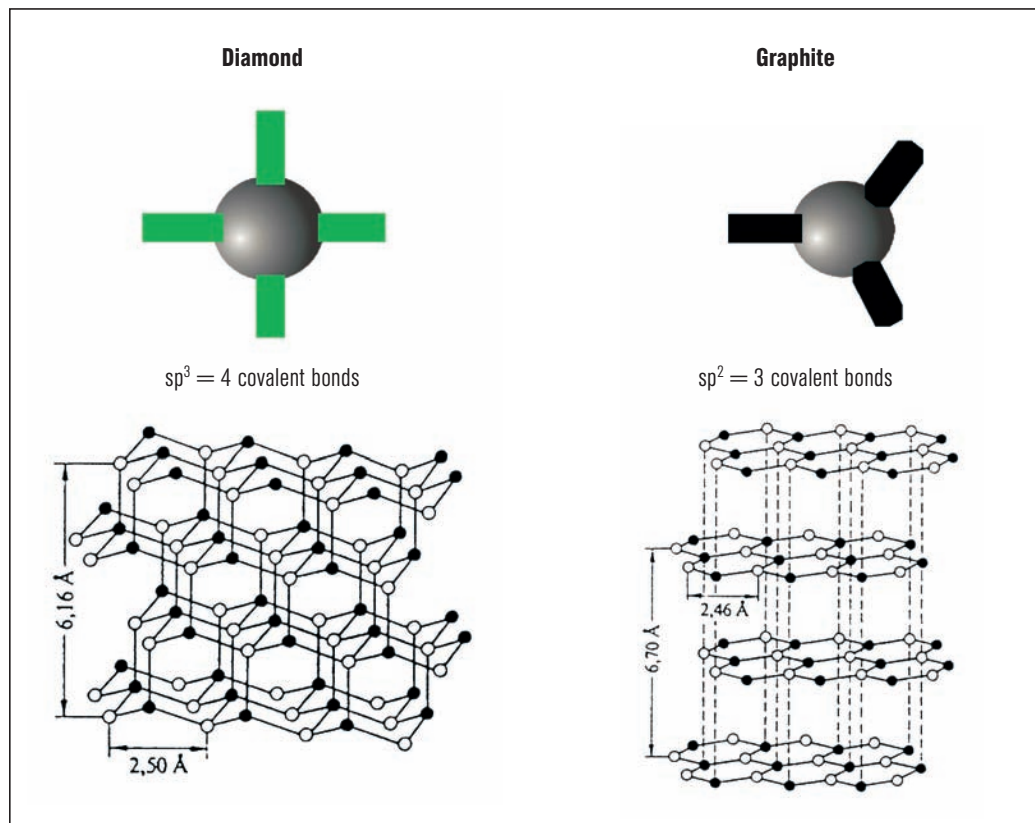
## What is a diamond?

Diamond is the hardest natural material that is known. The difference between diamond and graphite lies in the number of bonds and the number of covalent spacings between the atomic lattices.

Graphite has 3 covalent bonds, whereas diamond has 4 covalent bonds. The increased hardness results from the higher packing density of the diamond atomic lattice structure of, for example, graphite can be shifted slightly, which is the reason for the good lubricating properties of graphite associated with high wear (material removal).

## Diamond is not DLC (Diamond Like Carbon)

DLC is a coating process which EagleBurgmann uses in gas-sealing technology. DLC coatings have a high proportion of graphite (as high as 60% in some cases) so the material properties can be anywhere between those of graphite and those of diamond. DiamondFaces® technology on the other hand uses pure crystalline diamond.





### So why choose a diamond coating?

The SiC/SiC material pairings which have been increasingly favored for seal faces during the last 10-15 years offer excellent chemical resistance, high resistance to abrasion and are virtually wear-free, but only when adequate lubrication is provided in the sealing gap.

Any form of insufficient lubrication due to dry-running results in massive temperature increases and damages the sliding faces and secondary seals (O-rings). In extreme cases, the time to total failure of the sliding faces may be just a matter of a few seconds.



Combining SiC seal faces (seat housings) with the DiamondFaces® coating allows longer dry periods (up to several hours) with a reduced build-up of heat.

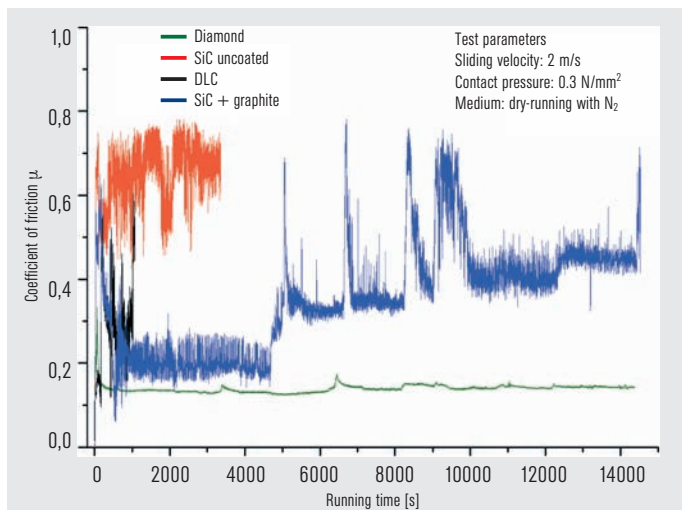
DiamondFaces® has the following outstanding characteristics:

1. Low coefficient of friction
2. Virtually no wear
3. Outstanding coating adhesion
4. Optimum surface evenness

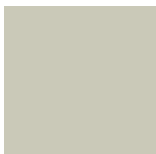
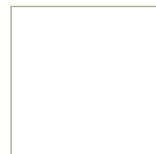
### 1. Considerable reduction of the coefficient of friction

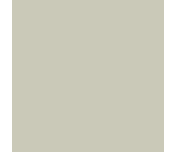
Extensive general and application-specific tests have been performed in order to optimize the composite material, SiC-diamond. The most important objective was to minimize the coefficient of friction during dry-running (gas lubrication using N<sub>2</sub>) and wet friction. The outstanding performance of the innovative DiamondFaces® coating has been confirmed during tests at EagleBurgmann and Fraunhofer IST.

The coefficient of friction measured when dry-running coated silicon carbide seal faces (DiamondFaces®) was lower than that measured for an SiC/SiC standard pairing by a factor of 5. Due to the excellent dry-running properties, the microcrystalline diamond coating withstood up to several hours of dry-running with reduced build-up of heat. This has been confirmed by extensive field tests in various applications.



Source: EagleBurgmann test-bench results, coefficient of friction for gas lubrication using dry nitrogen

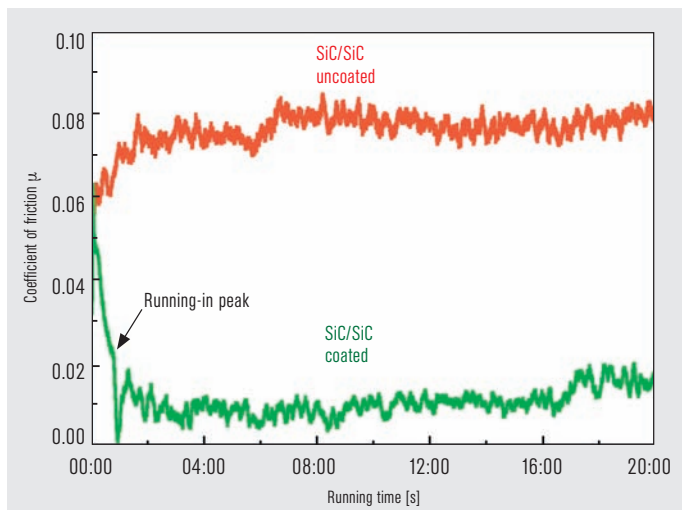
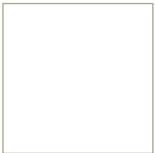
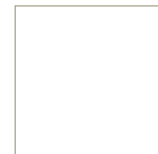




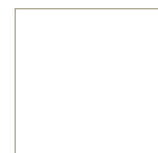
The difference between DiamondFaces® and SiC/SiC standard pairing was even greater with liquid lubrication. In this case, the coefficient of friction was up to 8 times lower.

**The essential advantages:**

- Reduced sliding-face friction reduces the heat generated by friction and therefore increases dry-running reliability.
- The minimized friction reduces the amount of heat generated in the seal and thus protects the secondary sealing elements (O-rings).
- The reduced power consumption of the sliding faces allows reduced cooling of double acting systems.
- Higher temperature application limits for low-boiling-point media
- The power demands of the pump are lower



Source: Fraunhofer IST test-bench results, deionized water,  $v_g = 7.6 \text{ m/s}$ ,  $p = 1 \text{ MPa}$





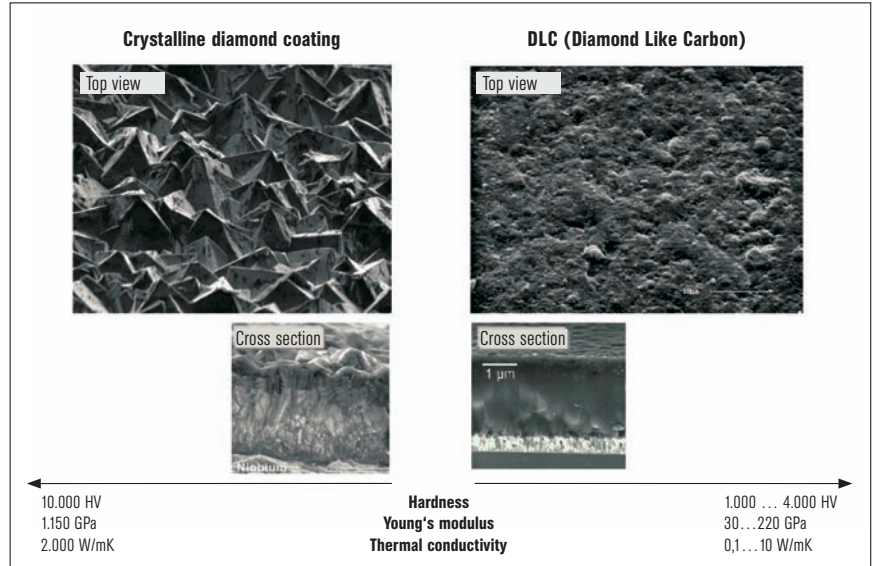
## 2. Virtually no wear

Diamond is famous for its unsurpassed hardness and excellent chemical and thermal resistance. It is extremely important to distinguish between diamond-like carbon coatings (DLC) – which EagleBurgmann has been using for many years for anti-wear protection in gas-lubricated mechanical seals – and the new DiamondFaces® coating. The DiamondFaces® coating is a crystalline diamond coating.

The diamond coating is characterized by virtually no wear, even when diamond coatings are running against each other. The 8- $\mu\text{m}$  thick microcrystalline diamond coating therefore guarantees an extremely long service life compared with uncoated SiC seal faces.

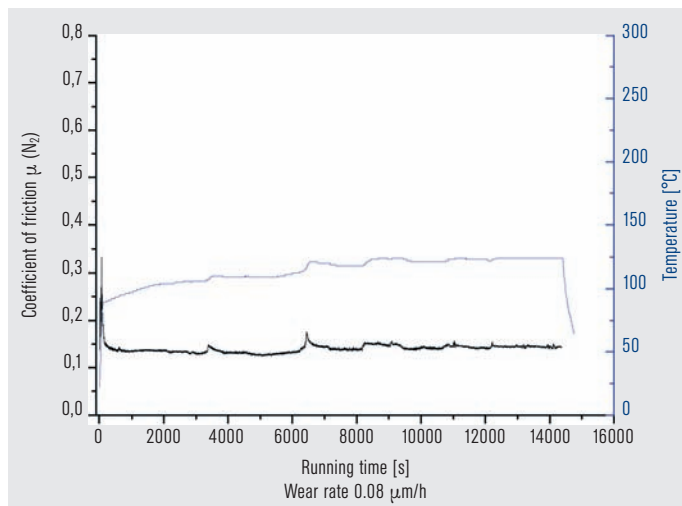
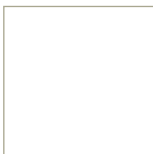
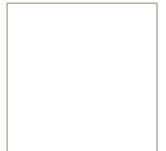
### Wear rate

The average wear rate during dry-running conditions ( $\text{N}_2$ ) is between 0.08  $\mu\text{m}$  and 0.2  $\mu\text{m}$  per hour and is determined by differential measurements before and after tribological tests.



### The essential advantages:

- Virtually no wear  
 (→ extremely long service life)
- Outstanding wear protection even with media with high solids content since diamond is the hardest known material
- Coated hard/hard pairing  
 → long service life (with a carbon/SiC pairing the service life would be limited by the carbon wear)
- No reduction in the application limits because of the instability of carbon, no support rings necessary
- Long service life even during partial dry-running
- Maximum chemical resistance  
 → enables standardization

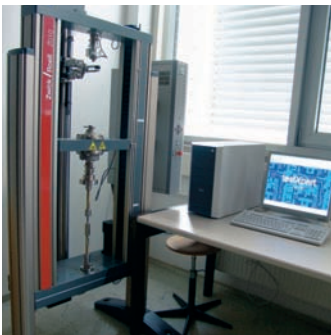
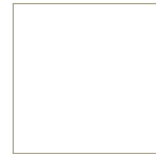


Source: Fraunhofer IST test bench results, random checking with  $\text{N}_2$  gas lubrication and wet medium deionized water

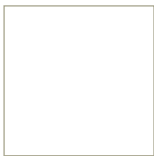


### 3. Outstanding coating adhesion

The diamond forms a chemical bond with the silicon carbide and the resultant coating adhesion exceeds all known practical requirements. The coating adhesion is continuously checked with tensile tests and sand blasting tests. During long-term tests too, there was no detachment of the coating.

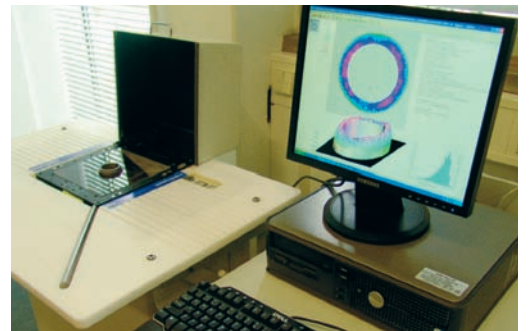


Source: EagleBurgmann, tensile test bench

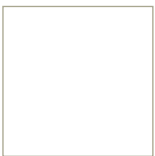


### 4. Optimum surface evenness

The evenness of the sealing faces is essential for the functional reliability of mechanical seals. In order to guarantee functional reliability, the evenness of the coated sliding faces must lie within the tolerance range of uncoated SIC sliding faces. With DiamondFaces®, the optimum evenness of the sealing faces is guaranteed.



Source: EagleBurgmann, quality assurance



# Manufacturing technology

We at EagleBurgmann have been making significant contributions to sealing technology for more than 120 years. We operate on the basis of intense cooperation with our customers and suppliers as well as research institutes in order to provide solutions to demanding challenges. DiamondFaces® represents a milestone in the development of mechanical seal technology and is opening up new dimensions in the performance of dynamic sealing systems.

## Manufacturing process for the diamond coating

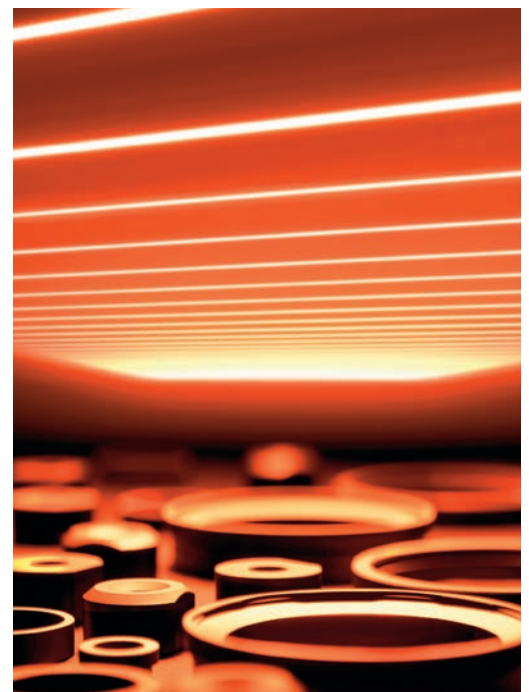
For the large-area, uniform coating of seal faces, an optimized HF-CVD (Hot Filament Chemical Vapour Deposition) process is used in order to meet these requirements. The surfaces are coated in a vacuum chamber. While this is happening, the topography of the surface and the orientation of the diamond crystals can be adjusted by selectively varying the process parameters.

A deposition process takes place during a period of approximately 24–36 hours in a reactor, during which diamond crystals are formed from a gas mixture of hydrogen and methane. These diamond crystals are deposited onto a SiC surface (seal face) at a temperature of 800 °C.

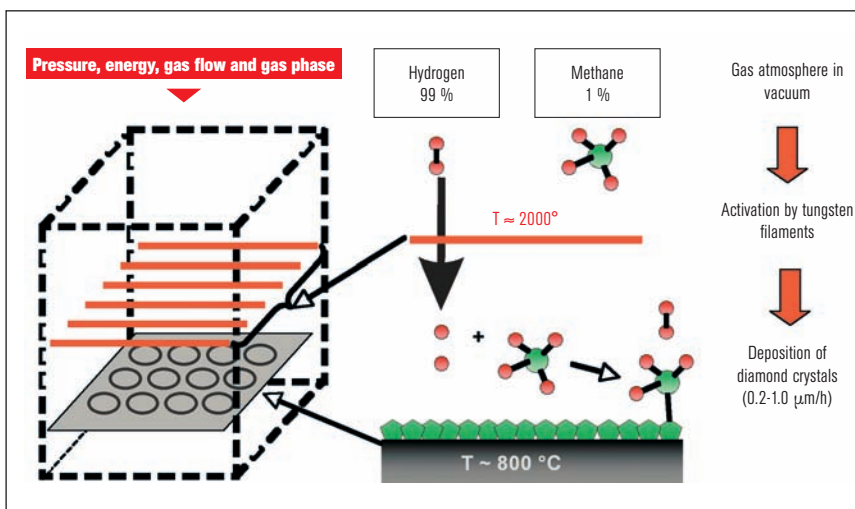
The diamond crystals created in this way grow together to form a closed layer. The deposition process is initiated with tungsten filaments which are

stretched horizontally across the reactor and heated to around 2000 °C.

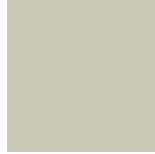
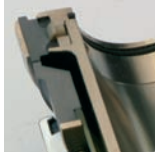
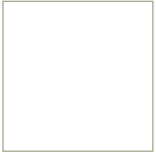
The arrangement of the tungsten filaments is one of the key factors for ensuring that the coated seal faces are perfectly flat. Only the horizontal filament arrangement makes it possible to provide the mechanical seals with a uniform blanket coating.



Source: Fraunhofer IST, seal face layout in the EagleBurgmann process with horizontal filament arrangement



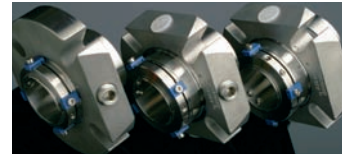
Process diagram (source: EagleBurgmann)



### The right seal for each application

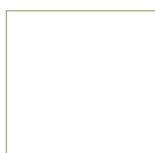
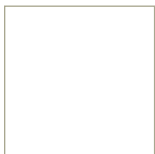
Because silicon carbide packing rings coated with DiamondFaces® have an extremely hard surface, further machining is almost impossible. In other words, the coating process has to be the last step in the manufacturing process before assembling the seal. The so-called shrink-fitting of seal faces into metal carriers is no longer appropriate since this impairs the planarity of the surface and re-polishing the sliding faces is out of the question.

However, EagleBurgmann also supplies a large number of service-proven ranges of seals for pumps and agitators which have design-dependent loose-fitted seal faces and seats and are therefore ideal for DiamondFaces®. There is also the option of relatively simple design adaptation for a whole series of seals.



### For which types of seal is DiamondFaces® suitable?

- For all seals with hard/hard pairings made of silicon carbide
- Single and multiple mechanical seals
- Generally all seals with loose-fitted seal faces and seats, such as M7, H7, Cartex® and MG1
- For ranges where design adaptation is relatively simple, e.g. Burgmann HR or SH or SeccoMix®



# Customer benefits

By optimizing crystalline diamond coatings, it is possible to increase the efficiency of mechanical seal systems considerably when there is insufficient lubrication, during dry-running or even when sealing against abrasive media.

1. Significant increase in the service life of the entire system
2. Return on investment within a very short time
3. Extension of the MTBF and MTBR values
4. Widening of the range of applications

## 1. Significant increase in the service life of the entire system

The reduced sliding-face friction reduces the heat produced by friction and therefore increases dry-running reliability. The minimized friction also reduces the amount of heat produced in the seal and therefore protects the secondary sealing elements (O-rings).

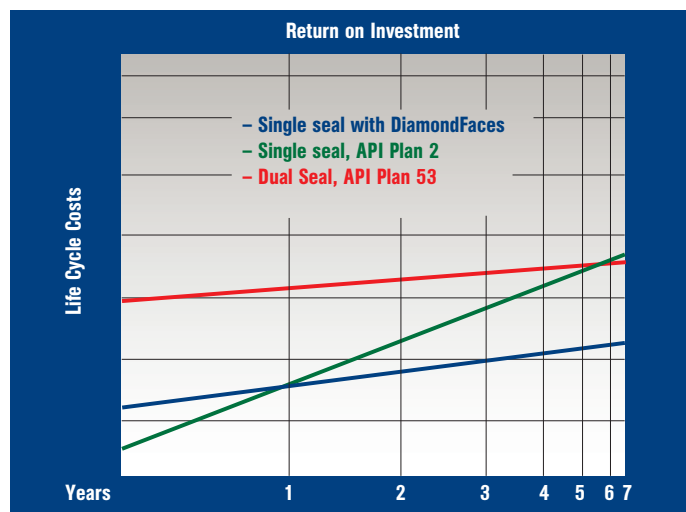
Since there is virtually no wear in the diamond coating, even when sliding faces coated with DiamondFaces® are running against each other, an extremely long service life is achieved even during partial dry-running. The diamond coating also makes for outstanding wear protection, even against media with high solids content.

## 2. Return on investment within a very short time

The innovative coating technology makes it possible to increase running time and operating reliability considerably and therefore decrease the overall costs over the lifecycle of a mechanical seal. Analyses have shown that the ROI (return on investment) can be obtained after only a very short time as result of the significantly increased service life achieved by a diamond-coated mechanical seal.

The main cost blocks which can be significantly influenced with DiamondFaces® are:

- Service and maintenance costs of the machine
- Service and maintenance costs of the seal
- Costs due to downtime and loss-of-production or precaution costs (such as redundant pumps)



Detailed ROI calculation using the FSA/ESA software "Life-Cycle Cost Estimator"

### 3. Extension of the MTBF and MTBR values

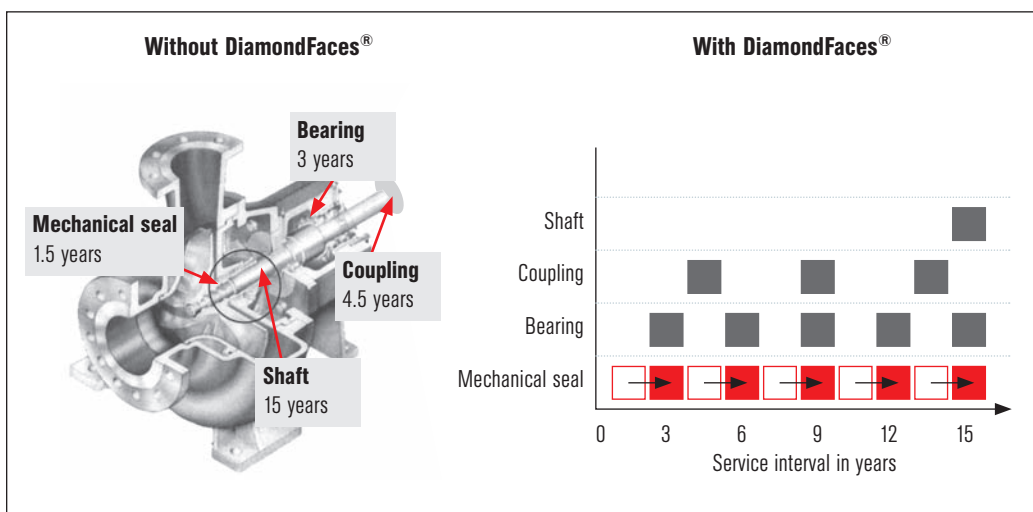
The average increase in service life can be exploited to combine maintenance activities with those of other engineering or plant components such as bearings or couplings.

According to this analysis of the average component service life, pump repairs and the associated downtimes and production stops can be avoided by successfully increasing the service life of the mechanical seals.

### 4. Widening of the range of applications

The DiamondFaces® innovation comes into its own when it is the reliability of pumps and mixers that matters. DiamondFaces® is ideal for applications in the oil and gas industries, chemical and pharmaceutical industries, refineries, building services and slurry applications.

During normal operation, the amount of frictional heat produced is also reduced by the reduced sliding friction. The lower friction output of the sliding surfaces permits reduced cooling with double seal systems and higher temperature limits with low-boiling-point media. The universal chemical resistance demonstrated by the product and its insensitivity to media with high solids content has meant that it can be used in the chemical and pharmaceutical industries as standard. Carbon graphite materials, which can lead to inadmissible product contamination under abrasion, can in many cases be replaced.



Example showing where the service life is increased from 1.5 years to 3 years

# References



## **Total Deer Creek/ Bornemann, Canada**

### **The challenge**

The new Steam Assisted Gravity Drainage process is used to exploit large oil-sand fields in Canada. With this process, oil components are dissolved by exposure to steam and transported using a multiphase pump from Bornemann. Because of the extreme abrasive properties of the delivery medium and the dry-running condition, the average service life of a mechanical seal is 2 weeks.

### **Operating conditions**

- Substrate: Buka 22
- Medium (product): Hot water, oil, gas and sand
- Product pressure p: 1.0 bar (abs)
- Product temperature t: 100 °C
- Rotational speed: 1300 min<sup>-1</sup>
- Sliding velocity: 6 m/s

### **The solution**

The service life was increased more than tenfold by using the innovative DiamondFaces® coating in combination with the Burgmann HJ4S1/80-G179.1 mechanical seal. The new coating innovation is the optimum sealing technology for all multiphase applications.





### Refrigeration technology, screw compressor

#### The challenge

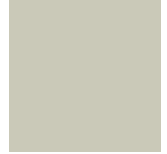
The operationally induced evaporation of dissolved coolant in the sealing gap of the refrigeration plant is unavoidable. The screw compressor is therefore forced to run dry, which in turn frequently leads to leaks at the mechanical seal. This required a cost-effective solution with improved dry-running capability for the mechanical seal.

#### Operating conditions

- Substrate: Buka 22
- Medium (product): Oil with 12 % R404A (dissolved)
- Product pressure p: 17.5 bar (abs)
- Product temperature t: 45 °C
- Rotational speed: 3000 min<sup>-1</sup>
- Sliding velocity: 17 m/s

#### The solution

The leakage rate was reduced by a factor of 4 to 5 by using a Burgmann H75/N/85-00 with DiamondFaces®.



### Dry-running tests

#### The Challenge

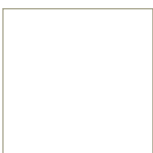
Performance of dry-running tests in different (high-temperature) applications in the laboratory of BT-Burgmann in benchmark with Q<sub>6</sub>Q<sub>6</sub> without coating.

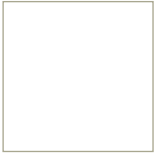
#### Operating conditions

- Medium (product): Air
- Product pressure p: 1.0 bar (abs)
- Product temperature t: 25 °C
- Rotational speed: 3000 min<sup>-1</sup>
- Sliding velocity: 2.3 - 3.3 m/s

#### Results

- Q<sub>6</sub>Q<sub>6</sub> without coating, failure after a few minutes.
- DiamondFaces®, in good condition after 60 minutes.





**Lapping and washing at EagleBurgmann, Atec Automatisierungstechnik**

**The challenge**

Increase the service life of mechanical seals during lapping and washing of SiC seal faces. The product handled is an abrasive medium, with the barrier pressure being applied intermittently.

**Operating conditions**

- Medium (product): Diamond and SiC water suspensions
- Product pressure p: 1.8 bar (abs)
- Product temperature t: 25 °C
- Barrier medium: Water
- Barrier pressure p: 4-6 bar (abs)
- Rotational speed: 300 min<sup>-1</sup>
- Sliding velocity: 0.9 m/s

**The solution**

The Burgmann double seal Cartex/40 and M7N/40 with DiamondFaces® on Buka 27 was successfully used and the service life extended by a factor of 6.



**Pump start-up without media**

**The challenge**

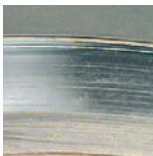
Prevent seal failure during dry-running and insufficient lubrication when commissioning a pump without the product medium.

**Operating conditions**

- Substrate: Buka22
- Medium (product): Water/air
- Product pressure p: 2.0 bar (abs)
- Product temperature t: 20 °C
- Rotational speed: 3000 min<sup>-1</sup>
- Sliding velocity: 17 m/s

**The solution**

Burgmann MG/125 with DiamondFaces®. Tests showed significant improvement during dry-running and when there was insufficient lubrication.

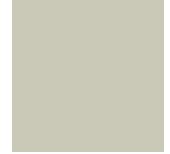
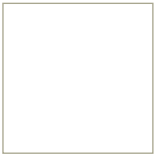


**Without coating:**  
Damage to sliding faces after 1500-2000 h, very high leakage



**DiamondFaces®:**  
Sliding faces in good condition after 11500 h, no leakage





## Water pumps in swimming pools

### The challenge

Prevent seal failures during dry-running and when there is insufficient lubrication when restarting a swimming-pool pump which has, for instance, been shut down for the season.

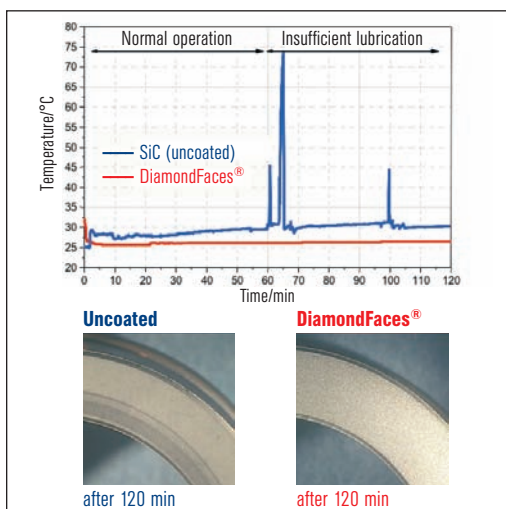
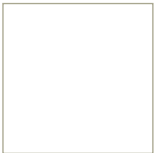
### Operating conditions

- Medium (product): Air
- Product pressure p: 2.4 bar(abs)
- Product temperature t: 24°C
- Rotational speed: 1450 min<sup>-1</sup>
- Sliding velocity: 2.5 m/s

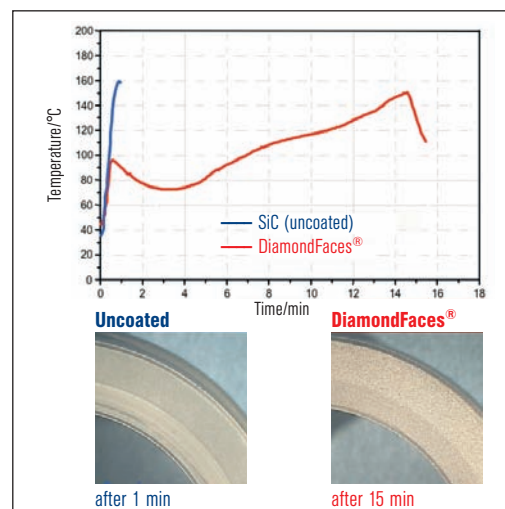


### The solution

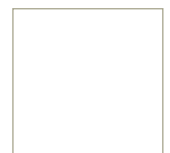
Burgmann MG/28 with Buka22  
DiamondFaces® made for:  
improved dry-running capability  
under conditions involving insufficient  
lubrication and permanent seal failure.



Normal operation with occasional insufficient lubrication



Dry-running



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