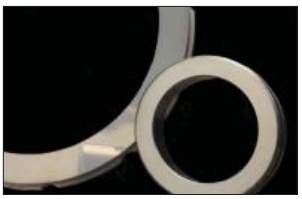
UNCD® Faces

Technical Information



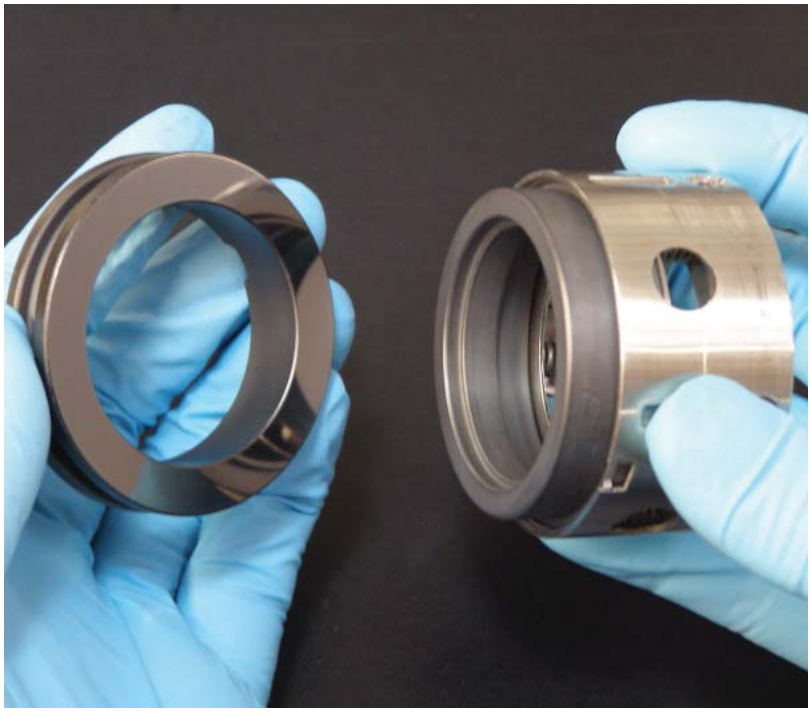
ADVANCED DIAMOND TECHNOLOGIES, INC.

UNCD Faces

The outstanding attributes of diamond are now available for enhancing mechanical seals. UNCD® Faces are made with a patented form of diamond that is so smooth that the faces can be run directly against conventional seal face materials such as blister resistant carbons and silicon carbides. Unlike other commercial diamond seal faces, UNCD does not require the added cost of having both faces coated with diamond. Besides excellent wear resistance and outstanding low friction, UNCD is known for its chemically inert, non-sticking, and biocompatible properties.

Benefits of UNCD

- Longer lasting seals in demanding applications.
- More resistant to dry and poor lubricating environments.
- Increased energy efficiency.
- Enables the use of hard faces in applications pumping thermally sensitive media.
- Suitable for a wide range of media.



Diamond mechanical pump seal, 1.375"

Products

UNCD Faces: UNCD Faces are available to seal manufacturers to enhance the performance of their branded mechanical seals. ADT offers seal faces in a wide variety of types and sizes to meet the requirements of seal manufacturers. Due to the outstanding low friction of UNCD, these faces perform superbly with a variety of counterface materials, including carbon and SiC.

UNCD Faces outperform SiC faces in extreme wear tests. After thousands of hours of operation, UNCD Faces have consistently outlasted SiC faces in poor lubricating conditions of 250-300 °F hot water. In head-to-head industrial tests, UNCD Faces have shown negligible or minimal wear whereas SiC faces experienced deep grooving resulting in pump leakage. UNCD Faces have also been shown, when running against SiC, to have coefficients of friction (CoF) of 0.02-0.04. These are well below the typical values when running SiC in hard-on-hard applications. The reduced friction during operation of UNCD Faces results in reduced seal cavity temperatures when running in ANSI slurry pumping applications.

Special Applications

For specific applications that are not addressed by our current product offerings, please contact us to discuss your application.

UNCD Faces

We can supply UNCD Faces for practically any seal ring design to meet your requirements. UNCD is a pure-phase diamond material that is much harder and wear resistant than materials described as "diamond-like" such as DLCs and is suitable for both contact and non-contacting seal designs. To request a quote for UNCD faces, simply provide us an engineering drawing of your seal ring. We will use your drawing for costing the machined substrate that will be UNCD coated, and promptly respond to you with a quote.

Our standard substrate material is alpha self-sintered silicon carbide, sourced from a high quality domestic supplier. If your drawings are proprietary, we would be happy to sign a non-disclosure agreement to protect your drawings.

We have engineering and technical support to help ensure that OEMs and seal manufacturers can quickly incorporate UNCD Faces into existing products and develop new products based on the unique properties of UNCD. UNCD technology may be just what you have been looking for to offer your customers new improved products and to help accelerate your business growth.

Engineering Support

Our technical experts and support staff will work with you to understand your needs and deliver a manufactured UNCD Faces product that best meets your requirements. We have extensive surface characterization capabilities and dynamic seal testing loops that can be used to reduce the development time to introduce diamond into your products.

Value Proposition

Value

The nanometer-sized grains of UNCD result in extremely smooth as-deposited films that provide the excellent wear resistance and reduced friction characteristics of diamond. Cooler sealing surfaces extend the life of the seal, which provides increased robustness, reduced maintenance costs, and the ability to use SiC faces in temperature sensitive applications. Diamond is known to be chemically inert, non-sticking, and biocompatible.

Validation

The coefficient of friction (CoF) of UNCD running against SiC has been measured nominally at 0.02 – 0.04, well below the seal industry standard when running "hard-on-hard" (SiC vs. SiC). These friction results were measured using actual pump seals and were confirmed indirectly by measuring a significant reduction in seal chamber temperatures when UNCD seals were running in 1.375 shaft ANSI pumps. The wear of UNCD versus carbon faces in an aggressive hot-water evaluation (250°F and 150 psig) has been measured at orders of magnitude lower than the wear of alpha-SiC (self-sintered) faces running against carbon.

Readiness

UNCD Faces are available today for enhancing mechanical seal performance, and can be made to meet customer's specific seat type and dimensional requirements. As a convenience to customers for trial evaluation, we offer a component type mechanical seal already containing the UNCD seal face that is designed to accommodate ANSI pumps.

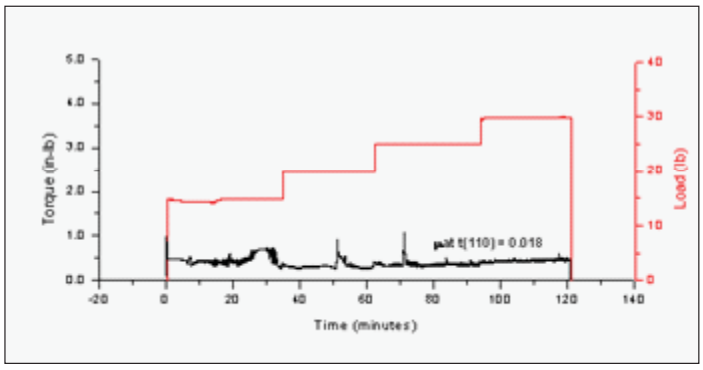
Testing Results: UNCD Faces CoF

Coefficient of Friction (CoF)

The CoF of UNCD faces running against SiC primaries has been routinely measured between 0.018 and 0.04 (see figure below). The CoF test rig measures the resulting torque of a rotating 1.375 inch A05 seal at various face loads. The CoF is calculated from a series of data points considered representative of the data collected toward the end of the test when the dynamic events associated with the start up and load variations have stabilized. The same test using SiC running against SiC measured greater than 0.18 and SiC against resin-bonded carbon routinely measures between 0.08 and 0.1.

Stationary Ring	Rotating Ring	CoF (in water)
UNCD	SiC	0.018 - 0.040
SiC	SiC	> 0.180
UNCD	C	0.06 - 0.1
SiC	C	0.08 - 0.1

To validate the benefits of the friction measurements made on the CoF test rig, a slurry-rig was instrumented at Argonne National Laboratory to measure the temperature of seal chambers when pumping a 10 wt% solid abrasive in Goulds 3196 pumps. The seal chambers of the pumps using UNCD Seals were found to operate six degrees (Fahrenheit) cooler than those pumps using industry standard SiC face seals. The low friction enables UNCD faces to be paired with SiC primaries in applications that would otherwise require softer carbon faces due to intermediate dry operation or temperature sensitive media. UNCD's lower friction can



ADT has the capability, equipment, staff, and business practices in place to supply seals in commercial quantities. ADT routinely processes seals with shaft diameters ranging from 0.375 to 10 inches. Processing capabilities exist to handle both contacting and non-contacting face designs. ADT also has the test and characterization capabilities to qualify seal face materials, evaluate seal wear resistance, and characterize specific end-use performance.

Testing Results: Hot Water

Advanced Diamond Technologies on-site seal testing

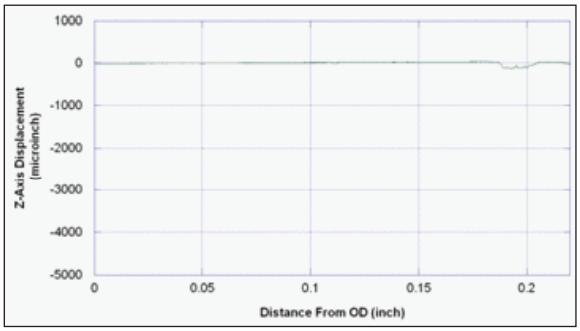
Dynamic Hot-Water Testing

UNCD Faces have been evaluated and testing in over thirty 100 hour dynamic "hot water" tests. These tests included critically evaluating both the mating and primary faces before and after being exposed to a poorly lubricating environment of hot water at 250 °F-300 °F and 100-150 psig using ANSI 3196 (Goulds) pumps. These conditions have been shown to create very aggressive face wear which enables the comparison of different face materials. The 100 hour hot water test simulates over two years of normal operation. The evaluations were run using a conventional blister-resistant carbon primary running against either an alpha-phase, self-sintered SiC mating ring or the UNCD Face using the same SiC.

UNCD Faces within Type A05 Component Seals have neither failed nor leaked within this series of 100 hour evaluations. The UNCD faces have measured minimal wear (tens of micro inches) after completing the 100 hour test. Standard SiC rings, however, exhibit deep grooves measuring well over 4,000 micro-inches which developed in 50 to 75 hours. None of the standard SiC seals ran for the targeted test length of 100 hours due to seal leakage. The standard seals leaked so severely that the tests were consistently aborted. The full technical article detailing these results was published in "Using Ultrananocrystalline Diamond to Improve Mechanical Seal Performance Using Ultrananocrystalline Diamond Performance" in the January 2008 issue of Maintenance Technology.

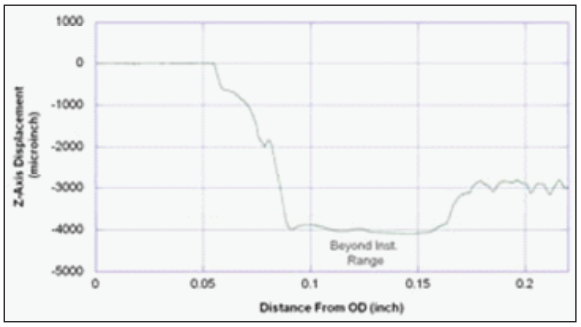
UNCD Seal Face

Surface condition of a UNCD seal face after running in 250 °F water at 100 psig, showing almost no wear.



SiC Seal Face

Surface condition of a silicon carbide seal face after running in 250 °F water at 100 psig, showing deep grooves.



The extreme wear resistance of UNCD Seals has been confirmed by **Argonne National Laboratory**, Advanced Diamond Technologies, Inc. (ADT), and a major seal manufacturer. ADT has a hot water test rig and the necessary characterization equipment to conduct these tests in its facilities. This testing equipment is used to rigorously evaluate suppliers of silicon carbides and other seal elements.

Frequently Asked Questions

What is UNCD?
UNCD (a form of nanocrystalline diamond) captures many of the best properties of natural diamond in a scalable thin film technology enabling diamond to be integrated into a wide range of products including mechanical seal faces. UNCD encompasses a proprietary family of materials manufactured using patented chemical vapor deposition processes. UNCD coatings are not diamond-like carbon films, but phase-pure crystalline diamond materials. For more information about UNCD, please check www.thindiamond.com.

What are the advantages of UNCD Faces?
Advantages of UNCD Faces include lower wear, lower friction, chemical resistance, non-sticking, biocompatibility, and can be mated against both soft and hard face materials.

Why should I use UNCD Faces?
Some reasons are: improve seal reliability, minimize seal leakage, longer seal service life, lower maintenance and operational costs, reduced heat generation for handling temperature sensitive fluid, dry running capability and increased energy efficiency.

Why does UNCD improve mechanical seal performance?
Heat and wear are common reasons for mechanical seal failure. UNCD's very fine grain size and hardness result in exceptionally low friction and outstanding wear resistance for improving mechanical seal performance.

How thick is the UNCD film on the seal face?
The UNCD film on the seal face is only several micrometers thick.

How flat is the UNCD coated seal face?
The flatness is retained from the pre-coated seal face.

Is adhesion of UNCD coating a concern?
No, UNCD has excellent adhesion to the silicon carbide substrate. We pretreat the silicon carbide surface to ensure strong adhesion. The adhesion of the UNCD to the SiC has been measured to be stronger than the intrinsic strength of the SiC.

What counterface materials can be mated with UNCD?
UNCD is so smooth that it can be mated for high seal performance with either soft (carbon) or hard (silicon carbide) faces. Commercial diamond faces of other manufacturers have much coarser larger grain size than UNCD which require a diamond mating face to prevent the counterface from getting chewed up.

Can a UNCD face be mated with itself?
Our focus thus far has involved mating UNCD against conventional seal face materials. Using just one diamond face, instead of both faces diamond, helps lower the cost for the mechanical seal.

How much cooler is the sealing surface due to UNCD's low friction?
The degree of cooling depends on the application. However, with UNCD faces, less heat will be generated that needs to be flushed from the seal.

How smooth is the UNCD coating?
Coating roughness depends on several factors, including the roughness of the substrate and thickness of the coating layer. UNCD coating is smooth as deposited with a typical surface roughness of about 30 nm RMS (approx. 1 microinch).

What tests have been conducted to prove UNCD performance?
Extensive validation tests of UNCD including wear and friction have been conducted over the past several years by us, Argonne National Laboratory, and seal manufacturers.

How does the increased cost of a UNCD seal compare to increased performance?
Every application seems unique. Customers should consider the total cost of ownership of the seal rather than just the purchase price. UNCD can be a great bargain when factoring such benefits as a more reliable seal, and lower maintenance and operational costs. Downtime for many process applications can be very expensive.

How do you grow the UNCD film?
The UNCD film coating is applied to the carbide substrate using a chemical vapor deposition (CVD) method. This method results in converting carbon from a gas to a solid diamond structure using elevated temperatures.

What materials can be coated with UNCD?
We can deposit thin films of UNCD on a variety of substrate materials. Our standard substrate material for UNCD seal faces is alpha self-sintered silicon carbide which is sourced from a variety of leading manufacturers. Chances are good that we can accommodate your chosen grade and brand of silicon carbide.

If I send you a part, will you coat it?
We are not a coating company. We would be happy to supply you seal seats per your engineering drawing with UNCD. If you require a specific source of silicon carbide, please contact us.

Can UNCD facing be repaired or recoated?
Due to the extreme hardness and chemical inertness of UNCD, it is typically impractical to repair. In most cases it is more cost effective to replace than to repair or recoat.

What is the warranty provided with UNCD?
Our warranty is defined in our standard terms and conditions of sale shown at our website.

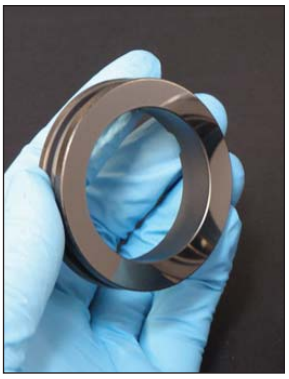
About Advanced Diamond Technologies, Inc. and the history of UNCD Seals:
Advanced Diamond Technologies, Inc. (ADT) is a leading advanced materials company pioneering the use of nanocrystalline diamond films for engineering applications.

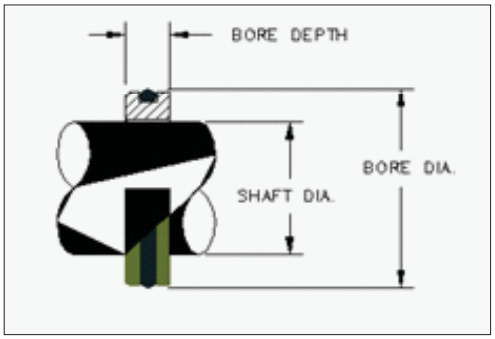
UNCD was invented at Argonne National Laboratory, and Argonne's basic research on UNCD was funded by the Department of Energy's Office of Science. The Industrial Technologies Program (ITP) in DOE's Office of Energy Efficiency and Renewable Energy played a critical role in translating the UNCD technology from basic science into one with industrial benefits — namely UNCD Seals.

After the core UNCD technology was licensed from Argonne into ADT, the National Science Foundation (NSF) has greatly accelerated the development and scale-up of UNCD for pump seal applications via SBIR Phase I, II and IIB grants.

To learn more about ADT, and the UNCD technology, visit ADT's corporate website, at www.thindiamond.com.

UNCD Faces - Datasheet





Product Description

UNCD® is a form of diamond that features very low friction, chemical inertness, and superior wear resistance. UNCD Faces are offered to OEM and seal manufacturers enabling easy access to the benefits of diamond faces. Custom and small-lot quantities of UNCD Faces are routinely produced to our client's engineering drawings providing a "drop-in" improvement to current products and enabling new products with the benefits of diamond. Additionally UNCD Type M05 Stationary Seats are offered for standard ANSI pumps requiring O-ring style mating rings. UNCD Faces have a smooth, thin film of UNCD on silicon-carbide (alpha phase, self-sintered) to improve mechanical seal service life and performance and can be mated against either conventional SiC or carbon counterfaces.

Benefits of UNCD Faces

- Offer the compelling benefits of diamond to your customers with a minimum investment and risk
- Longer lasting seals in demanding applications
- Increased energy efficiency
- Reduced downtime and maintenance costs
- Performs exceptionally well against carbon and silicon carbide counterfaces
- Greater tolerance to dry running and poor lubricating conditions, abrasive slurries, and liquids above their boiling point

Applications and Features

UNCD Faces are designed for industrial applications including chemical, pharmaceutical, petrochemical, food and beverage processing, power generation, pipeline, and pulp and paper. They are particularly suitable for poor lubricating environments, including hot-water and applications that include temperature sensitive media. The low friction of UNCD Faces enables them to be mated with a variety of rotary seal materials including carbon-graphite and silicon carbide. The coefficient of friction (CoF) of the UNCD-silicon carbide combination is between 0.02 - 0.04, well below the CoF values of running carbon against silicon carbide.

In extreme wear tests, the combination of running UNCD against carbon has far outperformed silicon carbide running against carbon.

Product Offering

UNCD Faces are offered to customers engineering drawings in sizes up to 12 inches OD. UNCD Type M05 Stationary Seats are offered in five sizes to accommodate ANSI pumps with shafts from 1.125" to 2.125" diameters. See below for dimensions and related information.

For a quotation for your application, please provide the outside dimensions and/or an engineering drawing and your volume requirements. ADT will provide a quotation for your approval.

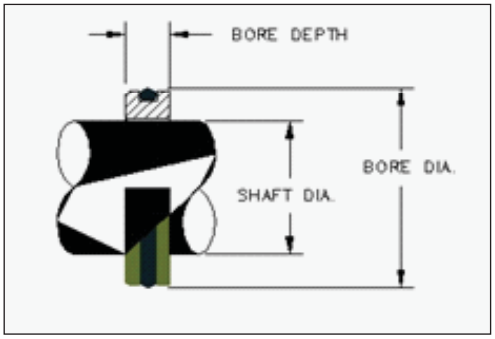
Shaft Dia.	Bore Dia. (+/- 0.002)	Bore Depth	UNCD Mating Faces
1.125	1.750	0.437	M05112503
1.375	2.000	0.437<	M05137503
1.750	2.500	0.500	M05175003
1.875	2.625	0.500	M05187503
2.125	3.000	0.559	M05212503

M05 Seats Tested with Type A05 Componenet Seals

Performance (Operating) Limits

Pressure:	200 psig (13.8 bar g)
Temperature:	-15°F to +400°F (-26°C to 205°C)
PV:	Tested to 350,000 psi•ft/min
Speed:	Up to 5,000 fpm (25 m/s)

UNCD Type A05 Seals for Evaluation



Product Description

UNCD® Type A05 seals are long-lasting, wear-resistant diamond multi-spring pusher component seals that feature the patented UNCD form of diamond. O-rings are used as secondary sealing elements. Components use a snap-ring design and are able to be shaft mounted.

A05 component seals are offered to enable end-users, OEM, and seal manufacturers a quick and easy method of procuring UNCD seals for pilot plant and evaluation purposes in common ANSI pump sizes. In addition to these A05 seals, UNCD Faces are offered to OEM and seal manufacturers in standard ANSI mating ring geometries and can be manufactured to your custom engineering drawings. Please contact us for further information regarding UNCD Faces for your products.

Shaft Dia.	Rotary OD	Rotary Length	Bore Dia. (+/-0.0002)	Bore Depth
1.125	1.562	1.000	1.750	0.437
1.375	1.937	1.375	2.000	0.437
1.750	2.312	1.375	2.500	0.500
1.875	2.500	1.375	2.625	0.500
2.125	2.815	1.687	3.000	0.559

All dimensions in the table above are shown in inches

Applications and Features

These evaluation seals are designed for industrial applications including chemical, pharmaceutical, petrochemical, food and beverage processing, power generation, pipeline and pulp and paper. A05 seals are particularly suitable for poor lubricating environments including hot-water and applications that include temperature sensitive organics. Though the standard A05 configuration pairs a blister resistant carbon primary with a UNCD mating ring, A05 seals are also available in a "hard-on-hard" configuration with a silicon carbide (SiC) primary and UNCD mating ring. The coefficient of friction (CoF) of this hard-on-hard combination is between 0.02-0.04, well below the CoF values of carbon faces running against SiC. Additional technical details and performance testing results can be found here.

Performance (Operating) Limits

Pressure:	200 psig (13.8 bar g)
Temperature:	-15°F to +400°F (-26°C to 205°C)
PV:	Tested to 350,000 psi•ft/min
Speed:	Up to 5,000 fpm (25 m/s)

Media

UNCD seals are appropriate for industrial fluids, aqueous solutions, chemicals, corrosive liquids, high pressure liquids, lubricating fluid, hydrocarbons and solvents.

Materials of Construction

Primary Face:	Blister Resisitant Carbon
Stationary Face: (Mating Ring)	UNCD on SiC
Metal Components:	Stainless Steel and Hastelloy‡ Springs
Elastomers:	Viton†

* Other materials available upon request

† Viton is a registered trademark of DuPont Performance Elastomers LLC
‡ Hastelloy is a registered trademark of Hayes

Sizes

Currently, the A05 Seal is offered in five sizes to accommodate ANSI pumps with shafts of 1.125" to 2.125" diameters. Alternate sizes can be special ordered. All seals are supplied with a rotary head and mating ring whose general design and geometry match the drawing above. DIN sizes are also available. Please contact us to discuss details regarding your specific requirements.

ADVANCED DIAMOND TECHNOLOGIES, INC.

Type A05 —*Multi-spring pusher seals*

Applications

- chemical/ refining
- pharmaceutical
- power generation
- food processing
- pipeline
- pulp & paper
- water/ waste water

Benefits

- Longer lasting seals in demanding applications
- Affordable for mainstream use
- Tolerates dry running and poor lubricating environments
- Low friction enables the use of hard faces in thermally demanding appli-

Product Description

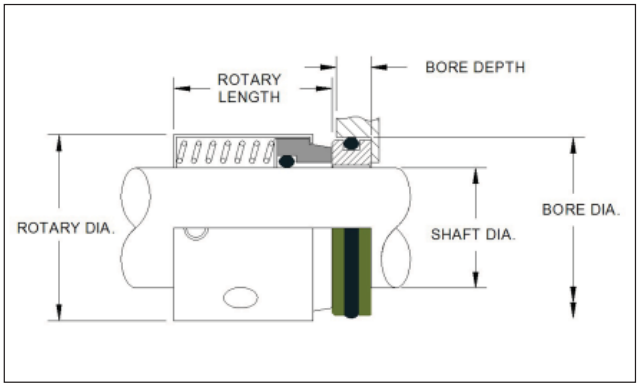
Type A05 seals are long-lasting, multi-spring pusher component seals that feature a proprietary UNCD® form of diamond on the seal ring face. Multiple spring design provides uniform loading of seal face. O-rings are used as secondary sealing elements. Rotary components

Dimensional Data

The UNCD Type A05 Seal is offered in five sizes to accommodate ANSI pumps with shafts of 1 - 1/8" to 2 - 1/8" diameters. Alternate sizes available upon request. All seals are supplied with rotary head and mating ring whose general design and geometry match the drawing and table below.

SHAFT DIA. (+/-0.002)	ROTARY OD	ROTARY LENGTH	BORE DIA. (+/-0.002)	BORE DEPTH	ADT PART NUMBER
1.125	1.562	1.000	1.750	0.375	A051125 C031 122
1.375	1.937	1.375	2.000	0.375	A051375 C031 122
1.750	2.312	1.375	2.500	0.438	A051750 C031 122
1.875	2.500	1.375	2.625	0.438	A051875 C031 122
2.125	2.815	1.687	3.000	0.500	A052125 C031 122

Units in inches



Materials of Construction

Standard construction is 316 stainless steel with Hastelloy® springs and either an alpha-phase self-sintered silicon carbide or a blister resistant carbon primary ring. Mating ring is alpha-phase self-sintered SiC with UNCD Face. O-ring elastomers are Viton® and anti-extrusion ring is PTFE (polytetraflu-

Primary Face: SiC or Blister Resistant Carbon

Stationary Face: SiC with UNCD Face

Metal Components: 316 Stainless Steel & Hastelloy Springs

Performance Limits

Pressure: 200 psig (13.8 bar g)

Temperature: -13 F to +392 F (-25 C to 200 C)

Pressure Velocity: Tested to 350,000 psi.ft.min^{-1}

Media

UNCD Type A05 Seals are appropriate for industrial fluids, aqueous solutions, chemicals, corrosive liquids, high pressure liquids, lubricating fluid, hydrocarbons, and

Version 4.1

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ADVANCED DIAMOND TECHNOLOGIES, INC.

Type A06 —*Bellows seals*

Benefits

- Longer lasting seals in demanding applications
- Affordable for mainstream use
- Tolerates dry running and poor lubricating environments
- Low friction enables the use of hard faces in thermally demanding ap-
- Clog resistant single spring

Applications

- chemical/ refining
- pharmaceutical
- power generation
- food processing
- pipeline
- pulp & paper
- water/ waste water

Product Description

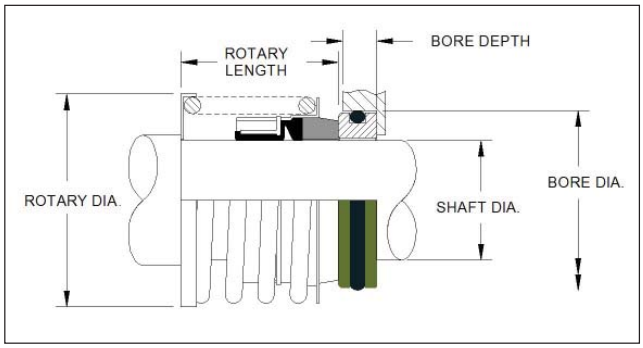
Type A06 seals are long-lasting, wear-resistant, single-spring full convoluted elastomeric bellows seals that feature a proprietary UNCD® form of diamond on the seal ring face. Single coil spring helps reduce risk of clogging. Bellows compensates for abnormal shaft move-

Dimensional Data

The UNCD Type A06 is offered in eight sizes to accommodate ANSI pumps with shafts of 1 - 1/8" to 2 - 1/2" diameters. Alternate sizes available upon request. All seals are supplied with a rotary head and mating ring whose general design and geometry match the drawing and table below.

SHAFT DIA. (+/-0.002)	ROTARY OD	ROTARY LENGTH	BORE DIA. (+/-0.002)	BORE DEPTH	ADT PART NUMBER
1.125	1.625	1.625	1.750	0.375	A061125 C031 122
1.375	1.875	1.687	2.000	0.375	A061375 C031 122
1.500	2.000	1.687	2.125	0.375	A061500 C031 122
1.750	2.375	2.000	2.500	0.438	A061750 C031 122
1.875	2.500	2.125	2.625	0.438	A061875 C031 122
2.000	2.625	2.125	2.750	0.438	A062000 C031 122
2.125	2.812	2.375	3.000	0.500	A062125 C031 122
2.500	3.187	2.500	3.375	0.500	A062500 C031 122

Units in Inches



Materials of Construction

Standard construction is 316 stainless steel and either an alpha-phase self-sintered silicon carbide or a blister resistant carbon primary ring. Mating ring is alpha-phase self-sintered SiC with UNCD Face. Bellows and o-ring elas-

Primary Face: SiC or Blister Resistant Carbon

Stationary Face: SiC with UNCD Face

Metal Components: 316 Stainless Steel

Performance Limits

Pressure: 400 psig (27.2 bar g)

Temperature: -13 F to +392 F (-25 C to 200 C)

Pressure Velocity: Tested to 350,000 psi.ft.min^{-1}

Media

UNCD Type A06 Seals are appropriate for industrial fluids, aqueous solutions, chemicals, corrosive liquids, high pressure liquids, lubricating fluid, hydrocar-

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