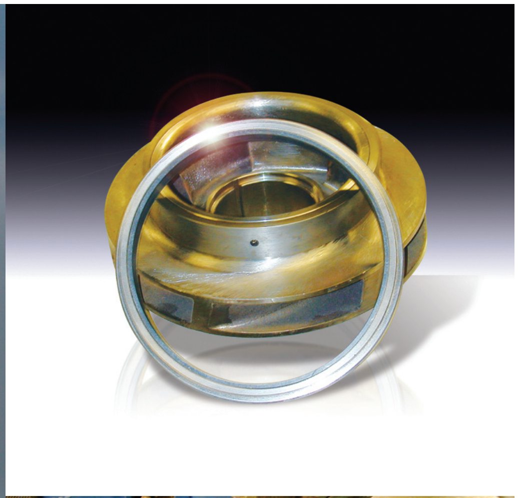
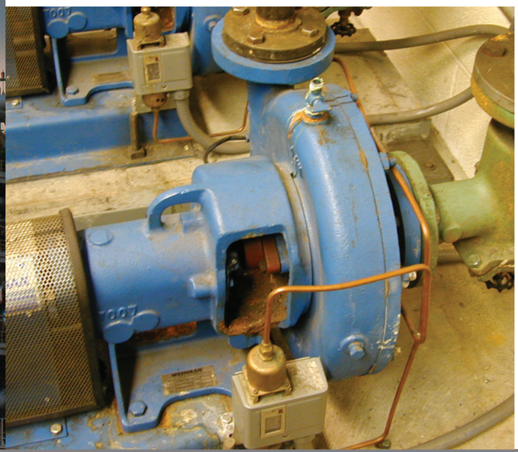
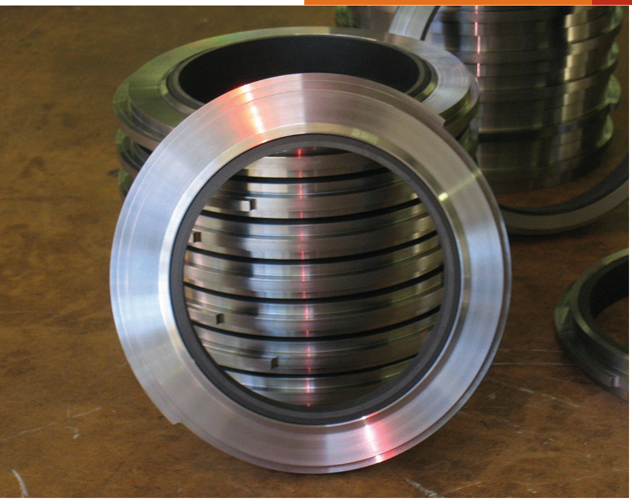




DuPont™ Vespel® CR-6100

APPLICATION AND INSTALLATION GUIDE FOR CENTRIFUGAL PUMP STATIONARY WEAR PARTS

The miracles of science™



Fluid processing industries have embraced the use of composite materials in pumps to reduce vibration, increase mechanical seal life and MTBR (mean time between repair), reduce the risk of seizure, increase efficiency, and reduce repair costs. API 610, 10th Edition (ISO standard 13709), the latest centrifugal pump standard from the American Petroleum Institute (API), recognizes the use of composites to achieve these benefits.

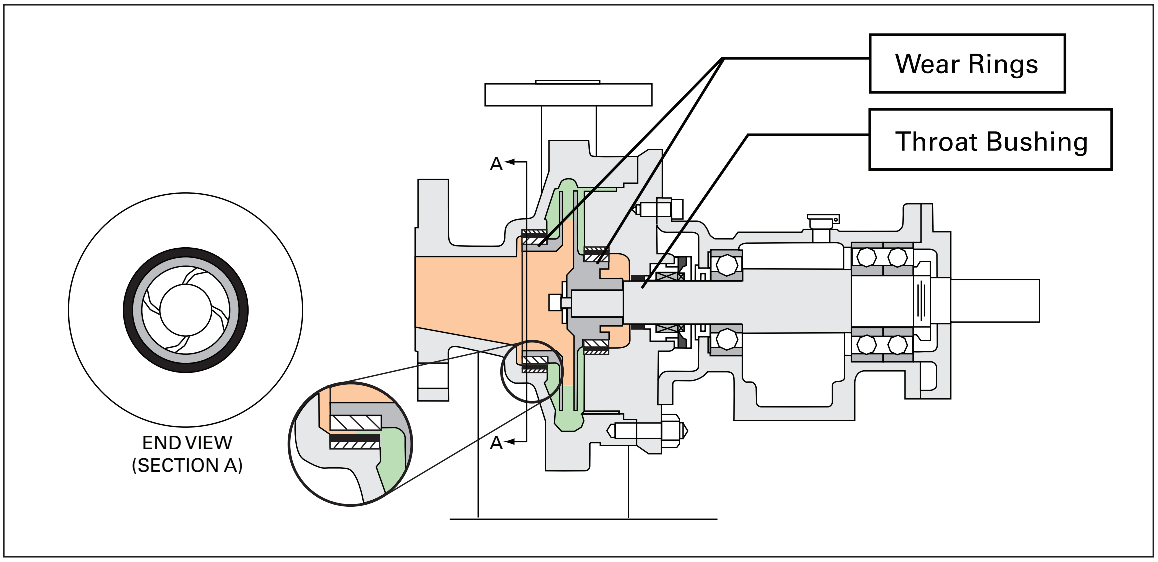
The function of wear rings

Wear rings are installed with close radial clearances and separate rotating and stationary, higher and lower-pressure sections of a pump. When shaft deflection occurs due to off-design operation, wear rings can experience contact. Historically, wear rings have been made from metal, which can gall and seize the pump under contacting or run-dry conditions, resulting in abrupt, high-energy pump failure. With metal wear rings, design clearance is increased to prevent failure, which has a negative effect on efficiency, suction conditions, and overall pump vibration. Vespel® CR-6100 can be installed with reduced clearances, without increasing the risk of seizure while improving pump performance. (See **Figure 1**.)

Background

The CR-6100 grade of DuPont™ Vespel® parts and shapes is a composite material consisting of carbon fibers held in a Teflon® fluorocarbon resin matrix (PFA/CF Reinforced Composite, 20 wt% random x-y oriented carbon-fiber). Vespel® CR-6100 has been installed in thousands of pumps in refineries, chemical plants, power plants, and other fluid processing facilities since 1996. It has replaced metal and other composite materials used for pump wear rings, throat bushings, and line shaft bearings to help users increase pump reliability and performance. The properties of Vespel® CR-6100 help to reduce the risk of pump seizure and allow internal rotating-to-stationary part clearances to be reduced by 50% or more.

Figure 1. The function of wear rings



Operational and Safety Benefits of Vespel® CR-6100 Wear Parts

DuPont™ Vespel® CR-6100 mitigates the risk of damage from wear ring contact, which can result from mechanical failure, off-design operation, or dry running. When metal wear rings contact, the extreme friction generates heat, the materials gall (friction weld), and the pump can seize. This is potentially a high energy, dangerous situation, which can result in extensive equipment damage and potential release of process fluid to the atmosphere. Vespel® CR-6100 wear rings minimize the risk of galling or seizure, thereby reducing the consequences of failure and risk of damage to expensive cast metal parts, reducing repair costs.

Vespel® CR-6100 wear rings also minimize the impact of run-dry conditions. Pumps resist seizure during periods of suction loss, off-design operation, slow rolling, or start-up conditions. When the upset condition has been corrected, the pump can frequently continue in service without further damage or loss of performance. Conversely, pumps with metal wear rings exposed to these conditions frequently experience galling and seizure, requiring removal from service, disassembly, and repair.

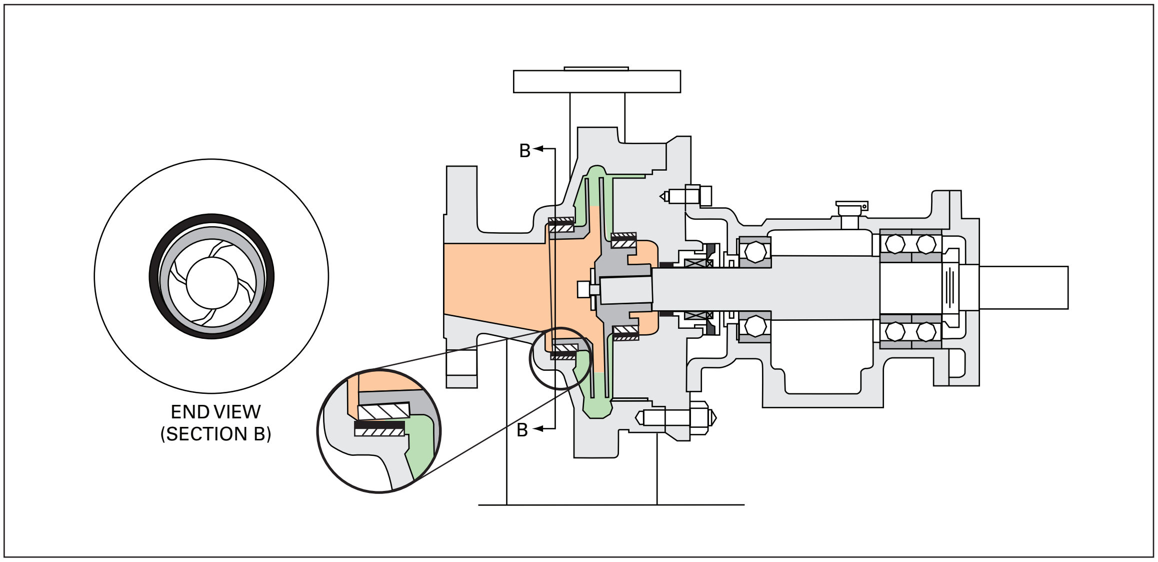
The impact of off-design operation

Hydraulically off-design operation or mechanical faults result in shaft deflection and wear rings running off-center, frequently resulting in wear ring contact. When this occurs, metal wear rings can seize causing the pump to fail. Vespel® CR-6100 is not known to seize, allowing the pump to continue operation under these conditions. (See **Figure 2**.)

Maintenance Benefits

For personnel who are repairing pumps, the easy installation of Vespel® CR-6100 reduces repair time. This increases equipment availability for service and reduces the operational tensions of long-term equipment repair. Repair time is reduced because parts can be produced and fitted quickly. Vespel® CR-6100 can be machined into parts with thin radial walls of 1/8 in (3.175 mm) (up to 10 in [125.4 cm] diameter) allowing application in nearly all pump configurations. The material properties of Vespel® CR-6100 allow it to be machined at high speeds and feed rates with the use of standard machine tooling. It does not require heat-treating or hard facing like some metal wear materials. In addition, material selection is simplified as Vespel® CR-6100 has near universal chemical compatibility and can run against metallic wear ring materials.

Figure 2. The impact of off-design operation



Properties of DuPont™ Vespel® CR-6100 for Centrifugal Pump Wear Parts

Vespel® CR-6100 offers a combination of properties, allowing material standardization over a wide range of process services due to its low coefficient of thermal expansion, high temperature limit, chemical compatibility, machining characteristics, high impact strength, low coefficient of friction, and high PV (pressure-velocity) capacity. The low coefficient of thermal expansion, low coefficient of friction, low wear rate, and high PV combine to provide performance in run-dry conditions. Vespel® CR-6100 machines easily and the high impact strength reduces the risk of breakage during installation and under pump operating conditions such as extreme cavitation, bearing failure, or high vibration.

The Benefit of Reduced Clearances

When the risk of seizure is mitigated, wear ring clearance can be reduced. Reduced wear ring clearance increases reliability and performance. **Table A** lists sample Vespel® CR-6100 clearances compared to standard API clearances.

Reduced clearance increases pump reliability because wear rings act as hydrodynamic bearings within the pump--a phenomenon known as the Lomakin Effect. The radial force from the wear rings is a function of differential pressure, speed, the process fluid properties, and the inverse of the wear ring clearance. Therefore, reductions in wear ring clearance increase the hydraulic radial force on the rotor. In many pump types, this additional hydraulic force will have the effect of reducing overall pump vibration, reducing shaft deflection, and increasing the pump life.

Reduced clearance also reduces internal pump re-circulation, which yields equivalent production flow at reduced horsepower (i.e., increased efficiency). Applied on large pumps or across a large population of equipment, substantial annual savings are possible. Alternatively, reduced clearance can increase the production capacity of existing equipment. A further benefit of reduced clearance is that the pump Net Positive Suction Head Required (NPSHR) may decrease by as much as 2–3 feet (60.96–91.44 cm), often providing the margin required in tough applications.

Table A: Vespel® CR-6100 clearances compared to standard minimum API diametrical clearances

Bore Diameter (in)	Bore Diameter (mm)	Vespel® CR-6100 Clearance	API Minimum Clearance
4.001–5.000	101.6–127.0	0.007 in (0.187 mm)	0.015 in (0.381 mm)
5.001–6.000	127.0–152.4	0.008 in (0.203 mm)	0.017 in (0.4381 mm)
6.001–7.000	152.4–177.8	0.009 in (0.2286 mm)	0.018 in (0.4572 mm)
7.001–8.000	177.8–203.2	0.010 in (0.254 mm)	0.019 in (0.4826 mm)
8.001–9.000	203.2–228.6	0.011 in (0.2794 mm)	0.020 in (0.508 mm)

DuPont™ Vespel® CR-6100 is suitable for pump wear rings, throat bushings, and line shaft bearings.

Service Limits

Vespel® CR-6100 can be used in temperatures from cryogenic up to 550°F (288°C). The low x-y plane thermal growth of Vespel® CR-6100 allows close clearances to be maintained over the entire temperature range. (**Figure 3** shows the orientation of the x-y plane and z direction.) Note that interference fits and axial clearance need to be adjusted with temperature. Best performance is achieved in non-abrasive services. Vespel® CR-6100 has been installed with success in services with low concentrations of solids, however, performance may not be consistent due to many variables, which can cause premature wear. Pipe scale and other common debris in low concentrations are not typically a problem. Users should rely upon field experience and apply appropriately.

Table B: Pump parts, which can be converted to Vespel® CR-6100.

Pump Type	Vespel® CR-6100 Parts
Overhung and Vertical Inline (API Pumps)	Stationary* wear rings and throat bushings
Single stage between bearings	Stationary wear rings and throat bushings
Multi-stage horizontal	Stationary wear rings, throat bushings, inter-stage bushings, and pressure reducing bushings
Vertical	Stationary wear rings, inter-stage bushings, line shaft bearings, and throat bushings

*Vespel® CR-6100 should be mounted in compression, which in nearly all pumps will be the stationary, case and head rings.

Wear Rings

Vespel® CR-6100 is used as the stationary wear rings in a wide range of centrifugal pump types (**Table B**). For pumps in non-abrasive services under 550°F (288°C), Vespel® CR-6100 can be applied to reduce wear ring clearance, resulting in improved reliability and performance. Vespel® CR-6100 can also be applied to services prone to off-design operation, minimizing the risk of seizing failures associated with metal wear rings and allowing the pump to continue in service after temporary run-dry conditions.

Figure 3. Orientation of material

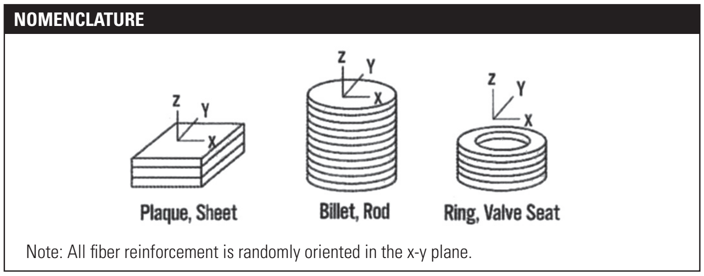
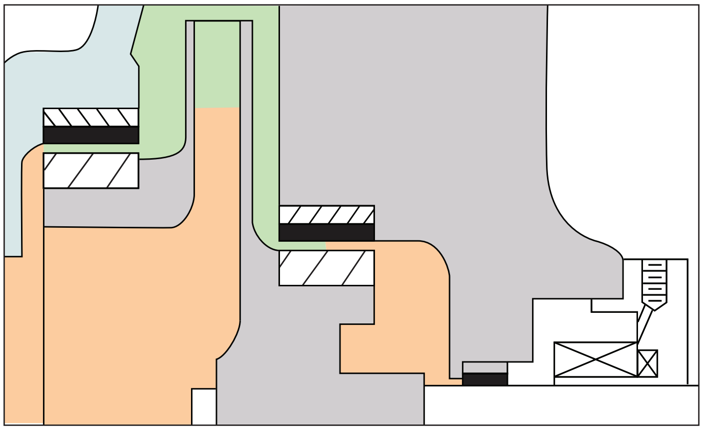


Figure 4. Installation of Vespel® CR-6100 wear rings and throat bushing in typical overhung pump



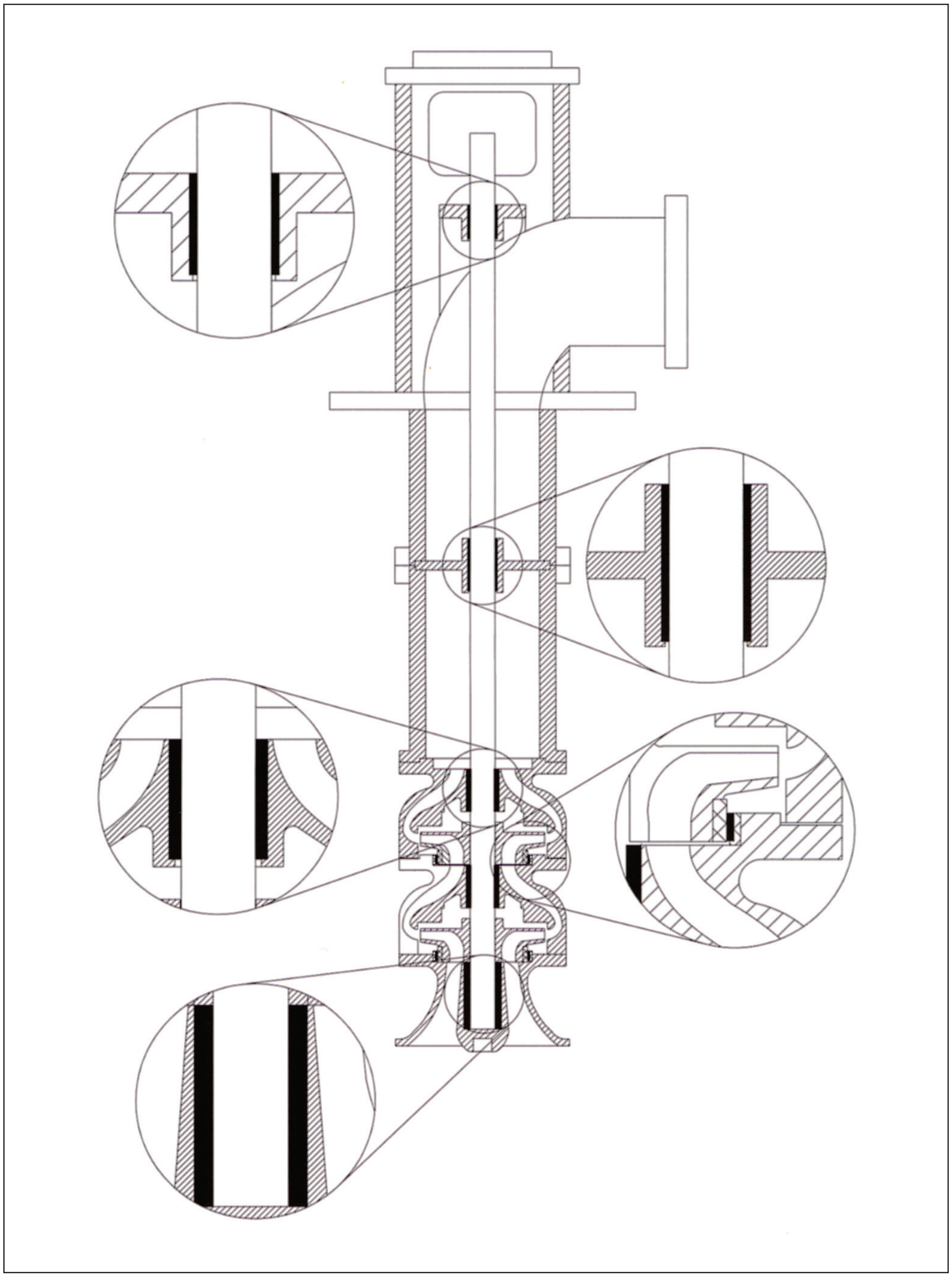
Throat Bushings

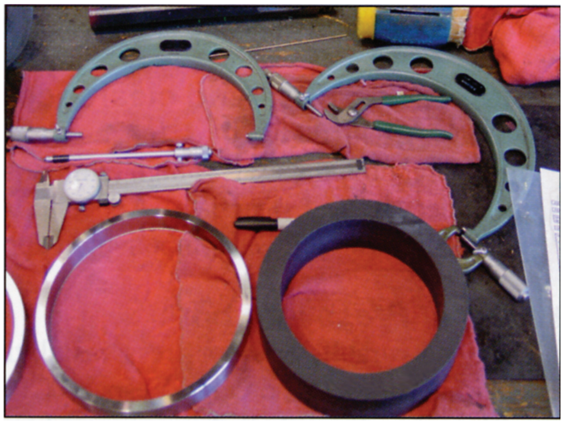
Mechanical seals generally require a flush with a close clearance throat bushing installed to control the fluid environment at the mechanical seal. The close clearance forms a barrier, which isolates the mechanical seal environment from the process fluid. Vespel® CR-6100 throat bushings can used instead of specially fabricated, spring-loaded, carbon bushings for close clearance applications. Vespel® CR-6100 bushings are less expensive, easier to install, and more durable than the specialty bushings. Vespel® CR-6100, installed with minimal clearance, improves the performance of several common seal flush plans used across the fluid processing industries.

Vertical Pump Parts

DuPont™ Vespel® CR-6100 can be used for vertical pump line shaft bearings, wear rings, throat bushings (**Figure 5**). Typically these parts are made from rubber, bronze, carbon, or other materials, which can be replaced with Vespel® CR-6100. In light hydrocarbons, condensate, or other services with limited lubricity, Vespel® CR-6100 delivers improved pump reliability. (Additional clearance may be required for some vertical pump components; see "Note on Vertical Pumps" in installation section.)

Figure 5. Vespel® CR-6100 installed in vertical pump





DuPont™ Vespel® CR-6100 pump components are easy to machine and install. Components are fitted into machined holders or directly into the pump casing, whichever is easier and more economical. Because Vespel® CR-6100 can be installed with thin radial walls (**Appendix A, Table 5**) end-users often find that installing a Vespel® CR-6100 "sleeve" inside an existing metal wear component is the easiest way to use the material. Whether the Vespel® CR-6100 is installed as a sleeve or a solid component, it is essential for it to be installed with the correct interference fit, clearance, and end clearance for axial growth.

Step 1: Select interference fit from Table 1 or Table 2

Because metals have higher coefficients of thermal expansion than Vespel® CR-6100 in the x-y plane (the O.D./I.D. of a wear ring), the interference fit at ambient temperature will be different than interference fit at process temperature. Use maximum process fluid temperature and component diameter to determine fits.

A. Appendix A, Table 1 (Carbon Steel): shows the installation fits for a range of application temperature when Vespel® CR-6100 is installed into pumps made of carbon steel (or other metals with a similar coefficient of thermal expansion).

B. Appendix A, Table 2 (Stainless Steel): shows installation fits for a range of application temperatures when Vespel® CR-6100 is installed into metal components made of 300 series stainless steel (or other metals with similar coefficients of thermal expansion).

Note: In general, components with cross sections of less than 0.250 inch (6.35 mm) the bore will decrease on a 1 to 1 ratio with the interference fit (i.e., if the interference fit is 0.015 inch (0.381 mm), the bore will decrease by 0.015 inch (0.381 mm) after the press operation)

Step 2: Select running clearance from Table 3

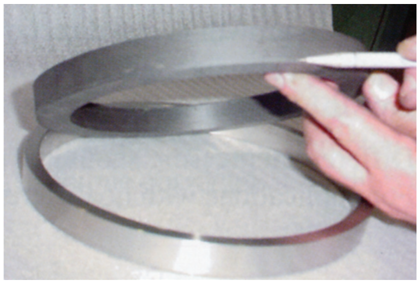
Appendix A, Table 3 shows recommended running clearance based on component diameter. Unlike materials with high coefficients of thermal expansion, the installed clearance of Vespel® CR-6100 remains constant over the full application temperature range. This is because as temperature increases, stress in the material is relieved and the I.D. will increase at the same CTE as the material of the bore that it is pressed into. Temperature correction is only required when the impeller and case are different materials (which is true for all wear ring materials). Simply identify the I.D. of the Vespel® CR-6100 component, and select the appropriate clearance from the table.

Note: Where possible it is recommended to final machine the I.D. of the Vespel® CR-6100 component after the press fit operation. This practice ensures the best possible accuracy, surface finish, and concentricity of the component bore.

Note on Vertical Pumps: Many multi-stage vertical pumps are assembled in sections with pilot fits that may be larger than the recommended minimum clearance for Vespel® CR-6100. In these situations, it is essential that the repair facility either install the Vespel® CR-6100 line shaft bearings with additional clearance, or tighten the pilot fits between sections to ensure adequate rotor concentricity.

Step 3: Establish end clearance

DuPont™ Vespel® CR-6100 has directional carbon fibers, which provide a low CTE in the x-y plane. In the z direction, the CTE is high (similar to the resin), which requires components to be installed with adequate end clearance. **Appendix A, Table 4** shows required end clearance per inch of axial length for a given component in applications to 550°F (288°C).



Pilot or chamfer as indicated

Step 4: Press into bore

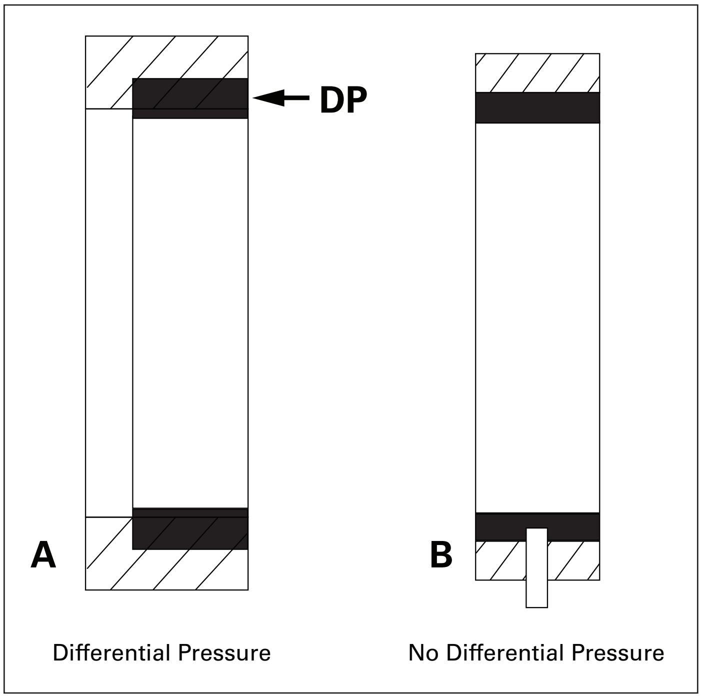
Using a hydraulic or arbor press, install the DuPont™ Vespel® CR-6100 component. Before pressing, be sure that the metal bore has an adequate lead-in chamfer and all sharp corners have been removed. Many users also find the press operation easier if the leading edge of the Vespel® CR-6100 wear ring has been machined with a 0.08 inch (2 mm) long, zero interference pilot fit.

Step 5: Locking

Installed with the proper interference fit, field experience indicates additional mechanical locking devices in Vespel® CR-6100 wear rings are **not** required. However, differential pressure should be pushing the Vespel® CR-6100 against a shoulder (**Figure 6, A**) to prevent axial movement of the Vespel® CR-6100 component. For applications with no differential pressure, radial pins can be used for retention (**Figure 6, B**).

Typically a shoulder 0.06 inch (1.524 mm) minimum thick is provided to prevent the stationary wear ring from becoming dislodged axially from the holder due to differential pressure. The radial wall thickness of the holder typically is 0.125 in (3.175 mm) minimum. For applications where differential pressures are very high, or the pump has other unique characteristics, the solution should be engineered to fit. Contact your local DuPont™ Vespel® CR-6100 representative for additional support.

Figure 6. Retention for differential pressure



Appendix A

Table 1A: Carbon Steel Case/Head—English Units   CTE = 6.5 x 10^{-6} in/in/F
These are recommended installation interference fits.

Bore Diameter (in)	Pump Operating Temperature, °F									
	At or below Ambient	100	150	200	250	300	350	400	450	500
0.001–1.000	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.005
1.001–2.000	0.005	0.005	0.006	0.006	0.006	0.007	0.007	0.007	0.008	0.008
2.001–3.000	0.007	0.007	0.008	0.009	0.009	0.010	0.010	0.011	0.011	0.012
3.001–4.000	0.008	0.008	0.009	0.010	0.011	0.012	0.013	0.013	0.014	0.015
4.001–5.000	0.010	0.011	0.012	0.013	0.014	0.015	0.016	0.017	0.018	0.019
5.001–6.000	0.012	0.013	0.014	0.015	0.017	0.018	0.019	0.021	0.022	0.023
6.001–7.000	0.014	0.015	0.016	0.018	0.019	0.021	0.023	0.024	0.026	0.027
7.001–8.000	0.016	0.017	0.019	0.021	0.022	0.024	0.026	0.028	0.029	0.031
8.001–9.000	0.018	0.019	0.021	0.023	0.025	0.027	0.029	0.031	0.033	0.035
9.001–10.000	0.020	0.021	0.024	0.026	0.028	0.030	0.033	0.035	0.037	0.039
10.001–11.000	0.022	0.023	0.026	0.028	0.031	0.033	0.036	0.038	0.041	0.043
11.001–12.000	0.024	0.026	0.028	0.031	0.034	0.036	0.039	0.042	0.045	0.047
12.001–13.000	0.026	0.028	0.031	0.034	0.037	0.040	0.042	0.045	0.048	0.051
13.001–14.000	0.028	0.030	0.033	0.036	0.039	0.043	0.046	0.049	0.052	0.056
14.001–15.000	0.030	0.032	0.035	0.039	0.042	0.046	0.049	0.052	0.056	0.059
15.001–16.000	0.032	0.034	0.038	0.041	0.045	0.048	0.052	0.056	0.059	0.063

Table 1B: Carbon Steel Case/Head—SI Units   CTE = 11.8 x 10^{-6} cm/cm/C
These are recommended installation interference fits.

Bore Diameter (mm)	Pump Operating Temperature, °C									
	At or below Ambient	38	66	93	121	149	177	204	232	260
0.0–25.4	0.102	0.102	0.102	0.102	0.102	0.127	0.127	0.127	0.127	0.127
25.4–50.8	0.127	0.127	0.152	0.152	0.152	0.178	0.178	0.178	0.203	0.203
50.8–76.2	0.178	0.178	0.203	0.229	0.229	0.254	0.254	0.279	0.279	0.305
76.2–101.6	0.203	0.203	0.229	0.254	0.279	0.305	0.330	0.330	0.356	0.381
101.6–127.0	0.254	0.279	0.305	0.330	0.356	0.381	0.406	0.432	0.457	0.483
127.0–152.4	0.305	0.330	0.356	0.381	0.432	0.457	0.483	0.533	0.559	0.584
152.4–177.8	0.356	0.381	0.406	0.457	0.483	0.533	0.584	0.610	0.660	0.686
177.8–203.2	0.406	0.432	0.483	0.533	0.559	0.610	0.660	0.711	0.737	0.787
203.2–228.6	0.457	0.483	0.533	0.584	0.635	0.686	0.737	0.787	0.838	0.889
228.6–254.0	0.508	0.533	0.610	0.660	0.711	0.762	0.838	0.889	0.940	0.991
254.0–279.4	0.559	0.584	0.660	0.711	0.787	0.838	0.914	0.965	1.041	1.092
279.4–304.8	0.610	0.660	0.711	0.787	0.864	0.914	0.991	1.067	1.143	1.194
304.8–330.2	0.660	0.711	0.787	0.864	0.940	1.016	1.067	1.143	1.219	1.295
330.2–355.6	0.711	0.762	0.838	0.914	0.991	1.092	1.168	1.245	1.321	1.422
355.6–381.0	0.762	0.813	0.889	0.991	1.067	1.168	1.245	1.321	1.422	1.499
381.0–406.4	0.813	0.864	0.965	1.041	1.143	1.219	1.321	1.422	1.499	1.600

Table 2A: 300 Series Stainless Case/Head—English Units CTE = 9.60 x 10^{-6} in/in/F
These are recommended installation interference fits.

Bore Diameter (in)	Pump Operating Temperature, °F									
	At or below Ambient	100	150	200	250	300	350	400	450	500
0.001–1.000	0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.005	0.005	0.006
1.001–2.000	0.005	0.005	0.006	0.007	0.007	0.008	0.008	0.009	0.009	0.010
2.001–3.000	0.007	0.008	0.009	0.010	0.011	0.011	0.012	0.013	0.014	0.015
3.001–4.000	0.008	0.009	0.010	0.012	0.013	0.014	0.016	0.017	0.018	0.020
4.001–5.000	0.010	0.011	0.013	0.015	0.016	0.018	0.020	0.022	0.023	0.025
5.001–6.000	0.012	0.013	0.015	0.018	0.020	0.022	0.024	0.026	0.028	0.030
6.001–7.000	0.014	0.016	0.018	0.021	0.023	0.026	0.028	0.031	0.033	0.036
7.001–8.000	0.016	0.018	0.021	0.024	0.027	0.029	0.032	0.035	0.038	0.041
8.001–9.000	0.018	0.020	0.023	0.027	0.030	0.033	0.037	0.040	0.043	0.047
9.001–10.000	0.020	0.022	0.026	0.030	0.033	0.037	0.041	0.044	0.048	0.052
10.001–11.000	0.022	0.024	0.029	0.033	0.037	0.041	0.045	0.049	0.053	0.057
11.001–12.000	0.024	0.027	0.031	0.036	0.040	0.045	0.049	0.054	0.058	0.063
12.001–13.000	0.026	0.029	0.034	0.039	0.044	0.048	0.053	0.058	0.063	0.068
13.001–14.000	0.028	0.031	0.036	0.042	0.047	0.052	0.057	0.063	0.068	0.073
14.001–15.000	0.030	0.033	0.039	0.046	0.050	0.056	0.061	0.067	0.072	0.078
15.001–16.000	0.032	0.036	0.042	0.048	0.056	0.060	0.066	0.072	0.078	0.084

Table 2B: 300 Series Stainless Case/Head—SI Units CTE = 17.4 x 10^{-6} cm/cm/C
These are recommended installation interference fits.

Bore Diameter (mm)	Pump Operating Temperature, °C									
	At or below Ambient	38	66	93	121	149	177	204	232	260
0.0–25.4	0.102	0.102	0.102	0.127	0.127	0.127	0.127	0.127	0.127	0.152
25.4–50.8	0.127	0.127	0.152	0.178	0.178	0.203	0.203	0.229	0.229	0.254
50.8–76.2	0.178	0.203	0.229	0.254	0.279	0.279	0.305	0.330	0.356	0.381
76.2–101.6	0.203	0.229	0.254	0.305	0.330	0.356	0.406	0.432	0.457	0.508
101.6–127.0	0.254	0.279	0.330	0.381	0.406	0.457	0.508	0.559	0.584	0.635
127.0–152.4	0.305	0.330	0.381	0.457	0.508	0.559	0.610	0.660	0.711	0.762
152.4–177.8	0.356	0.406	0.457	0.533	0.584	0.660	0.711	0.787	0.838	0.914
177.8–203.2	0.406	0.457	0.533	0.610	0.686	0.737	0.813	0.889	0.965	1.041
203.2–228.6	0.457	0.508	0.584	0.686	0.762	0.838	0.940	1.016	1.092	1.194
228.6–254.0	0.508	0.559	0.660	0.762	0.838	0.940	1.041	1.118	1.219	1.321
254.0–279.4	0.559	0.610	0.737	0.838	0.940	1.041	1.143	1.245	1.346	1.448
279.4–304.8	0.610	0.686	0.787	0.914	1.016	1.143	1.245	1.372	1.473	1.600
304.8–330.2	0.660	0.737	0.864	0.991	1.118	1.219	1.346	1.473	1.600	1.727
330.2–355.6	0.711	0.787	0.914	1.067	1.194	1.321	1.448	1.600	1.727	1.854
355.6–381.0	0.762	0.838	0.991	1.168	1.270	1.422	1.549	1.702	1.829	1.981
381.0–406.4	0.813	0.914	1.067	1.219	1.422	1.524	1.676	1.829	1.981	2.134

Table 3A: Recommended Running Clearance—English Units

Bore Diameter (in)	Diametrical Clearance (in)
0.001–1.000	0.004
1.001–2.000	0.004
2.001–3.000	0.005
3.001–4.000	0.006
4.001–5.000	0.007
5.001–6.000	0.008
6.001–7.000	0.009
7.001–8.000	0.010
8.001–9.000	0.011
9.001–10.000	0.012
10.001–11.000	0.013
11.001–12.000	0.014
12.001–13.000	0.015
13.001–14.000	0.015
14.001–15.000	0.016
15.001–16.000	0.016

Table 3B: Recommended Running Clearance—SI Units

Bore Diameter (mm)	Diametrical Clearance (mm)
0.0–25.4	0.102
25.4–50.8	0.102
50.8–76.2	0.127
76.2–101.6	0.152
101.6–127.0	0.178
127.0–152.4	0.203
152.4–177.8	0.229
177.8–203.2	0.254
203.2–228.6	0.279
228.6–254.0	0.305
254.0–279.4	0.330
279.4–304.8	0.356
304.8–330.2	0.368
330.2–355.6	0.381
355.6–381.0	0.394
381.0–406.4	0.406

Table 4A: Axial End Clearance—English Units

Process Temperature, °F	Axial Growth at Temperature in inches per inch (based on 68°F ambient temperature)
–100	–0.030
–50	–0.020
0	–0.012
50	–0.003
100	0.006
150	0.015
200	0.024
250	0.033
300	0.042
350	0.054
400	0.067
450	0.092
500	0.118

Table 4B: Axial End Clearance—SI Units

Process Temperature, °C	Axial Growth at Temperature in mm per mm of axial length (based on 20°C ambient temperature)
–73	–0.030
–46	–0.020
–18	–0.012
10	–0.003
38	0.006
66	0.015
93	0.024
121	0.033
149	0.042
177	0.054
204	0.067
232	0.092
260	0.118

Table 5A: Minimum Wall Thickness—English Units

Bore Diameter (in)	Minimum Wall Thickness (in)
0.000–2.000	0.062
2.001–4.000	0.087
>4.000	0.125

Table 5B: Minimum Wall Thickness—SI Units

Bore Diameter (mm)	Minimum Wall Thickness (mm)
0.0–50.8	1.575
50.8–101.6	2.210
>101.6	3.175

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K-16392-4 (09/09) Printed in the U.S.A.

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