# DuPont™ Vespel®
# Pump Reliability Technology

## Vespel® CR-6100 USAGE GUIDELINES

The miracles of science™

## Purpose

This document is intended to provide a standard method for the appropriate design, installation and application of Vespel® CR-6100 composite wear components in pump repairs, new pump design and pump upgrades.

## Benefits

Improved rotor dynamics, reliability and efficiencies may be realized on pumps equipped with Vespel® CR-6100 wear parts. Performance benefits are possible for the following pump application operating conditions and needs:

- Dry running caused by suction loss for short periods.
- Slow roll, start up and transient conditions.
- Extended running at low flow conditions.
- High vibration applications which cause reduced bearing and mechanical seal life.
- Low pump efficiency affecting pump flow and power consumption.
- Increased seal chamber pressure requirements.
- Minimize internal pump component damage and repair costs in the event of pump failure.
- Decreased mechanical seal emissions and improved pump and plant safety.

## Scope

Vespel® CR-6100 can be applied in many types of pumps and pump components. Experience includes:

- Wear rings (always mount parts in compression, which in nearly all pumps will be the stationary case and head rings, not the rotating impeller rings)
- Throat bushings
- Center-stage bushings (Solid and split type)
- Pressure reducing bushings
- Bowl bushings
- Line shaft bushings
- Single stage overhung pumps, horizontal and vertical in-line
- Between bearing pumps, single stage and multi-stage
- Vertical suspended pumps, turbine and multi-stage

## Material Description

The CR-6100 grade of DuPont™ Vespel® is a composite material consisting of carbon fibers held in a Teflon® fluorocarbon resin matrix (PFA/CF reinforced composite 20% random x-y oriented carbon fiber). Typical properties are listed in **Table 7** and may also be found at the DuPont website www.vespel.dupont.com.

## Application Limits

Vespel® CR-6100 has been successfully applied under the following applications conditions and limits:

- Continuous use temperature limits: -423F (-253 C) to 550F (288C).
- Maximum differential pressure across parts: 350 psi/linear inch (0.095MPa/linear mm). (Note: Applications with a greater differential pressure require an engineering review. Consult your Vespel® distributor).
- Fluid compatibility: Vespel® CR-6100 has been applied in various refinery, chemical process and utility services. Usages include service in cooling tower water, condensate, boiling water, process water, boiler feed water, foul water, hydrocarbons containing water, propane, butane, LPG, ammonia, diesel oil, residuum, fuel oil, gasoline, naptha, kerosene, gas oil, lube oil, cumene, MEK, xylene, ethylene, isomerate, sea water, sour water, lean MEA, lean DEA, sulfuric acid, phosphoric acid, acetic acid, hydrofluoric acid, hydrochloric acid, aniline, liquid bromine, and fluorocarbon products.*
- Abrasion resistance: Vespel® CR-6100 has been used in services with low concentrations of solids. Recommended upper limits have yet to be determined. 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. Avoid highly abrasive services which can include crude oil, tower bottoms, catalyst and coker pumps. In general, if the current pump wear component materials are hardened or hard coated with specialty metals to manage high abrasion environment, Vespel® CR-6100 should not be used as a replacement.

Vespel® CR-6100 wear rings and bushings have demonstrated the ability to operate running against all of

* This information is based on DuPont general experience and testing and is believed reliable and descriptive of the typical characteristics of the product. However, it is the customer's responsibility to test the product in each specific application to determine the performance and safety in each end use product, device or other application.

the standard metal shaft and rotating impeller wear ring materials listed in API Standard 610. The use of composite impeller wear rings running against Vespel® CR-6100 however is not recommended. The use of metal impeller rings running against Vespel® CR-6100 stationary wears is more cost effective and provides the best proven wear performance. Vespel® CR-6100 must also be held in compression with an interference fit on its OD. Mounting Vespel® CR-6100 on its ID will impart high tensile stress and should be avoided.

## Machining Practices

Vespel® CR-6100 can be machined on metal working equipment by standard lathe single point turning. Suggested techniques include:

- Use carbide tipped tools with a 5 degree to 15 degree rake angle at the front face and a positive (0 to 5 degree) back rake angle. For longer production runs, diamond tipped tools or inserts provide increased tool life.
- Use feeds and speeds appropriate for turning aluminum.
- Coolant is not normally required for turning, unless there is a particular need to maximize dimensional stability.
- Turned diameter surface finishes of 63 micro-inches (1.6 micro-meters) are typical using a visual surface finish reference guide.

Additional information can be found at the DuPont™ Vespel® website www.vespel.dupont.com in the document "Vespel® CR-6100 General Machining Guide".

Bushing grooves, axial and spiral type, can be generated using standard carbide tipped broaching tools or end mills.

As in machining all fluorocarbon materials, part temperature should be maintained below 572°F (300°C) to avoid the possible liberation of a fine particulate fume. Inhalation may cause polymer fume fever. See the DuPont MSDS for Vespel® CR-6100 if more detailed information is required.

## General Design Guidelines

- Vespel® CR-6100 components can be installed directly into a pump casing, cover or fitted into machined metal sleeve holders, whichever is easier and more economical.
  - o End users often find that installing thin walled sleeves of Vespel® CR-6100 inside an existing metal wear component or fabricating a holder is the easiest way to use and handle the material.
    Vespel® CR-6100 is offered in standard tube sizes with a wall thickness of 0.750 in (19.05 mm). If the required OD and ID combination for a component falls between the standard tube diameter combinations, the use of a metal holder with thin walled inserts can be very cost effective. Non standard tubes are also available on special request.
  - o For multi-stage horizontal axially split pumps, metal holders are normally always used for stationary wear rings, center stage bushings, throttle bushings and throat bushings. However, there are low temperature applications where the wear rings have been utilized without metal holders.
- The minimum recommended radial wall thickness of Vespel® CR-6100 rings and bushing components is listed in **Table 5**. The radial wall thickness of the metal holder is typically 0.125 in (3.175 mm) or larger. For applications where the differential pressures are very high (>250 psig (1.73 MPa) per stage), the solution should be engineered to fit.
- Where possible, it is recommended to final machine the inside diameter of the Vespel® CR-6100 component after the press fit assembly operation. This practice ensures the best possible size control, roundness and concentricity of the component bore.
- Many times multi-stage vertical pumps can be assembled in sections with register or pilot fits that control squareness and concentricity, these fits may be larger than the recommended minimum clearance shown in **Table 3**. Particularly in the case of a repair, it is essential that either these pilot fits be tightened or additional clearance, beyond that listed in **Table 3** be added to the line shaft or bowl bushing bores to compensate. Diametrical clearances twice that of **Table 3** are often recommended.
- Bushings and wear rings which are subject to a pressure differential across the wear part must be axially retained with a shoulder at the low pressure side to prevent axial movement. Typically the required thickness of this step is 0.06 in (1.5 mm).

- Rotational retention of Vespel® CR-6100 wear rings is achieved with a diametrical interference fit to prevent rotation during possible rubbing. Anti-rotation screws staking or pins are not recommended and can be detrimental to performance.
- Often bushings lengths are longer than the standard Vespel® CR-6100 tube shape size. It is common practice to use multiple lengths of Vespel® for these cases.

## Application Information Requirements

To design the proper wear ring configuration, as a minimum, the following information is required:

- Housing material, or housing CTE and ID of the housing bore.
- Rotating material and OD of the impeller or shaft.
- Operating temperature and pumped fluid.
- Available axial depth of the casing bore or metal holder.

## Design and Installation Procedure For Wear Rings

Vespel® CR-6100 is successfully being used as wear rings in both horizontal and vertical centrifugal pumps. The following guidelines are applicable for both types.

Step 1: Using the pump operating temperature and the metal bore diameter, select the recommended interference fit from **Table 1** or **Table 2**. Add this to the metal holder bore to determine the recommended outside diameter of the Vespel® CR-6100 wear ring insert. (Note: If the CTE of the metal case, cover or holder being used is different than shown, it can be calculated as a simple ratio of the CTE used in the Tables).

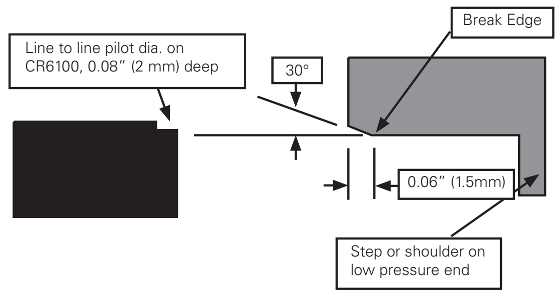
Step 2: Select the recommended diametrical running clearance from **Table 3**. Add this to the metal impeller wear ring diameter to determine the installed wear ring bore diameter. Use **Table 5** to review the design for minimum wall thickness

Step 3: Using **Table 4**, calculate the total axial end clearance and finished length required for the wear ring.

Example, for a 1 in (25.4 mm) long wear ring operating at 250F (121 C), the required part length is 0.967 in (24.56 mm), prior to assembly.

Step 4: Machine and prepare the metal holder or casing with the lead in chamfer, low pressure end step and edge break features as shown in **Figure 1**.

## Figure 1: Installation Configuration Features




Note: For interference fits less than 0.012 in (0.3 mm), the Vespel® CR-6100 pilot fit can be replaced with a 30 degree by 0.08 in (2mm) long lead in chamfer.

Step 5: Machine the Vespel® CR-6100 component outside diameter to provide the correct interference fit. Machine the chamfer or pilot diameter on the leading edge per Figure 1.

Step 6: If the Vespel® CR-6100 wear ring inside diameter is to be finish machined to size after assembly into the case or a holder, machine the inside diameter undersize by approximately 0.06 in (1.5 mm).This allows for machining stock after assembly.

If the wear ring is to be sized for no machining after assembly, the target size must be determined. If the Vespel® CR-6100 radial wall thickness is small, less than 10% of its outside diameter, approximately 100% of the diametrical interference fit will go into decrease of the Vespel® CR-6100 inside diameter after assembly. The recommended wear ring ID size is the sum of the impeller wear ring outside diameter + the diametrical clearance **(Table 3) +** the interference fit (See Step1). Machine the inside diameter to this calculated dimension. It should be noted that this method will result in the least control of size and concentricity due to tolerance stack ups of the components.

Step 7: Machine by parting to the length determined in Step 3.

Step 8: Press fit the Vespel® CR-6100 wear ring into the metal holder, cover  or case using an arbor press or hydraulic press. Heating or freezing of the components is not required. Some users do however employ heating of the holder for applications over 350°F (177°C.).

Step 9: Final machine the inside diameter of the installed Vespel® CR-6100 determined in Step 2. Or, if the wear ring was pre-sized in Step 6, verify the installed diameter.

## Design and Installation  Procedure for Bushings

Vespel® CR-6100 is successfully used for line shaft bushings, bowl bushings, bottom bushings and throat bushings. These wear components can exist in many horizontal or vertical type pumps. There are successful applications and designs for split bushings mounted in holders, these are currently considered engineered designs. The following guidelines are applicable for all solid bushing types.

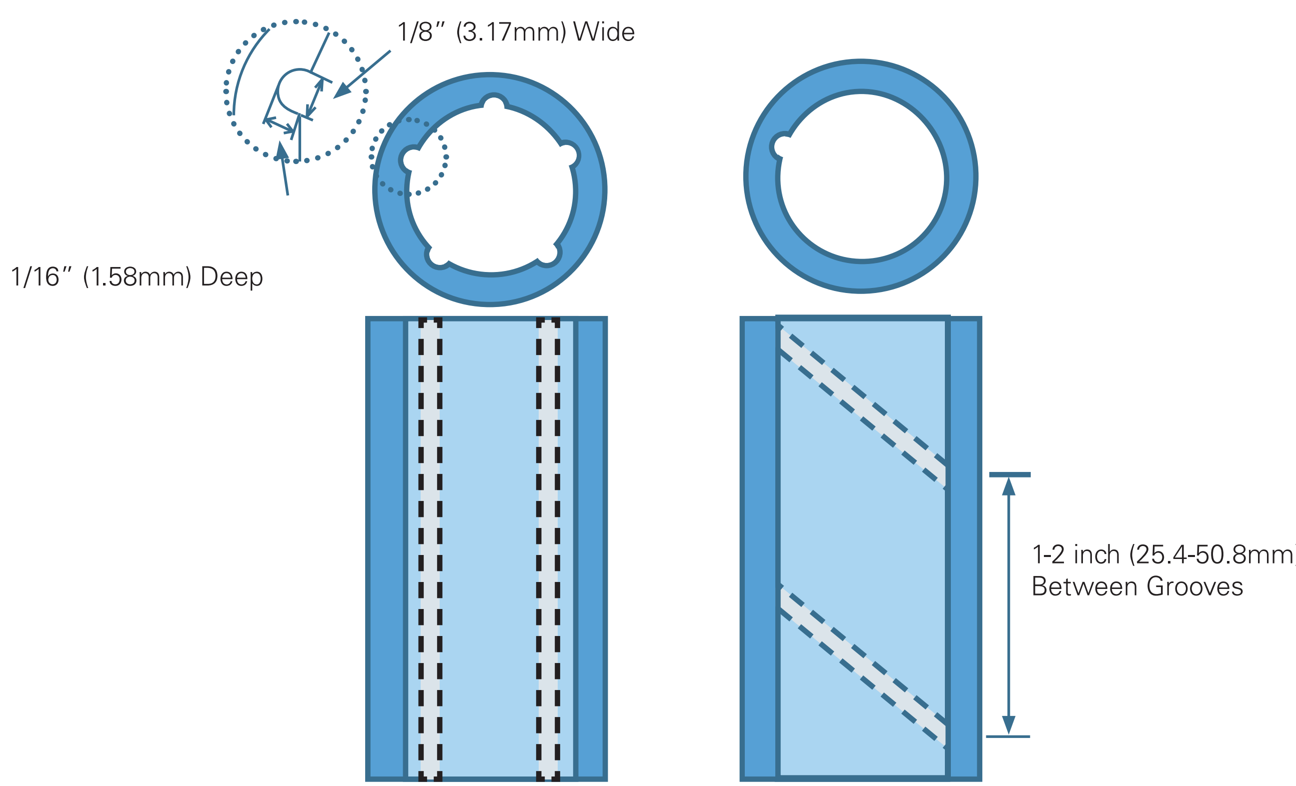
Step1: Using the pump operating temperature and the metal bore diameter, select the recommended interference fit from **Table 1** or **Table 2**. Add this to the metal holder bore to determine the outside diameter of the Vespel® CR-6100 bushing.

Step 2: Based on shaft diameter, select the recommended diametrical clearance from **Table 3**.  For horizontal pump bushings, add this to the shaft diameter to determine the installed bushing bore diameter. For vertical pump bushings select the diametrical clearance from **Table 6**, add this to the shaft diameter to determine the installed bore diameter. Use **Table 5** to review the design for minimum wall thickness.

Step 3: Using **Table 4**, calculate the total end clearance and finished length of the bushing based on the pump operating temperature. The Vespel® CR-6100 bushing should not overhang the bushing length at ambient or elevated temperature. If no differential pressure exists across the bushing, no axial retention step is required in the metal holder to prevent axial motion.

Step 4: Bushing ID grooves can be used on Vespel® CR-6100 bushings.  Axial grooves are typically used in vertical pumps for line shaft bushings which experience no differential pressure across the length. Use spiral grooves in bowl bushings and where a differential pressure exists in conjunction with a step to prevent axial movement **Figure 2** describes common groove configurations.

### Figure 2: Typical Groove Configurations



Step 5: Machine and prepare the metal holder or casing with a lead in chamfer, pilot or low pressure end step if applicable and edge breaks as shown previously in **Figure 1**.

Step 6: Face machine the end, and machine the OD of the Vespel® CR-6100 to provide the correct interference fit (See Step 1). Generate the pilot diameter at the same size as the metal holder bore or use the alternate lead in chamfer and edge breaks.

Step 7: Machine the inside diameter of the bushing including the grooves as necessary. If the bushing bore is to be finish machined after assembly into its holder, machine the bore undersize by approximately 0.06 in (1.5 mm).

If the bushing is to be sized for no machining after assembly, the size prior to assembly must be determined. If the Vespel® CR-6100 wall radial thickness is small, less than 10% of its outside diameter, approximately 100 % of the diametrical interference will go into closedown of the bore after assembly. The recommended bushing "pre-press" size is the sum of the shaft diameter + two times the recommended the wear ring running clearance **(Table 3) +** the interference fit. Machine the bushing bore to this diameter.

Step 8: Machine by parting to the length determined in Step 3.

Step 9: Press fit the bushing into the metal holder, case or spider as appropriate. Use an arbor press or hydraulic press. No heating or freezing of the components is required. Some users do however employ heating of the metal holder for applications over 350°F (177°C).

Step 10: Final machine the inside diameter of the installed bushing as determined in Step 2. Or, if the bushing bore was pre-sized, verify the assembled size.

## Throat Bushings

Throat bushings are designed and installed in the same manner as other bushings. Close clearance bushings are often required to control the environment at the mechanical seal. The throat bushing clearance should be recommended by the mechanical seal provider and engineered in conjunction with the mechanical seal flush plan.

**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.**

| | Pump Operating Temperature, °F | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bore Diameter (in) | 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.**

| | Pump Operating Temperature, °C | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bore Diameter (mm) | 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 (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) | Diametrical Clearance (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) | Diametrical Clearance (mm) |
|---|---|
| 0.0–50.8 | 1.575 |
| 50.8–101.6 | 2.210 |
| >101.6 | 3.175 |

**Table 6A: Recommended Running Clearance Vertical Pump Bushings-English Units**

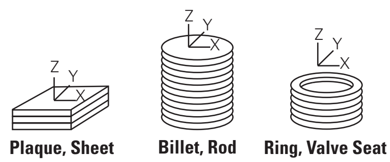
| Shaft Diameter (in) | Diametrical Clearance (in) |
|---|---|
| 0.000-2.000 | 0.006 |
| 2.001-3.000 | 0.007 |
| 3.001-4.000 | 0.008 |
| 4.001-5.000 | 0.009 |
| 5.001-6.000 | 0.010 |
| 6.001-7.000 | 0.011 |

**Table 6B: Recommended running Clearance Vertical Pump Bushings –SI Units**

| Shaft Diameter (mm) | Diametrical Clearance (mm) |
|---|---|
| 0.000-50.8 | 0.152 |
| 50.8-76.2 | 0.178 |
| 76.2-101.6 | 0.203 |
| 101.6-127.0 | 0.229 |
| 127-152.4 | 0.254 |
| 152.4-177.8 | 0.279 |

Note : To facilitate ease of assembly, the register/pilot fit clearance of major pump components ( e.g. Head/case, bowl/column, etc.) must be less than the running clearance of the stationary vs rotating part.The total diametrical running clearance should be held to a tolerance of +0.002"/-0.000" (+0.05 mm/-0.00 mm).

**NOMENCLATURE**




Note: All fiber reinforcement is randomly oriented in the X-Y plane.

## Table 7: Typical Properties

| MECHANICAL | TEST METHOD | SI UNITS | ENGLISH UNITS |
|---|---|---|---|
| **ULTIMATE TENSILE STRENGTH (x-y plane)** | ASTM D-3039 | 221 MPa | 32 ksi |
| **TENSILE MODULUS (x-y plane)** | ASTM D-3039 | 18,000 MPa | 2,600 ksi |
| **ULTIMATE FLEXURAL STRENGTH (x-y plane)** | ASTM D-790 | 152 MPA | 22 ksi |
| **FLEXURAL MODULUS (x-y plane)** | ASTM D-790 | 10,800 MPa | 1,600 ksi |
| **ULTIMATE COMPRESSIVE STRENGTH (x-y plane)** | ASTM D-695 | 80 MPa | 11.7 ksi |
| **COMPRESSIVE MODULUS (x-y plane)** | ASTM D-695 | 2,600 MPA | 383 ksi |
| **ULTIMATE COMPRESSIVE STRENGTH (z-direction)** | ASTM D-695 | 302 MPa | 43.8 ksi |
| **COMPRESSIVE MODULUS (z-direction)** | ASTM D-695 | 2,200 MPA | 318 ksi |

| THERMAL | TEST METHOD | SI UNITS | ENGLISH UNITS |
|---|---|---|---|
| **SOFTENING POINT** | Thermal Mechanical Analysis | 287°C | 550°F |
| **THERMAL EXPANSION COEFFICIENT (x-y plane) (RT–500°F/RT–260°C)** | ASTM D-696 | 3.3x10$^{-6}$m/m/°C | 1.8x10$^{-6}$in./in./°F |
| **THERMAL EXPANSION COEFFICIENT (z-direction) (RT–300°F/RT–149°C)** | ASTM D-696 | 326x10$^{-6}$m/m/°C | 180x10$^{-6}$in./in./°F |
| **THERMAL EXPANSION COEFFICIENT (z-direction) (300–400°F/149–204°C)** | ASTM D-696 | 453x10$^{-6}$m/m/°C | 250x10$^{-6}$in./in./°F |
| **THERMAL EXPANSION COEFFICIENT (z-direction) (400–500°F/204–260°C)** | ASTM D-696 | 923x10$^{-6}$m/m/°C | 510x10$^{-6}$in./in./°F |

| OTHER PROPERTIES | TEST METHOD | SI UNITS | ENGLISH UNITS |
|---|---|---|---|
| **SPECIFIC GRAVITY** | ASTM D-792 | 2.05 gr/cm3 | 0.074 lbs./cu. in. |
| **HARDNESS** | ASTM D-2240 | 75-80 Shore D | 75-80 Shore D |
| **WATER ABSORPTION** (24 hrs. at 23°C) | ASTM D-5229 | <1% | <1% |

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