

Submitted for recognition as an American National Standard

### Rectangular Cross Section Polymeric Sealing Rings (Metric)

1. **Scope**—The purpose of this SAE Recommended Practice is to establish guidelines for the automatic transmission and hydraulic systems Engineer to design rectangular cross section seals for rotating and static grooved shaft applications. Also included are material property comparisons of polymeric materials suitable for these applications. Material covered in this document is not intended to include aluminum applications.
2. **References**
  - 2.1 **Applicable Publications**—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.
    - 2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1236—Cast Iron Sealing Rings (Metric)  
SAE Technical Paper 980734—Improving Automatic Transmission Quality with High Performance Polyimide Rotary Seal Rings
    - 2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 648—Test Method for Deflection Temperature of Plastics Under Flexural Load  
ASTM D 695—Test Method for Compressive Properties of Rigid Plastics  
ASTM D 696—Test Method for Coefficient of Linear Thermal Expansion of Plastics  
ASTM D 792—Test Method for Specific Gravity (Relative Density) and Density of Plastics by Displacement  
ASTM D 1708—Test Method for Tensile Properties of Plastics by Use of Microtensile Specimens  
ASTM E 228—Test Method for Linear Thermal Expansion of Solid Materials with a Vitreous Silica Dilatometer
3. **Materials**—Polymeric sealing rings are made from various materials as described in the following paragraphs. These base polymer materials may be compounded with a variety of filler types to achieve specific performance properties such as increased resistance to wear, fluids, and temperature. Other desirable properties include reduced abrasion of mating components, reduced friction, increased strength, and resistance to damage. Examples of fillers include: glass, graphite, brass, and various polymers. Factors to be considered when choosing a material include: application temperature, fluid type, contaminant exposure, configuration (solid or split), and assembly issues. It is suggested that a seal material supplier be consulted during the selection process.

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- 3.1 **P.T.F.E. (Polytetrafluoroethylene)**—These materials are normally sintered from powders which have been compacted/molded to specific sizes under extreme pressure. The materials are sintered to promote specific mechanical properties, crystallinity, and shape memory. The sintered materials are then cut into rings of specific dimensions, and can be split or left as a solid ring depending on assembly and functional requirements. Solid rings must be stretched to install over the shaft diameter. If stretched, then a subsequent sizing operation may be required depending on the recovery rate of the material.
- 3.2 **Polyimide**—These materials are typically compression molded into the desired size and shape. Polyimide rings have a higher modulus than P.T.F.E. and also provide higher strength and tolerance to deformation under pressure. Due to the high modulus of Polyimide, these rings must be split to install over the shaft diameter.
- 3.3 **P.E.E.K. (Polyetheretherketone)**—These materials are typically injection molded into the desired size and shape, or they are extruded and then finished by machining. P.E.E.K. properties are similar to Polyimide. P.E.E.K. rings will also require a split configuration due to its high modulus and relative rigidity.
- 3.4 **Comparison of Materials—Physical Properties (Table 1)**—Physical properties listed are typical approximate values for reference only. Actual physical properties will vary significantly depending on types and amounts of filler materials. (Contact material supplier for details related to a specific material formulation).

**TABLE 1—COMPARISON OF MATERIALS—PHYSICAL PROPERTIES**

	ASTM Test #	Units	P.T.F.E.	Polyimide	P.E.E.K
Max. Use Temp. (No Load)	NA	°C	288	260	250
Heat Deflect Temp. (455 kPa)	D 648	°C	121	NA	NA
Heat Deflect Temp. (1.82 MPa)	D 648	°C	56	360	167
Coef. of Linear Expans (D 696)	E 228	10E-5/°K	7.5	2.7–5.5	2.2–7.4
Ultimate Elongation	D 1708	%	250–350	2.5–5.5	1.3–3.5
Specific Gravity	D 792	NA	2.1–2.3	1.42–1.56	1.44–1.48
Compressive Strength	D 695	MPa	12–24	220	150
Coefficient of Friction	NA	NA	0.05–0.13	0.08–0.12	0.11–0.16

- 4. **Application Design Data**—The four configurations shown in Figures 1 to 4, are the most common. Other joint configurations are in use to solve specific applications issues.

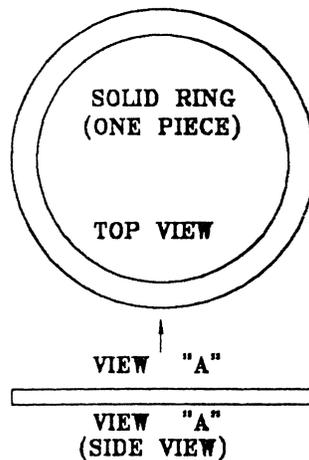


FIGURE 1—SOLID RING

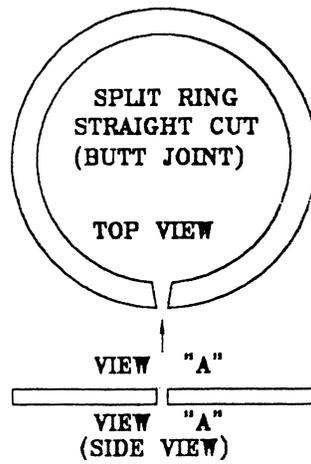


FIGURE 2—SPLIT RING—STRAIGHT CUT

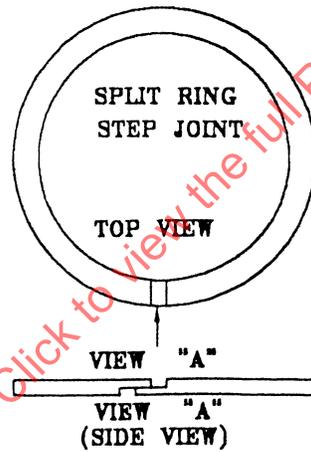


FIGURE 3—SPLIT RING—STEP JOINT

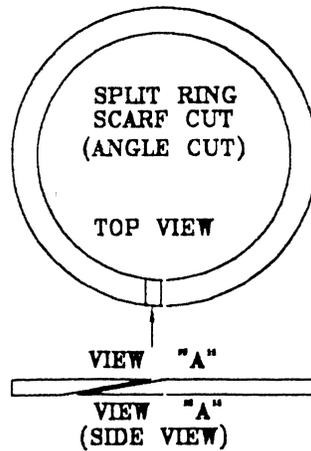


FIGURE 4—SPLIT RING—SCARF CUT

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**4.1 Axial Width (W)**—(The widths shown in Table 2 are considered “common” sizes). The axial widths for polymeric sealing rings are dependent on the expected application pressure, and are calculated using the physical properties of the finished seal materials. Consult the seal ring manufacturer for specific applications. The values listed in Table 2 indicate a 0.08 mm minimum axial clearance between seal and groove width. This amount of clearance is intended for solid, straight cut, and step joint configurations. Scarf cut seals will require a greater amount of side clearance to prevent interference caused by “ramping” at joint location.

TABLE 2—SEALING RING WIDTH

Minimum Axial Groove Width	Maximum Axial Sealing Ring Width	Maximum Suggested Seal Radial Wall (T)
2.00 mm	1.92 mm	1.73 mm
2.39 mm	2.31 mm	2.08 mm
3.00 mm	2.92 mm	2.63 mm
3.16 mm	3.08 mm	2.77 mm
3.97 mm	3.89 mm	3.50 mm
4.00 mm	3.92 mm	3.53 mm
4.75 mm	4.67 mm	4.20 mm
5.00 mm	4.92 mm	4.43 mm
6.00 mm	5.92 mm	5.33 mm
6.34 mm	6.26 mm	5.63 mm

**4.2 Radial Wall Thickness (T)**—It is recommended that sealing ring radial wall thickness not exceed the axial width shown in Table 2. Radial wall thickness (T) typically should be 90% of the axial width for proper function, ease of assembly, and to minimize the required groove depth. (See 4.8.)

**4.3 End Clearance or Compressed Gap (G)**—(Refer to Figure 5) This dimension is measured with seal ring installed inside a minimum diameter bore or ring gauge at room temperature. Consult a ring manufacturer for the upper limit since this dimension can affect cost and performance. The lower limit is calculated based on thermal expansion of the seal and bore.

4.3.1 P.T.F.E. SEALS—Minimum gap should be zero at room temperature for all joint types.

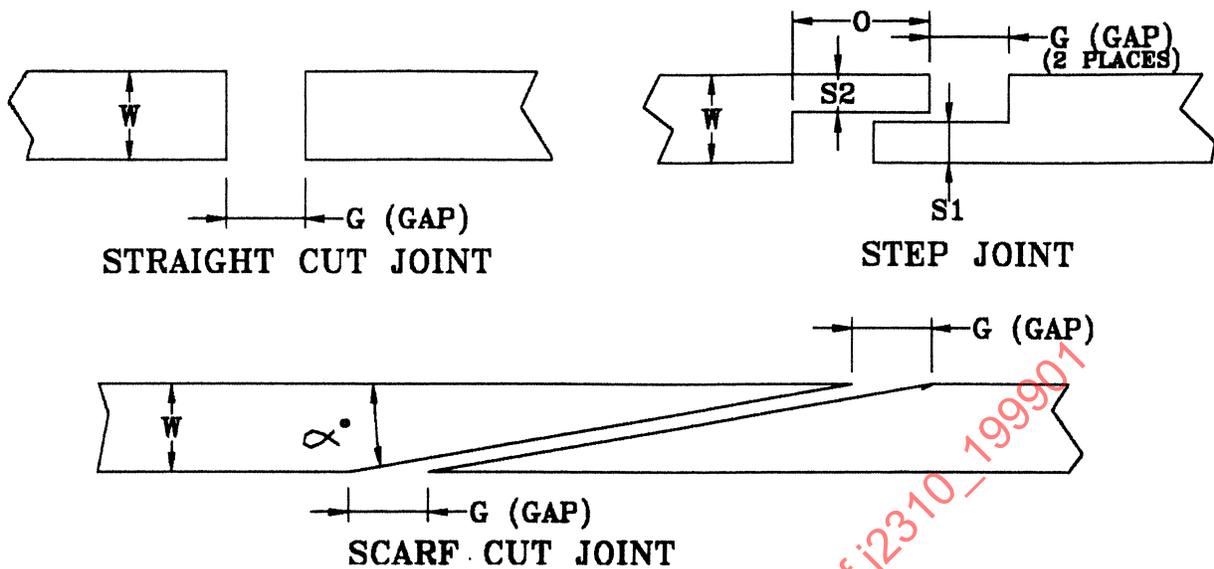
4.3.2 POLYIMIDE AND P.E.E.K. SEALS—The minimum gap should approach zero at maximum operating temperature to minimize leakage at gap location on straight cut and step joints. Scarf cut seals should have zero minimum gap at room temperature.

**4.4 Continuous (Solid) Ring or Split**—(Refer to Figures 1 to 4.)

This document applies to both solid and split rings. Seal diameter specifications apply only to P.T.F.E. solid ring seals before installation. Polyimide and P.E.E.K. materials are not suitable for solid type rings due to rigidity. The size of split rings is controlled by gap dimension as described in 4.3 and the term “gap” only applies to split rings.

#### 4.5 Joint Type Operating Principles

- Straight Cut Joint (Figure 2)—Some leakage at gap will result until gap closes from thermal expansion.
- Step Cut Joint (Figure 3)—Operating pressure seals gap and joint thickness remains constant regardless of thermal expansion. Step over-engagement can cause the ring to buckle, causing a loss of seal contact with the groove face.
- Scarf Cut Joint (Figure 4)—Operating pressure seals gap regardless of thermal expansion. However, thickness at joint will vary with thermal expansion variation. Excessive scarf cut overlap will result in ramping and possibly wedging of the seal with the groove at the gap area. P.T.F.E. will also possibly “weld” or stick together at the gap under pressure if the temperature is excessive.



G = Compressed Gap when installed in a minimum diameter bore at room temperature. (Allow sufficient gap to accommodate thermal expansion at maximum operating temperature.) (Refer to 4.3.)  
 Min. "G" = Zero at room temperature for all P.T.F.E. seals and all scarf cut seals.  
 Min. "G" =  $[\pi BJ(\text{Max. Temp.} - \text{Room Temp.})] - [\pi BK(\text{Max. Temp.} - \text{Room Temp.})]$  for Polyimide and P.E.E.K. straight cut and step joint seals.

O = Step Length

W = Axial Width

S = Step Width (S1 + S2 must be  $\leq$  W)

J = Coefficient of Linear Thermal Expansion for Seal Material

K = Coefficient of Linear Thermal Expansion for Bore Material

B = Bore Diameter (Minimum)

$\alpha$  = Scarf Cut Angle (10 to 12 degrees is recommended. A shallow angle is desired to minimize ramping effect. Small diameter seal rings may require a steeper angle. Axial clearance between groove and seal must be sufficient to prevent wedging in a groove.)

FIGURE 5—JOINT DETAILS

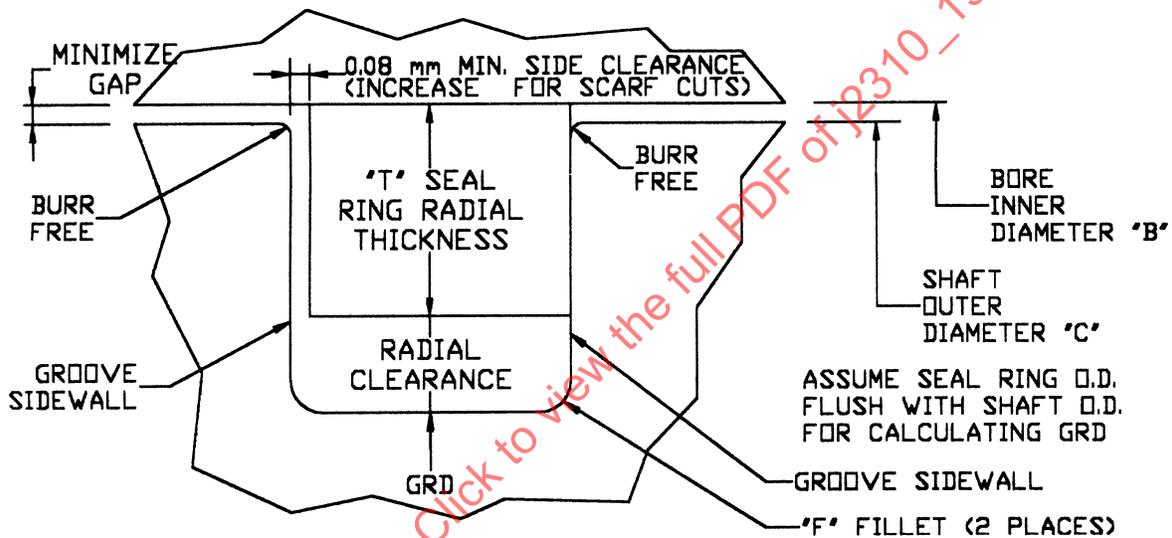
**4.6 Anti-Rotation Features**—Anti-rotation features will prevent the seal from rotating when material incompatibility (i.e., softer materials) might be a problem. The tabs will engage in a geometric feature in either the shaft or bore. (See Figure 6.)



EXAMPLES OF OPTIONAL ANTI-ROTATIONAL FEATURES ON SEAL RINGS. (LOCATE 90 DEGREES FROM JOINT.)  
 VIEW "A"

FIGURE 6—ANTI-ROTATION FEATURES

- 4.7 Sealing Mechanism**—The sealing of polymeric rotary seal rings is accomplished by the hydraulic pressure compressing the seal face to the groove sidewall and the seal outer diameter to conform with the bore. This hydraulic pressure, coupled with thermal expansion of the seal, causes the surfaces of the gap to engage. This creates an effective seal which can approach a minimum leakage condition. In some applications, it may be necessary to provide a controlled leakage rate to lubricate and cool bearings located downstream of the seal. If a controlled leakage is desirable, then it is recommended that grooves or slots be designed into the seal, to provide the required leak rate.
- 4.8 Mating Surface Finish**—In an ideal rotating seal application, the outside diameter of the seal expands and remains stationary with the bore while the seal face rotates relative to the shaft groove sidewall. (See Figure 7.) Typical finish differential between bore and shaft = 2 to 1 to insure low wear and proper relative motion. (e.g., 3.0  $\mu\text{m}$  Ra for the bore and 1.5  $\mu\text{m}$  Ra for the groove sidewall). For reciprocating seals, which do not rotate, the finish ratio should approach 1 to 1. Finish values should be minimized to reduce wear. The Mating surface finishes for specific materials should be discussed with seal manufacturers.



Design GRD to provide radial clearance to prevent seal corner interference with groove fillet radius "F" for Polyimide and P.E.E.K. seals. Minor interference on P.T.F.E. seals will have no negative impact on seal performance. (Typical radial clearance for P.T.F.E. = 0.13 – 0.18 mm)

$$\text{GRD}_{\text{MAX}} = C_{\text{MIN}} - 2(T_{\text{MAX}} + E_{\text{MAX}} + F_{\text{MAX}})$$

$$\text{GRD}_{\text{MIN}} = \text{GRD}_{\text{MAX}} - 0.25 \text{ mm}$$

Recommended values for E and F:

$$E_{\text{MAX}} = 0.065 \text{ mm}$$

$$F_{\text{MAX}} = 0.25 \text{ mm RADIUS}$$

Recommended C diameter: This dimension should be as large as possible for best ring function. The limiting factor is usually the runout or wobble of the shaft to the bore with the shaft being sized so the lands do no contact the bore.

FIGURE 7—GROOVE DIAMETER AND SIDE CLEARANCE

- 4.9 Handling and Installation**—Solid type Polymeric Sealing Rings will be stretched during assembly and may not recover fully depending on material properties. Seal sizing of these solid rings is recommended after installation to prevent seal damage from interference with bore during assembly. A cone type sizing sleeve should be used that sizes parts to the smallest size possible. It is recommended that this sizing sleeve remain over seal until shortly before installing shaft and seal assembly into bore.

Split rings must be assembled with care to assure that joint overlap is correct. (See Figures 3 and 4.)

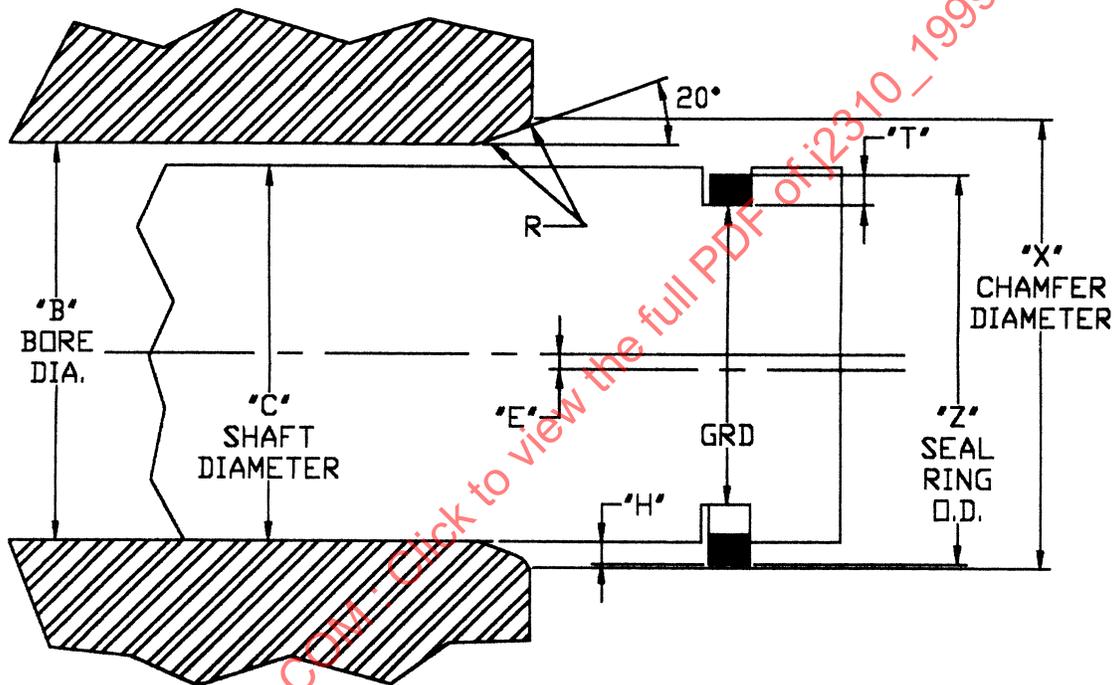
## 5. Sample Calculation

**5.1 Loading Chamfer Diameter Calculation**—In order to properly install the shaft and ring assembly in the bore, without a ring compressor, a chamfer of sufficient diameter is required to allow for the ring bottoming in the groove on one side and the ring hanging out on the other side as illustrated in Figure 8. The minimum radial dimension of the chamfer is equal to the maximum hang-down and can be calculated using Equation 1:

$$H_{\text{MAX}} = Z_{\text{MAX}} - \left( \frac{\text{GRD}_{\text{MIN}} + C_{\text{MIN}}}{2} + T_{\text{MIN}} - E_{\text{MAX}} \right) \quad (\text{Eq. 1})$$

The minimum diameter of the chamfer can be calculated using Equation 2:

$$X_{\text{MIN}} = B_{\text{MAX}} + 2H_{\text{MAX}} \quad (\text{Eq. 2})$$



- B = Bore Diameter (Bore to be round within 0.05 mm. Total out-of-round not to occur in arc less than 90 degrees. Diameter should not vary more than 0.05 mm within operating area of the seal.)
- C = Shaft Diameter (Minimize gap between shaft and bore.)
- E = Eccentricity GRD to C
- F = Groove Fillet (Size is dependent on machining capability and design requirements to control stress levels. Fillet radius must not interfere with seal.)
- GRD= Groove Root Diameter
- H = Hang-Down (Shaft OD to Ring OD)
- T = Ring Radial Thickness
- X = Bore Chamfer Diameter
- Z = Seal Ring Free OD (Add allowance, for distortion from weight on joint, if required.)
- Solid Ring OD calculation: Max. seal ring outer diameter = Min. bore diameter + 0.13 mm.  
(Solid rings apply to P.T.F.E. only and OD specification applies only prior to installation/sizing.)
- Split ring OD calculation: Not applicable. (Control gap when installed in Min. diameter bore.)

FIGURE 8—LOADING CHAMFER DETAILS