SAE Aerospace
An SAE International Group

AEROSPACE INFORMATION REPORT

SAE AIR1243

REV. B

Issued 1978-03
Revised 1999-12
Reaffirmed 2005-04

Superseding AIR1243A

(R) Anti Blow-By Design Practice for Cap Seals

1. SCOPE:

This SAE Aerospace Information Report (AIR) provides information on anti blow-by design practice for cap seals. Suggestions for piston cap seal sidewall notch design and other anti blow-by design details are also described. It also includes information on two key investigations based on the XC-142 as part of the text and as Appendix A.

1.1 Purpose:

The purpose of this document is to provide adequate information to the designer so that the problem will not reoccur.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 3678	Molded or Extruded Polytetrafluoroethylene (PTFE) Unfilled, Pigmented and Filled Compounds
AS568	Aerospace Size Standard for O-Rings
ARP1233	Gland Design; Elastomeric O-Ring Seals, Dynamic Radial, 1500 psi max
AS4716	Aerospace Standard, Gland Design, O-Ring and Other Elastomer Seals

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: custsvc@sae.org
SAE WEB ADDRESS: http://www.sae.org

SAE 100 Leading Our World In Motion

2.2 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

Appendix A based on SEJPF Report 65-2 15 December 1965

Issued By: Systems Engineering Group Research and Technology Division Air Force Systems Command Wright-Patterson Air Force Base, Ohio

"Warning Regarding the Use of Polytetra-fluoroethylene Solid Ring and Elastomeric Ring Combinations as Piston Seals"

3. INTRODUCTION:

The mechanism of blow-by (see Figure 1) is described in an Air Force report in December 1965 which was issued following an XC-142 accident. This report has been updated and is attached (see Appendix A). Tests conducted by Vought Aeronautics Division, LTV Aerospace Corporation established that blow-by was a contributing factor to the accident.

Following is an excerpt from a magazine article prepared by J. R. Crissey of Vought entitled "How to Avoid the Blow-by Phenomenon" which addresses the XC-142 accident and contributes further to an understanding of blow-by. The text has been edited to include modern practices and references to current SAE standards and specifications.

"WHAT CAUSES BLOW-BY?"

"Blow-by occurs when pressure on top of a cap becomes greater than pressure underneath. Thus, the cap is compressed into the seal groove allowing a relatively unrestricted flow past the seal. When the cap is compressed into the groove, seal energizing pressure is momentarily unable to get under the cap. This allows system pressure to "wedge-in" across the top of the seal.

Pressure reversals across the seal were necessary to trigger a blow-by. For example, a XC-142 power actuator normally has 1500 psi on both sides of the seal with no load applied to the actuator. When the actuator is loaded, a differential pressure must be maintained to hold the load. A pressure reversal occurs when the differential pressure is in the direction to aid the load momentarily.

The pressure reversal occurred on the XC-142 aircraft because of the high frequency sinusoidal inputs to the servovalve. The seal malfunctions invariably "healed" themselves, usually within 1.5 s. Some blow-bys lasted as long as 9 s; others were as short as 0.2 s. Healing was instantaneous and the seal functioned normally until the next blow-by occurred.

3. (Continued):

Further testing showed that grooves (notches) cut in the edges of the PTFE cap permitted instant pressurization under the cap regardless of pressure condition, thus preventing blow-by. Seals which had readily malfunctioned in the test jigs could no longer be made to malfunction after the caps were reworked with grooves.

As a result of this investigation of the XC-142 propeller pitch actuator and system, it is now required that capseals be grooved for all LTV-designed components which use cap seals."

The following recommendations and design details outline current practice to provide rapid pressure response of piston (OD) cap seals, hence avoid piston blow-by.

Although the blow-by phenomenon is thought to be generally understood, information is fragmentary and documented service experience limited. Testing is recommended to confirm performance.

4. CONTROL DIAMETER CLEARANCE (SEE FIGURE 1):

Excessive diametral clearance may cause deformation (feathering into the extrusion gap) of the cap seal. This deformation may close off the seal side wall clearance, hence reduce the rate of pressure response of the seal assembly during rapid increase in hydraulic pressure. Diametral clearance per ARP1233 and AS4716 will serve to reduce the relative cap-strip seal deformation but will not in itself prevent blow-by.

Also, the cylinder designer should consider the increase in clearance due to cylinder pressures. A reinforced PTFE cap seal material per AMS 3678 is recommended to reduce seal deformation under conditions of long or repeated exposure to high temperature (over 135 °C) (275 °F) and pressure (over 2500 psi).

Low O-ring squeeze due to high clearance and/or groove diameter can also contribute to blow-by. AS4716 requires a minimum of 0.005 in squeeze which is an improvement over previous standards.

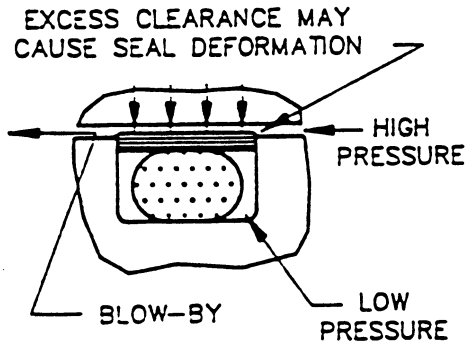


FIGURE 1

5. USE CAP-STRIP SEALS WITH ADEQUATE SIDE WALL CLEARANCE (SEE FIGURE 2):

The difference between the maximum axial length of the cap seal and the minimum length of the groove should not be less than shown in Table 1 to ensure rapid pressure response.

TABLE 1

O-Ring Cross-Section W	Minimum Side Wall Clearance A
0.070	0.010
0.103	0.010
0.139	0.012
0.210	0.014
0.275	0.016

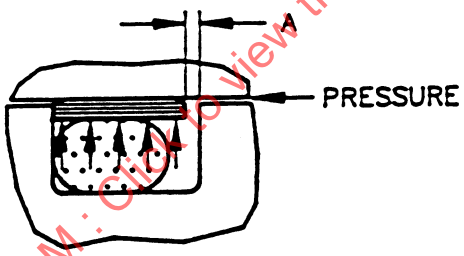


FIGURE 2

6. USE OF SIDE WALL NOTCHES ON PISTON (OD) CAP-STRIP SEALS (SEE FIGURES 3 AND 4):

In addition to the recommended diametral clearance and side wall clearance, notches in the seal side walls should be used to provide rapid pressure response and prevent blow-by. Recommended notch detail is shown in Figure 3.

Notches may not be practical on cap seals with less than 0.030 in (0.76 mm) radial thickness and less than 0.060 in (1.52 mm) axial length. Anti blow-by design recommendations for small cross-section seals are available from seal manufacturers and will vary with installation and service requirements. Procurement activity approval or testing is recommended.

Time in use, particularly at high temperature or high pressure or both, may cause distortion of the cap seal sufficient to restrict the effectiveness of the side wall notches. Chamfers can be used to improve the effectiveness of notches and also to extend the service life of the notch (see Section 7).

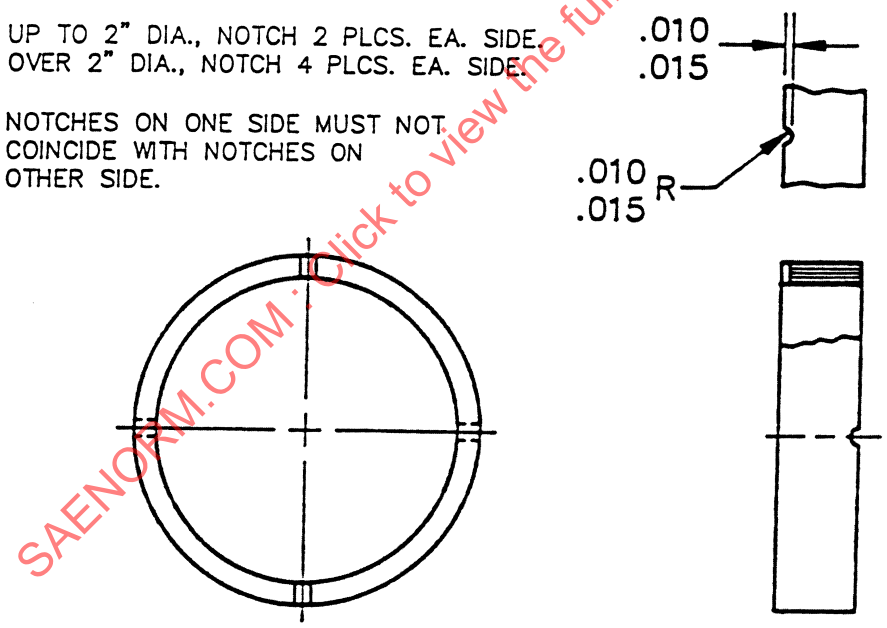


FIGURE 3 - Cap Seal With Straight Notch

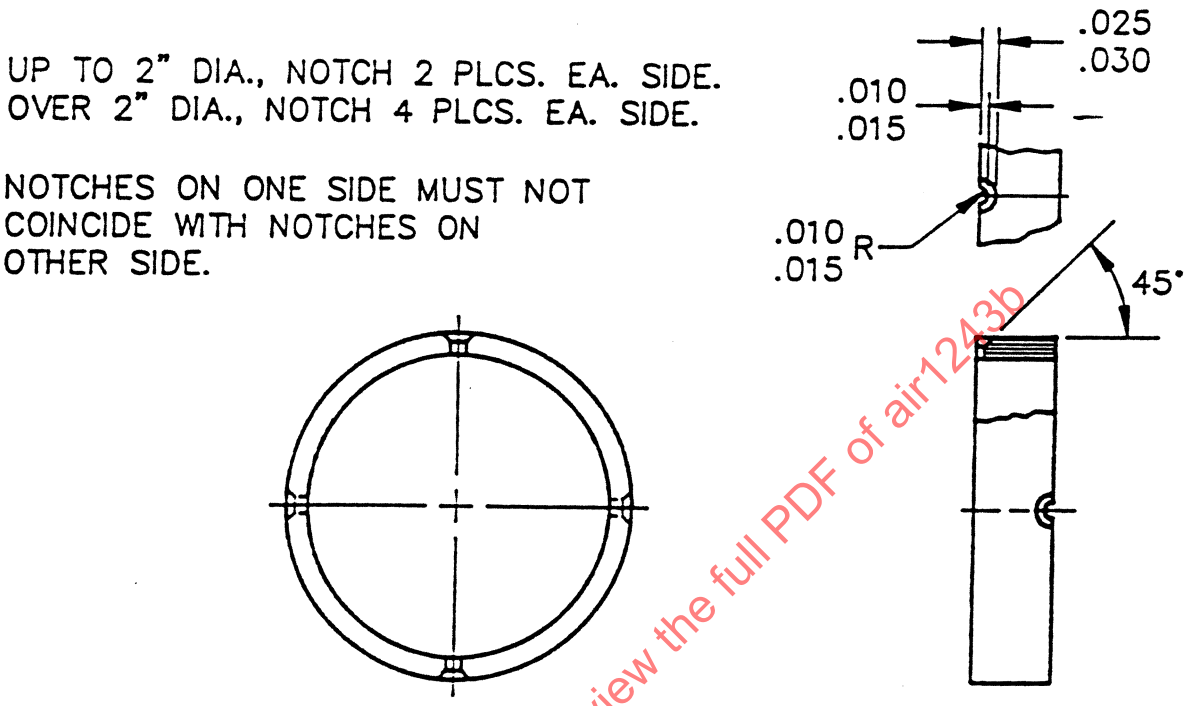


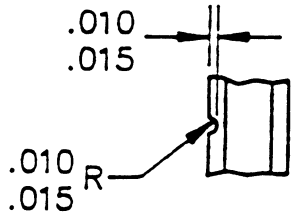
FIGURE 4 - Cap Seal With Chamfered Notch

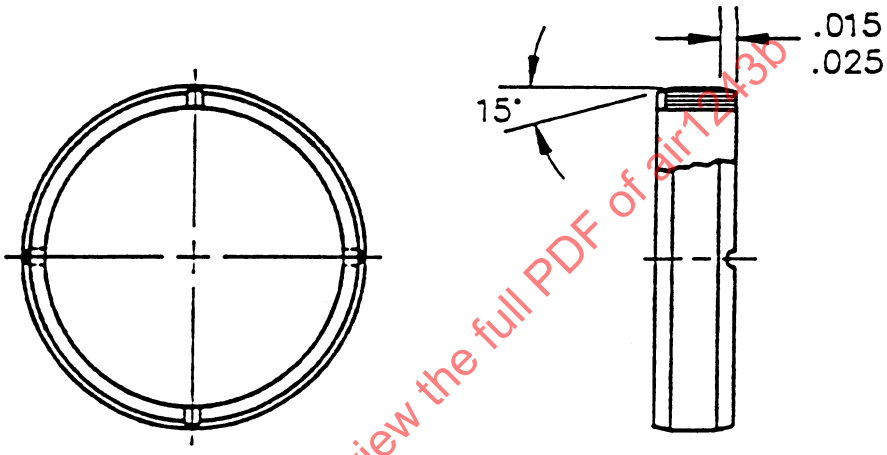
7. USE OF CHAMFERS ON PISTON (OD) CAP SEALS (SEE FIGURES 4 AND 5):

The effective life of side wall notches can be extended by incorporating chamfers in the cap seal that reduce the tendency of the notches to close off with seal use. The chamfers may be local at each notch on the outside diameter of the cap seal (see Figure 4) or circumferential chamfers may be used along the outside corners of the seals (see Figure 5). Circumferential chamfers are also effective in reducing the cap seal deformation shown in Figures 1 and 5. Testing is recommended.

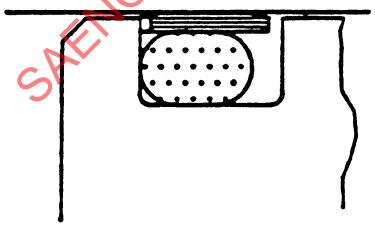
UP TO 2" DIA., NOTCH 2 PLCS. EA. SIDE.
OVER 2" DIA., NOTCH 4 PLCS. EA. SIDE.

NOTCHES ON ONE SIDE MUST NOT COINCIDE WITH NOTCHES ON OTHER SIDE.

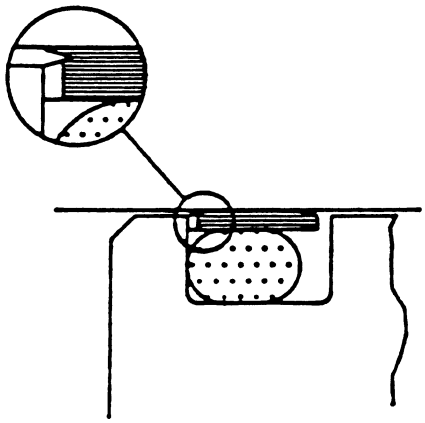




CAP SEAL WITH NOTCH AND CIRCUMFERENTIAL CHAMFER



SEAL AS INSTALLED



SEAL AFTER DISTORTION HAS OCCURRED

CHAMFER ENSURES RAPID PRESSURE RESPONSE EVEN IN THE PRESENCE OF DISTORTION.

FIGURE 5

8. USE OF HIGH MODULUS MATERIAL BACKUP RINGS WITH PISTON (OD) CAP SEALS (SEE FIGURE 6):

Backup rings made from high modulus material (such as nylon polyimide or filled PTFE) compatible with system operating parameters, may be located in the groove adjacent to the cap seal to protect the seal against extrusion. Adequate side wall clearance (0.010 in (0.25 mm) min) will ensure rapid pressure response of the cap seal. Notches in the backup rings on the radial surface facing the groove side wall can also be used advantageously to increase the fluid pressure response. Notches should be on both sides of backup ring to prevent misassembly.

CAUTION: The O-ring can be damaged in the gap below the high modulus backup ring. This can be minimized by 45° x T/4 chamfers on the backup ring at both the edge that contacts the O-ring and the edge which tends to ride up on the groove radius (not necessary for filled PTFE backup rings). A PTFE or filled PTFE ring next to the O-ring with a higher modulus ring outboard will also provide the necessary O-ring protection. Testing is recommended.

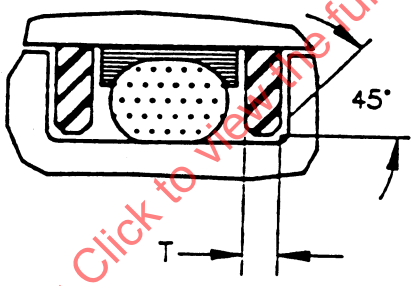


FIGURE 6

9. USE OF PISTON HEAD CHANNELS AND DRILLED HOLES (SEE FIGURE 7):

Channels in the piston head which admit fluid pressure into the seal groove will ensure rapid pressure response. A 0.010 in (0.25 mm) wide channel is effective. Channel depth should not exceed the minimum side wall height of the cap seal to avoid extrusion of the elastomer into the channel. Two to four channels are recommended on each side of the seal groove. Testing is recommended.

Drilled holes through the piston head can be used as an alternative to the piston head channel. Holes must be located in the seal groove so that the cap seal prevents O-ring extrusion into the hole. The number of holes and hole size will vary depending upon design requirements and limitations.

CAUTION: Experience with the design practice of using channel and drilled hole techniques to ensure rapid pressure response is limited. Testing is recommended.

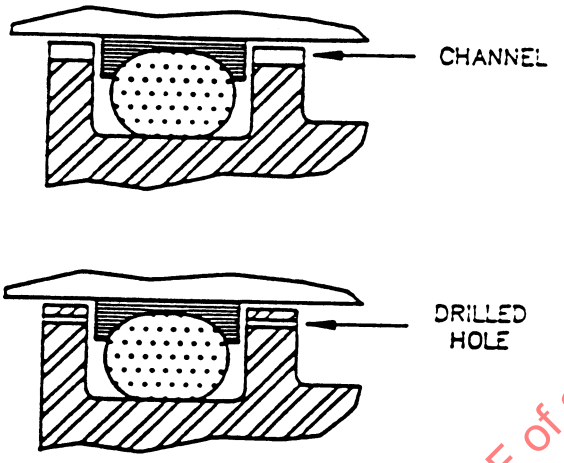


FIGURE 7

10. TESTING FOR BLOW-BY:

Blow-by can be demonstrated in the laboratory using a servo-actuator having a cap-strip-type seal on the piston. Use a motion transducer attached to the piston rod of the actuator, a pressure transducer located at each pressure port of a manual input servovalve, and a recorder.

Motion of the actuator piston must be restricted by an external load sufficient to create a pressure differential applicable to the service conditions being evaluated. When a rapid reversal of pressure is applied to the piston, a delay in the piston rod translation coincident in time with a loss in pressure is evidence of blow-by. The duration of the phenomenon may be momentary or for several seconds. Blow-by may be a random occurrence as the actuator is cycled. Typically, you must experiment with different applied loads and different step inputs of reversal to the valve. Blow-by has been known to occur as the input was reversed when the actuator was going through a no load point (changing from tension to compression load).

Blow-by is more likely to occur after considerable cycling at the maximum elevated temperature expected.

11. NOTES:

The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document.

PREPARED UNDER THE JURISDICTION OF
SAE SUBCOMMITTEE A-6C, FLUID POWER DISTRIBUTION ELEMENTS
OF COMMITTEE A-6, FLUID POWER, ACTUATION & CONTROL TECHNOLOGIES