AEROSPACE RECOMMENDED PRACTICE	ARP4912™	REV. C
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(R) Design Recommendations for Spare Seals in Landing Gear Shock Struts

RATIONALE

This document provides information surrounding the recommended hardware geometry for spare seals in landing gear shock struts, as well as the effects of stretch, fluid interaction, and grease interaction on elastomer seal properties. In addition, this ARP document now covers property characteristics of AMS-P-25732 and AMS-P-831461 elastomer materials after immersion in the three primary red oils (hydraulic fluids) used in industry, MIL-PRF-5606, MIL-PRF-87257, and MIL-PRF-83282. Changes in volume, tensile strength, and elongation are discussed after immersion in the aforementioned fluids, both in whole and in mixed percentages of fluid. These characteristics should be taken into account when incorporating and implementing fluid and/or fluid changes with specific elastomer materials in shock struts containing spare seals.

ARP4912C has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

This SAE Aerospace Recommended Practice (ARP) provides recommendations on cavity design, the installation of elastomer type spare seals in these cavities, and information surrounding elastomer material properties after contact with typical shock absorber hydraulic fluid(s) or grease. This ARP is primarily concerned with the use of spare seals on shock absorbers where only a single dynamic seal is fitted and in contact with the slider/shock absorber piston at any one time.

These shock absorbers typically have a spare (dynamic) seal gland located on the outer diameter of the lower seal carrier. This spare seal gland is intended to house a spare elastomer contact seal. Split Polytetrafluoroethylene (PTFE) backup rings can also be installed in the spare seal cavity.

During operation, if the fitted dynamic shock absorber standard seal begins to fail/leak, then the aircraft can be jacked up, allowing the lower gland nut of the shock absorber to be dropped down. The current used dynamic seal can be cut free, and the spare elastomer seal can be stretched over the seal carrier ring into the dynamic seal position. The shock absorber can be re-assembled and then the landing gear is ready to continue operation with a new seal in position after this relatively simple procedure.

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 International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS-P-83461 Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Improved Performance at 275°F (135°C)

AMS-P-25732 Packaging, Preformed, Petroleum Hydraulic Fluid Resistant, Limited Serivce at 275°F (135°C)

AS568 Aerospace Size Standard for O-rings

AS1241 Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D471 Standard Test Method for Rubber Property—Effect of Liquids

ASTM D1414 Standard Test Methods for Rubber O-Rings

2.3 U.S. Government Publications

Copies of these documents are available online at http://quicksearch.dla.mil.

MIL-PRF-5606 Hydraulic Fluid, Petroleum base; Aircraft, Missile, and Ordnance

MIL-PRF-83282 Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Metric, NATO Code Number H-537

MIL-PRF-87257 Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile

3. RECOMMENDATIONS

3.1 Spare seal cavities should be designed with maximum bottom radii, both to eliminate stress risers and to distinguish the spare seal cavity from the actual functional seal glands. Half round cavities may be considered for rod type T-Seals or O-rings (see Figure 2).

3.2 All spare seal cavity edges are to be smooth and free of sharp edges and burrs to eliminate seal damage during installation.

3.3 Design considerations must assure that spare seals cannot function as a static seal. Since overarching seal specifications require seal elastomers to swell 10 to 20% in MIL-PRF-5606 and 5 to 15% in MIL-PRF-83282, these increases in volume must be considered.

3.4 Where adequate space is available, the spare seal cavities should be located downstream (non-pressurized side) of the active static seals. This location minimizes fluid contact, reducing seal swell which can make seal installation difficult or impossible. Seal swell in excess of a 15% increase in circumference has been seen after 500-hour exposure in MIL-PRF-5606.

3.5 It is recommended that spare seals be installed in the spare cavity in a dry condition. Historically, spare seals were packed with grease to protect them from hydraulic fluid exposure and mitigate any negative impact of fluid swell when transferring the seal into the active location. Due to residual effects of some greases that can impede the operational characteristics of the seal, consideration needs to be made to avoid other secondary issues when using grease, (i.e., limiting desired swell at low temperature, remaining grease on the seal in operation affecting performance, false positive leakage events due to low melt point and separation of oils for some greases).

3.6 If grease is to be used with seals in the spare cavity, a list of greases and their typical swell values are included in Appendix A; listed typical swell values are applicable to AMS-P-83461 Nitrile seals only.

3.7 Seals are to be stored in their "as molded" orientation. When seals are turned inside out and stretched over the lower bearing, excessive stress is applied to the dynamic sealing surfaces.

3.8 If spare dynamic and/or static seals are installed in separate grooves, backup rings may be stored with the seals. Careful attention should be given when moving backup rings into the active location to ensure proper orientation with the elastomer component; scarf cut orientation should show proper overlap.

3.9 Another type of landing gear shock absorber design has become popular recently. This type of shock absorber uses a different seal configuration with an active spare dynamic seal. This design, as shown in Figure 1 uses two dynamic seals in tandem series. The primary seal is located on the outboard side of the arrangement, and this is pressure actuated through a bypass channel manufactured into the seal carrier. The spare seal/secondary seal is also mounted on the same shock absorber slider/piston diameter; and located in the inboard position. This secondary seal is in a pressure balanced condition during normal operation of the landing gear/aircraft. When the outboard primary seal fails, the bypass channel valve is closed and the inboard secondary seal becomes the primary pressure activated sealing component.

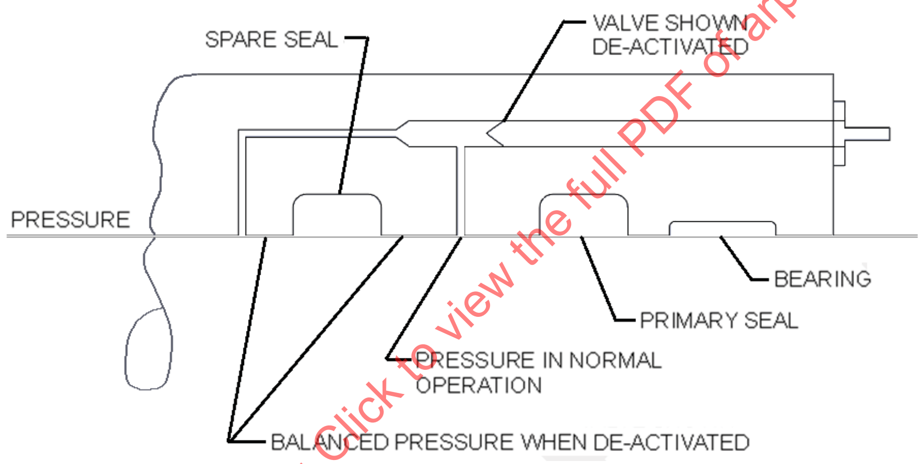


Figure 1 - Shock absorber with tandem seal and bypass mechanism

NOTE: The bypass type configuration shock absorber spare/secondary seal gland design is not covered by this ARP document. The bypass configuration secondary seal gland is made to house the seal at the correct compression/squeeze rate for the working operation upon its change over to the primary seal.

This ARP document is intended to cover only the gland design for the spare seals located in a non-contacting spare seal gland, which is made in a storage location typically in an area with a larger diameter than the shock absorber piston slider. This storage gland is sized so that the spare seal is not compressed when it is located in this spare seal gland position.

NOTE: There are advantages and disadvantages of both shock absorber seal configuration systems, they are outside the scope of this ARP document.

3.10 This document addresses nitrile type seals used with common shock strut hydraulic fluids, such as MIL-PRF-5606, MIL-PRF-83282, and MIL-PRF-87257.

NOTE: This document does not cover any Ethylene Propylene (EP) materials associated with Phosphate Ester systems using AS1241 fluids; EP type elastomers may exhibit different stretch and swell characteristics, and will therefore require alternate compatible fluids and/or greases for installation.

3.11 Design considerations should include the prevention of pressure trapping between the static seal and spare seals.

3.12 Recommended spare seal cavity dimensions are shown in tabular form in Figure 2.

3.13 The spare seal gland size and location should not allow deformation of the lower bearing created by extended loads of the shock strut piston rod during aircraft take off.

4. TEST RESULTS

Several tests have been completed to guide the designer in addressing the permanent set, swell of stored seals, and overall changes in material characteristics associated with potential interaction of the system fluid and the stored seals. These tests utilized elastomers meeting the AMS-P-25732 and AMS-P-83461 specifications.

4.1 Effects of Seal Stretch and Fluid Swell

4.1.1 In the first test, AMS-P-83461 type Nitrile material T-seals were stretched on mandrels 5, 10, 15, and 20% larger than the standard rod diameter for these seals, then aged 500 hours in MIL-PRF-5606 fluid at 160 °F (71 °C). The results are shown in Figure 3. This test was originally planned to extend to 1000 hours but fluid swell expanded the seal diameter beyond the mandrel diameter after 500 hours exposure.

4.1.2 The seals used in the above test were T-seals of the following size and application as shown in Table 1:

Table 1

Dash Size	Dimensions	Application
-451	11.500 OD x 0.275 CX	747 MLG Dynamic Strut Seal
-441	7.510 OD x 0.275 CX	DC-10 NLG Dynamic Strut Seal
-339	3.640 OD x 0.210 CX	737 NLG Dynamic Strut Seal

NOTE: Dash sizes to AS4716 gland standard.

4.1.3 Since seal swell was clearly the predominant factor, AMS-P-83461 and AMS-P-25732 type Nitrile O-Rings were immersed in commercial strut fluids and the measured volume swell results of the long-term soaks are shown in Figure 4. Volume swell was recorded at 70, 168, 500, and 1000 hour increments for each condition.

4.1.4 To isolate the effects of long-term tensile set without the effects of fluid, AMS-P-83461 Nitrile T-seals were stretched on mandrels 5, 10, 15, and 20% larger than the standard rod diameter for these seals, then aged 500 and 1000 hours in air at 160 °F (71 °C). The results of these tests are shown in Figure 5.

4.1.5 In a further attempt to isolate stored seals from fluid swell, a -441 size (7.510 inches OD x 0.275 inch Cross Section (CX)) T-Seal was installed with a typical 5% stretch and sealed in the groove with a viscous silicone grease (Dow Corning DC-55). The assembly was then dipped into MIL-PRF-5606 fluid once a week to simulate exposure to the spare seal caused by upstream seal leakage. The seal was removed after 6 months, the seal swell was measured to be 1.5% of the original diameter.

4.2 Effects of Fluid Ingress Past Static Seals

In addition to seal swell, the ingress of system fluid past the static seals may affect the performance of the seal when placed in the active seal location. The following details the assessed changes in material performance under typical landing gear operating conditions. The following results were tested at a temperature of 160 °F (71 °C) which is considered to be the maximum operating temperature for Landing gears.

Results are presented for two representative suppliers. It can be seen that property changes can differ between suppliers and this information should be considered when inter-mixing elastomer materials and system fluids.

For all of the data presented within 4.2, the values are for the percent change from the original non-immersed baseline test data/samples. This demonstrates how the affects of the various fluids can further increase or reduce the individual material properties investigated.

This investigation used AS568, -214 O-Rings for all testing conditions.

- Volume Swell was tested to ASTM D471
- Elongation Properties were to ASTM D1414
- Tensile Properties were tested to ASTM D1414

The fluids used for this immersion investigation are as listed below:

- MIL-PRF-5606 (Brayco Micronic 756)
- MIL-PRF-83282 (Brayco Micronic 882)
- MIL-PRF-87257 (Brayco Micronic 881)

NOTE: Baseline test data value is the median value from five tested samples.

Baseline Values for Reference:

Material	Company	Baseline Tensile Strength (psi)	Baseline Elongation (%)
AMS-P-25732	A	2133.5	257
AMS-P-83461	A	1554.8	152
AMS-P-25732	B	1441.7	144
AMS-P-83461	B	1884.0	139

NOTE: For immersed conditions, five samples were tested after the immersion conditions and the median value was used for comparison against the median baseline value.

4.2.1 Material Property Changes (AMS-P-25732)

For the sub-sections below, Tables 2, 4, and 6 will show AMS-P-25732 material property results for two conditions; the first is after immersion in a baseline initial fluid (100% fluid concentration), the second will be for material that has undergone immersion in an initial fluid (100% fluid concentration) followed by a secondary fluid (100% fluid concentration). This represents a flush of the system and full change of system fluid. This investigates if there will be any detrimental affects to the seal due to the full change in system fluid. The secondary fluid will not be the same as the baseline initial fluid and will be shown as N/A.

Tables 3, 5, and 7 will show AMS-P-25732 material property results for two conditions; the first is after immersion in a baseline initial fluid (100% fluid concentration), the second will be for material that has undergone immersion in an initial fluid (100% fluid concentration) and a secondary fluid (50/50 fluid concentration composed of the initial fluid and a secondary fluid). This represents a top off of the system with a secondary system fluid. This investigates if there will be any detrimental affects to a seal due to the partial change in system fluid. N/A is shown in the table under secondary fluid if the fluid concentration does not contain the initial fluid.

4.2.1.1 Percent Change in Volume After Immersion

Table 2 - Volume swell after 100% concentration X 100% concentration

Material: AMS-P-25732								
Baseline Initial Fluid*			Secondary Fluid*					
			MIL-PRF-5606		MIL-PRF-87257		MIL-PRF-83282	
	Company A	Company B	Company A	Company B	Company A	Company B	Company A	Company B
MIL-PRF-5606	7.4	4.2	N/A	N/A	6.7	3.9	7.1	0
MIL-PRF-87257	6.6	3.6	5.5	3.8	N/A	N/A	6.6	-1.2
MIL-PRF-83282	2.1	-0.7	0.7	3.5	1.5	4.6	N/A	N/A

Table 3 - Volume swell after 100% concentration X 50/50% concentration

Material: AMS-P-25732								
Baseline Initial Fluid*			Secondary Fluid*					
			MIL-PRF-5606 / MIL-PRF-87257		MIL-PRF-5606 / MIL-PRF-83282		MIL-PRF-87257 / MIL-PRF-83282	
	Company A	Company B	Company A	Company B	Company A	Company B	Company A	Company B
MIL-PRF-5606	7.4	4.2	6.3	2.9	3.9	0.6	N/A	N/A
MIL-PRF-87257	6.6	3.6	7.9	3.8	N/A	N/A	4.9	0.9
MIL-PRF-83282	2.1	-0.7	N/A	N/A	4.2	1.1	5.4	1.1

* Immersion for 70 hours at 160 °F (71 °C).

AMS-P-25732 material immersed in MIL-PRF-5606 resulted in an increase in volume (+4.2 to +7.4%); it can be considered that there will be no major detriments to seals from a gain or loss in volume swell if a system with MIL-PRF-5606 is flushed with or topped of with MIL-PRF-87257. If a system with MIL-PRF-5606 is flushed with MIL-PRF-83282, a reduction in volume swell could occur (up to -4.2%). If a system with MIL-PRF-5606 is topped off with MIL-PRF-83282, a reduction could occur (up to -3.6%). Loss in volume swell could have an adverse affect on the seal during low pressure or low temperature conditions if the seal were transitioned from the spare gland to become the active seal.

AMS-P-25732 material immersed in MIL-PRF-87257 resulted in an increase in volume (+3.6 to +6.6%). If a system with MIL-PRF-87257 is flushed with MIL-PRF-83282, a reduction in volume swell could occur (up to -4.8%). If a system with MIL-PRF-87257 is topped off with MIL-PRF-83282, a slight reduction in volume swell could occur (up to -2.7%). Loss in volume swell could have an adverse effect on the seal during low pressure or low temperature conditions if the seal were transitioned from the spare gland to become the active seal. It can be considered that there will be no major detriments to seals from a gain or loss in volume swell if a system with MIL-PRF-87257 is topped off with or flushed with MIL-PRF-5606.

AMS-P-25732 material immersed in MIL-PRF-83282 resulted in a small change in volume swell (-0.7 to +2.1%). If a system with MIL-PRF-83282 is flushed with MIL-PRF-5606 or MIL-PRF-87257, negligible changes or an increase in volume swell could occur (up to +5.3%). If a system with MIL-PRF-83282 is topped off with MIL-PRF-5606 or MIL-PRF-87257, an increase in volume swell could occur (up to +3.3%).

4.2.1.2 Percent Change in Elongation After Immersion

Table 4 - Elongation after 100% concentration X 100% concentration

Material: AMS-P-25732								
Baseline Initial Fluid*			Secondary Fluid*					
			MIL-PRF-5606		MIL-PRF-87257		MIL-PRF-83282	
	Company A	Company B	Company A	Company B	Company A	Company B	Company A	Company B
MIL-PRF-5606	-1.6	0.6	N/A	N/A	-5.7	-10.8	-4.2	-5.8
MIL-PRF-87257	-11.3	-5.2	-11.5	-7.3	N/A	N/A	-11.4	-13.1
MIL-PRF-83282	0	-5.8	-8.4	-2.5	-10.7	-5.5	N/A	N/A

Table 5 - Elongation after 100% concentration X 50/50% concentration

Material: AMS-P-25732								
Baseline Initial Fluid*			Secondary Fluid*					
			MIL-PRF-5606 / MIL-PRF-87257		MIL-PRF-5606 / MIL-PRF-83282		MIL-PRF-87257 / MIL-PRF-83282	
	Company A	Company B	Company A	Company B	Company A	Company B	Company A	Company B
MIL-PRF-5606	-1.6	0.6	-5.9	-5.3	-3.6	-5.1	N/A	N/A
MIL-PRF-87257	-11.3	-5.2	**	-5	N/A	N/A	**	-6.8
MIL-PRF-83282	0	-5.8	N/A	N/A	-6	-15.3	**	-9.2

* Immersion for 70 hours at 160 °F (71 °C).
** No data available.

AMS-P-25732 material immersed in MIL-PRF-5606 resulted in a negligible change in elongation properties (-1.6 to +0.6%). If a system with MIL-PRF-5606 is flushed with MIL-PRF-87257, a reduction in elongation properties could occur (-4.1 to -11.4%). If a system with MIL-PRF-5606 is flushed with MIL-PRF-83282, a reduction in elongation properties could occur (-2.6 to -6.4%). If a system with MIL-PRF-5606 is topped off with MIL-PRF-87257 or MIL-PRF-83282, a reduction in elongation properties could occur (-2 to -5.9%).

AMS-P-25732 material immersed in MIL-PRF-87257 resulted in a reduction in elongation properties (-5.2 to -11.3%); it can be considered that there will be no major detriments to seals if a system with MIL-PRF-87257 is flushed with MIL-PRF-5606, or topped off with either MIL-PRF-5606 or MIL-PRF-83282. If a system with MIL-PRF-87257 is flushed with MIL-PRF-83282, a reduction in elongation properties could occur (up to -7.9%).

AMS-P-25732 material immersed in MIL-PRF-83282 resulted in a slight reduction in elongation properties (up to -5.8%). If a system with MIL-PRF-83282 is flushed or topped off with MIL-PRF-5606, a reduction in elongation properties could occur (up to -9.5%). If a system with MIL-PRF-83282 is flushed with MIL-PRF-87257, a reduction in elongation properties could occur (up to -10.7%). If a system with MIL-PRF-83282 is topped off with MIL-PRF-87257, a reduction in elongation properties could occur (up to -3.4%).

4.2.1.3 Percent Change in Tensile Strength After Immersion

Table 6 - Tensile strength after 100% concentration X 100% concentration

Material: AMS-P-25732								
Baseline Initial Fluid*			Secondary Fluid*					
			MIL-PRF-5606		MIL-PRF-87257		MIL-PRF-83282	
	Company A	Company B	Company A	Company B	Company A	Company B	Company A	Company B
MIL-PRF-5606	1.7	13.5	N/A	N/A	3	15	4.6	28.9
MIL-PRF-87257	-10.1	16.9	-4.6	20.7	N/A	N/A	-4.7	14.7
MIL-PRF-83282	8.3	22.3	0.7	28.8	0.8	28.7	N/A	N/A

Table 7 - Tensile strength after 100% concentration X 50/50% concentration

Material: AMS-P-25732								
Baseline Initial Fluid*			Secondary Fluid*					
			MIL-PRF-5606 / MIL-PRF-87257		MIL-PRF-5606 / MIL-PRF-83282		MIL-PRF-87257 / MIL-PRF-83282	
	Company A	Company B	Company A	Company B	Company A	Company B	Company A	Company B
MIL-PRF-5606	1.7	13.5	3.2	21.5	8.2	22.9	N/A	N/A
MIL-PRF-87257	-10.1	16.9	**	20	N/A	N/A	**	20.1
MIL-PRF-83282	8.3	22.3	N/A	N/A	5.8	6.4	**	17.3

* Immersion for 70 hours at 160 °F (71 °C).
** No data available.

AMS-P-25732 material immersed in MIL-PRF-5606 did not result in any significant reduction in tensile properties; nor did it show any significant reduction in tensile properties after secondary immersion in MIL-PRF-87257 or MIL-PRF-83282, regardless of mixture ratio. It can therefore be considered that there will be no major detriments to seals from a tensile strength perspective if a system with MIL-PRF-5606 is topped off with or flushed with MIL-PRF-87257 or MIL-PRF-83282.

AMS-P-25732 material immersed in MIL-PRF-87257 experienced a reduction in tensile properties (up to -10.1%). It can be considered that there will be no further reduction in tensile properties to seals if a system with MIL-PRF-87257 is flushed or topped off with MIL-PRF-5606 or MIL-PRF-83282.

AMS-P-25732 material immersed in MIL-PRF-83282 did not result in any significant reduction in tensile properties; nor did it show any significant reduction in tensile properties after secondary immersion in MIL-PRF-87257 or MIL-PRF-5606, regardless of mixture ratio. It can therefore be considered that there will be no major detriments to seals if a system with MIL-PRF-83282 is topped off with or flushed with MIL-PRF-5606 or MIL-PRF-87257.

4.2.2 Material Property Changes (AMS-P-83461)

For the sub-sections below, Tables 8, 10, and 12 will show AMS-P-83461 material property results for two conditions; the first is after immersion in a baseline initial fluid (100% fluid concentration), the second will be for material that has undergone immersion in an initial fluid (100% fluid concentration) followed by a secondary fluid (100% fluid concentration). This represents a flush of the system and full change of system fluid. This investigates if there will be any detrimental affects to the seal due to the full change in system fluid. The secondary fluid will not be the same as the baseline initial fluid and will be shown as N/A.

Tables 9, 11, and 13 will show AMS-P-83461 material property results for two conditions; the first is after immersion in a baseline initial fluid (100% fluid concentration), the second will be for material that has undergone immersion in an initial fluid (100% fluid concentration) and a secondary fluid (50/50 fluid concentration composed of the initial fluid and a secondary fluid). This represents a top off of the system with a secondary system fluid. This investigates if there will be any detrimental affects to a seal due to the partial change in system fluid. N/A is shown in the table under secondary fluid if the fluid concentration does not contain the initial fluid.

4.2.2.1 Percent Change in Volume After Immersion

Table 8 - Volume swell after 100% concentration X 100% concentration

Material: AMS-P-83461								
Baseline Initial Fluid*			Secondary Fluid*					
			MIL-PRF-5606		MIL-PRF-87257		MIL-PRF-83282	
	Company A	Company B	Company A	Company B	Company A	Company B	Company A	Company B
MIL-PRF-5606	7.7	13.9	N/A	N/A	7.1	11.6	2	6.3
MIL-PRF-87257	7.8	11.9	7.8	13.6	N/A	N/A	2.8	7
MIL-PRF-83282	2.4	5.9	8.1	13.8	7.6	12.8	N/A	N/A

Table 9 - Volume swell after 100% concentration X 50/50% concentration

Material: AMS-P-83461								
Baseline Initial Fluid*			Secondary Fluid*					
			MIL-PRF-5606 / MIL-PRF-87257		MIL-PRF-5606 / MIL-PRF-83282		MIL-PRF-87257 / MIL-PRF-83282	
	Company A	Company B	Company A	Company B	Company A	Company B	Company A	Company B
MIL-PRF-5606	7.7	13.9	8	13.5	5.3	10.3	N/A	N/A
MIL-PRF-87257	7.8	11.9	8.2	13.5	N/A	N/A	5.1	9.7
MIL-PRF-83282	2.4	5.9	N/A	N/A	5.7	10.7	5.5	10

* Immersion for 70 hours at 160 °F (71 °C).

AMS-P-83461 material immersed in MIL-PRF-5606 resulted in an increase in volume (+7.7 to +13.9%). If a system with MIL-PRF-5606 is flushed with MIL-PRF-87257,a slight reduction could occur (up to -2.3%). If a system with MIL-PRF-5606 is flushed with MIL-PRF-83282, a reduction could occur (-5.7 to -7.6%). If a system with MIL-PRF-5606 is topped off with MIL-PRF-83282, a slight reduction could occur (up to -3.6%). It can be considered that there will be no major detriments to seals from a gain or loss in volume swell if a system with MIL-PRF-5606 is topped off with MIL-PRF-87257. Loss in volume swell could have an adverse affect on the seal during low pressure or low temperature conditions if the seal were transitioned from the spare gland to become the active seal.

AMS-P-83461 material immersed in MIL-PRF-87257 resulted in an increase in volume (+7.8 to +11.9%). If a system with MIL-PRF-87257 is flushed with MIL-PRF-83282, a reduction could occur (up to -5%). If a system with MIL-PRF-87257 is topped off with MIL-PRF-83282, a slight reduction could occur (up to -2.7%). It can be considered that there will be no major detriments to seals from a gain or loss in volume swell if a system with MIL-PRF-87257 is topped off with or flushed with MIL-PRF-5606. Loss in volume swell could have an adverse affect on the seal during low pressure or low temperature conditions if the seal were transitioned from the spare gland to become the active seal.

AMS-P-83461 material immersed in MIL-PRF-83282 resulted in an increase in volume (+2.4 to +5.9%). If a system with MIL-PRF-83282 is flushed with MIL-PRF-5606 or MIL-PRF-87257, an increase in volume can be expected (+5.2 to +7.9%). If a system with MIL-PRF-83282 is topped off with MIL-PRF-5606 or MIL-PRF-87257, an increase in volume can be expected (3.1 to 4.8%).

4.2.2.2 Percent Change in Elongation After Immersion

Table 10 - Elongation after 100% concentration X 100% concentration

Material: AMS-P-83461								
Baseline Initial Fluid*			Secondary Fluid*					
			MIL-PRF-5606		MIL-PRF-87257		MIL-PRF-83282	
	Company A	Company B	Company A	Company B	Company A	Company B	Company A	Company B
MIL-PRF-5606	-5	-13	N/A	N/A	0.3	-24.5	0.3	-19.5
MIL-PRF-87257	-5.3	-19.2	-5	-18.1	N/A	N/A	-1.5	-17.2
MIL-PRF-83282	-1.1	-15.4	-8.8	-19	-13.3	-24.1	N/A	N/A

Table 11 - Elongation after 100% concentration X 50/50% concentration

Material: AMS-P-83461								
Baseline Initial Fluid*			Secondary Fluid*					
			MIL-PRF-5606 / MIL-PRF-87257		MIL-PRF-5606 / MIL-PRF-83282		MIL-PRF-87257 / MIL-PRF-83282	
	Company A	Company B	Company A	Company B	Company A	Company B	Company A	Company B
MIL-PRF-5606	-5	-13	-9.8	-14	3.7	-15.2	N/A	N/A
MIL-PRF-87257	-5.3	-19.2	**	-15.7	N/A	N/A	-1.7	-21.1
MIL-PRF-83282	-1.1	-15.4	N/A	N/A	-0.1	-27.5	-4.6	-28.1

* Immersion for 70 hours at 160 °F (71 °C).

AMS-P-83461 material immersed in MIL-PRF-5606 resulted in a reduction in elongation properties (-5 to -13%); it can be considered that there will be no major detriments to seals from an elongation perspective if a system with MIL-PRF-5606 is topped off with MIL-PRF-87257 or MIL-PRF-83282. Reduction in elongation properties (up to -11.5%) could occur if a system with MIL-PRF-5606 is completely flushed with MIL-PRF-87257 or MIL-PRF-83282.

AMS-P-83461 material immersed in MIL-PRF-87257 resulted in a reduction in elongation properties (-5.3 to -19.2%); it can be considered that there will be no major detriments to seals from an elongation perspective if a system with MIL-PRF-87257 is flushed with MIL-PRF-5606 or MIL-PRF-83282; nor if a system is topped off with MIL-PRF-83282 or MIL-PRF-5606.

AMS-P-83461 material immersed in MIL-PRF-83282 resulted in a reduction in elongation properties (-1.1 to -15.4%). If a system with MIL-PRF-83282 is flushed or topped off with MIL-PRF-5606, a reduction in elongation properties could occur (up to -12.1%). If a system with MIL-PRF-83282 is flushed or topped off with MIL-PRF-87257, a reduction in elongation properties could occur (up to -12.7%).

4.2.2.3 Percent Change in Tensile Strength After Immersion

Table 12 - Tensile strength after 100% concentration X 100% concentration

Material: AMS-P-83461								
Baseline Initial Fluid*			Secondary Fluid*					
			MIL-PRF-5606		MIL-PRF-87257		MIL-PRF-83282	
	Company A	Company B	Company A	Company B	Company A	Company B	Company A	Company B
MIL-PRF-5606	-13.3	-38.7	N/A	N/A	-7.1	-49.3	2.8	-32.9
MIL-PRF-87257	-21.7	-39.9	-16	-34.7	N/A	N/A	1.6	-30.5
MIL-PRF-83282	0.2	-30.6	-25.9	-42	-26.2	-42.1	N/A	N/A

Table 13 - Tensile strength after 100% concentration X 50/50% concentration

Material: AMS-P-83461								
Baseline Initial Fluid*			Secondary Fluid*					
			MIL-PRF-5606 / MIL-PRF-87257		MIL-PRF-5606 / MIL-PRF-83282		MIL-PRF-87257 / MIL-PRF-83282	
	Company A	Company B	Company A	Company B	Company A	Company B	Company A	Company B
MIL-PRF-5606	-13.3	-38.7	-14	-29	1.2	-30.7	N/A	N/A
MIL-PRF-87257	-21.7	-39.9	-24.7	-35.1	N/A	N/A	-2.7	-37.5
MIL-PRF-83282	0.2	-30.6	N/A	N/A	1.7	-46.6	-7.6	-48.7

* Immersion for 70 hours at 160 °F (71 °C).

AMS-P-83461 material immersed in MIL-PRF-5606 resulted in a significant reduction in tensile properties (up to -38.7%); it can be considered that there will be no major detriments to seals if a system with MIL-PRF-5606 is topped off with MIL-PRF-87257 or MIL-PRF-83282; nor if a system is flushed with MIL-PRF-83282. However, there is potential for the seals to experience reduction in tensile properties (-10.6%) if the MIL-PRF-5606 system is completely flushed with MIL-PRF-87257.

AMS-P-83461 material immersed in MIL-PRF-87257 resulted in a significant reduction in tensile properties (-21.7 to -39.9%); it can be considered that there will be no major detriments to seals if a system with MIL-PRF-87257 is topped off with or flushed with MIL-PRF-5606 or MIL-PRF-83282.

AMS-P-83461 material immersed in MIL-PRF-83282 resulted in a significant reduction in tensile properties (up to -30.6%). Reduction in tensile properties (-11.4 to -26.4%) could occur if a MIL-PRF-83282 system is flushed with either MIL-PRF-5606 or MIL-PRF-87257. A reduction in tensile properties (-7.8 to -18.1%) may occur if a MIL-PRF-83282 system is topped off with either MIL-PRF-5606 or MIL-PRF-87257.

5. CONCLUSIONS

The information contained in this document is provided as a recommendation only and does not constitute a guarantee of performance. It is strongly recommended to test according to individual application conditions for the purpose of validation.

5.1 Seal swell due to fluid contact is a major problem when attempting to install a seal that has been exposed to hydraulic fluid.

5.2 Tensile set, even if seal is stretched 20%, should not be cause for concern.

5.3 By locating the spare seal downstream from the static seal, avoiding the use of oil as an aid during installation and packing it in low swell grease or a dry condition (preferred method), minimum swell and less installation difficulty will be encountered.

The following statements and recommendations are directed towards applications with an upper temperature limit of 160 °F (71 °C). For all recommendations below, regardless of fluid combination or concentration, the aircraft system in question should be monitored after introduction of new fluids due to potential impact to seal performance.

It is recommended to continue use of the initial system fluid whenever possible; if the system fluid must be changed, the below statements and recommendations should be reviewed.

5.4 Volume Swell: AMS-P-25732

5.4.1 The AMS-P-25732 material is expected to achieve positive volume swell when in MIL-PRF-5606 or MIL-PRF-87257 fluid; however, MIL-PRF-83282 may cause only minor volume swell and/or potentially negative volume swell. It is not recommended to use an AMS-P-25732 material in MIL-PRF-83282 fluid, or some mixed concentration of MIL-PRF-83282, as a reduction in volume swell may occur. If an AMS-P-25732 material is used in MIL-PRF-83282 fluid, the system should be monitored due to potential impact to the elastomer, which could lead to a reduction in sealing performance during low pressure or low temperature conditions. An AMS-P-25732 material should have equivalent increases in volume swell if a system with MIL-PRF-83282 fluid is replaced with either MIL-PRF-5606 or MIL-PRF-87257; this includes partial and full replacement of the system fluid. An AMS-P-25732 material should remain at a relatively consistent volume swell if it is in contact with either MIL-PRF-5606 and/or MIL-PRF-87257 (this includes mixed concentrations of both fluids).

5.5 Elongation Properties: AMS-P-25732

5.5.1 There is likely to be some loss in elongation properties of an AMS-P-25732 material when used in MIL-PRF-5606, MIL-PRF-87257, or MIL-PRF-83282 fluids; however, the observed loss in elongation properties are well below the specification limits of the AMS-P-25732 material. Therefore, it can be considered acceptable to use an AMS-P-25732 material in any of the above mentioned fluids, regardless of the starting fluid or mixed concentrations thereafter (this statement does not pertain to a concentration of all three of the above listed fluids).

5.6 Tensile Properties: AMS-P-25732

5.6.1 There should be no concerns regarding degradation or loss in tensile properties when using an AMS-P-25732 material in MIL-PRF-5606, MIL-PRF-87257, or MIL-PRF-83282 fluids, regardless of the starting fluid or concentrations of fluid thereafter (i.e., replacement of MIL-PRF-5606 with MIL-PRF-87257 or MIL-PRF-83282; this statement does not pertain to a concentration of all three of the above listed fluids).

5.7 Volume Swell: AMS-P-83461

5.7.1 The AMS-P-83461 material is expected to achieve positive volume swell when in MIL-PRF-5606, MIL-PRF-87257, or MIL-PRF-83282 fluid. However, it is not recommended to use an AMS-P-83461 material in MIL-PRF-83282 fluid, or some mixed concentration of MIL-PRF-83282 as low volume swell or a reduction in volume swell could occur. If an AMS-P-83461 material is used in MIL-PRF-83282 fluid, the system should be monitored due to potential impact to the elastomer, which could lead to a reduction in sealing performance during low pressure or low temperature conditions. An AMS-P-83461 material should have equivalent increases in volume swell if a system with MIL-PRF-83282 fluid is replaced with either MIL-PRF-5606 or MIL-PRF-87257; this includes partial and full replacement of the system fluid. An AMS-P-83461 material should remain at a relatively consistent volume swell if it is in contact with either MIL-PRF-5606 and/or MIL-PRF-87257 (this includes mixed concentrations of both fluids).

5.8 Elongation Properties: AMS-P-83461

5.8.1 If an AMS-P-83461 material is originally in MIL-PRF-5606 fluid, it is not recommended to completely replace the MIL-PRF-5606 fluid with MIL-PRF-87257 or MIL-PRF-83282 due to potential degradation and reduction in elongation properties of the AMS-P-83461 material. However, the MIL-PRF-5606 fluid may be replaced with small amounts of MIL-PRF-87257 or MIL-PRF-83282 with minimal anticipated affects to elongation properties.

5.8.2 If an AMS-P-83461 material is originally in MIL-PRF-87257 fluid, there should be no concerns regarding degradation or loss in elongation properties if the fluid is replaced with MIL-PRF-5606 or MIL-PRF-83282 in any concentration.

5.8.3 If an AMS-P-83461 material is originally in MIL-PRF-83282 fluid, it is not recommended to replace nor introduce the AMS-P-83461 material to high concentrations of MIL-PRF-5606 or MIL-PRF-87257 fluid as this could potentially lead to material degradation and an increased loss in elongation properties.

5.9 Tensile Properties: AMS-P-83461

5.9.1 If an AMS-P-83461 material is originally in MIL-PRF-5606 fluid, it is not recommended to completely replace the MIL-PRF-5606 fluid with MIL-PRF-87257 fluid due to potential degradation and loss of tensile properties to the AMS-P-83461 material. However, the MIL-PRF-5606 fluid may be replaced with small amounts of MIL-PRF-87257 with minimal anticipated affects to tensile properties. The MIL-PRF-5606 fluid can be replaced with MIL-PRF-83282 in any concentration as it should lead to minimal degradation of the AMS-P-83461 material.

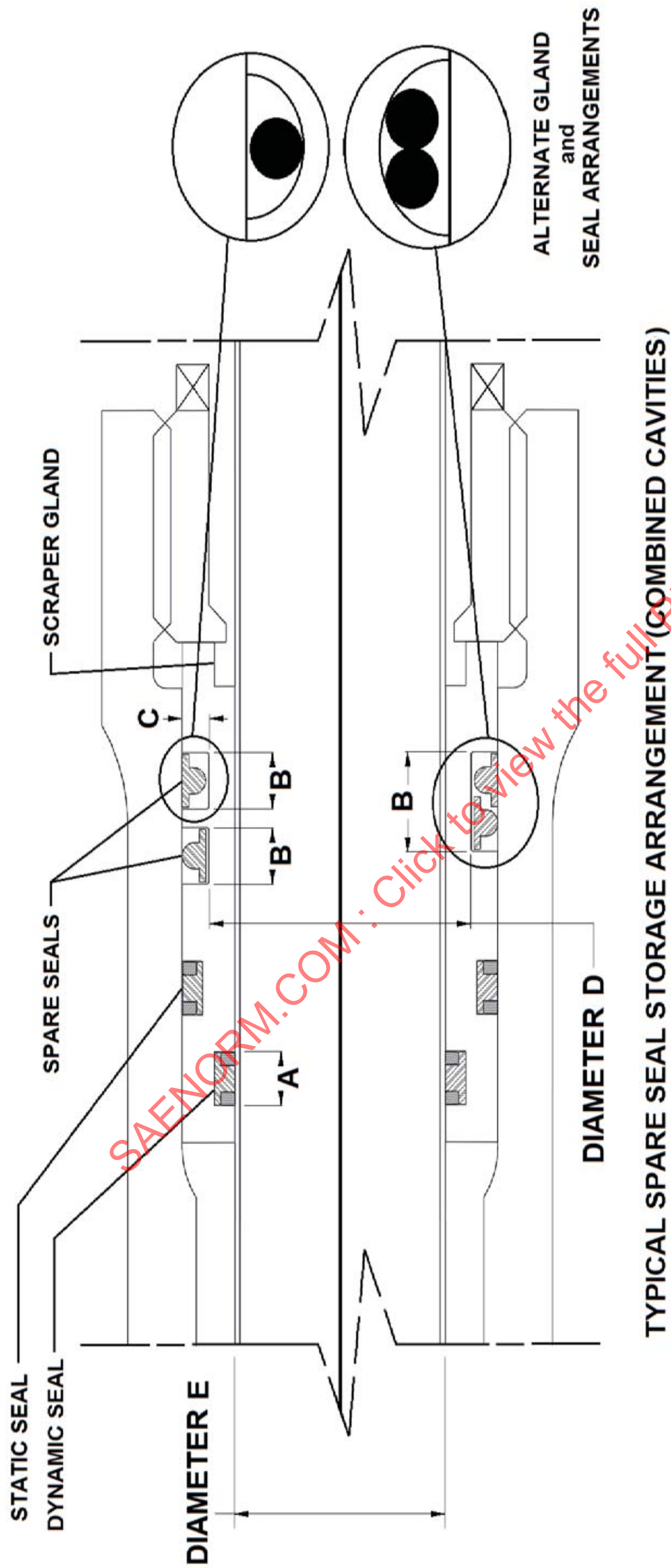
5.9.2 If an AMS-P-83461 material is originally in MIL-PRF-87257 fluid, there should be no concerns regarding degradation or loss in tensile properties if the fluid is replaced with MIL-PRF-5606 or MIL-PRF-83282 in any concentration.

5.9.3 If an AMS-P-83461 material is originally in MIL-PRF-83282 fluid, it is not recommended to replace nor introduce the AMS-P-83461 material to high concentrations of MIL-PRF-5606 or MIL-PRF-87257 fluid as degradation of the material and an increased loss in tensile properties are likely to occur.

6. NOTES

6.1 Revision Indicator

A 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, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.



NOMINAL SEAL CROSS SECTION	ACTIVE SEAL GLAND LENGTH	ROD DIAMETER	SPARE SEAL CAVITY			
			CAVITY LENGTH B		CAVITY DEPTH	CAVITY DIAMETER
			SINGLE CAVITY	COMBINED CAVITY	C	D
1/4	A	E	A + .020	1.75 (A + .020)	0.300	1.05E (MAX)
3/8	A	E	A + .020	1.75 (A + .020)	0.450	1.05E (MAX)

Figure 2 - Typical spare seal storage arrangement (separate cavities)