

Gland Design, Computation of Seal Squeeze and Gland Volume

RATIONALE

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1. SCOPE:

- 1.1 This SAE Aerospace Recommended Practice (ARP) presents two BASIC language computer programs to promote and standardize the computation of installed O-ring cross-section deflection hereafter referred to as "squeeze" and the computation of gland volume. The two programs were written with line numbers and without use of any system specific BASIC commands to allow usage with as many systems as possible with a minimum of editing. The programs support entry of customary U.S. or metric dimensions.

The squeeze program, called SQ.BAS, has the following features:

- a. allows selection of either piston or rod gland
- b. allows entry of cap strip seal thickness
- c. computes minimum and maximum squeeze
- d. allows checking and correction of entries before execution
- e. allows viewing of output on screen before printing
- f. gives advisory messages for excessive stretch or inadequate squeeze
- g. allows on-line review of essential input and output variables prior to running program
- h. computes clearance between minimum gland height and maximum backup radial height when the backup dimension is entered
- i. program output is viewable on screen or may be printed out using either of two methods

1.1 (Continued):

The gland volume program called GV.BAS, has the following features:

- a. allows selection of either piston or rod gland
- b. computes gland volume, O-ring volume and backup ring volume
- c. computes minimum and maximum percent occupancy
- d. allows viewing of output on screen before printing
- e. allows on-line review of essential input and output variables prior to running program
- f. allows entry of volume of a non-standard configuration or special seal such as a cap strip seal
- g. program output is viewable on screen or may be printed out using either of two methods

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 Telephone: 724-776-4970, Web address: <http://www.sae.org>

AS568	Aerospace Size Standard for O-rings
AS4716	Aerospace Standard, Gland Design, O-ring and Other Elastomeric Seals

2.2 U.S. Government Publications:

Available from DODSSP Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094 Telephone: 215-697-2179, Web address: <http://assist.daps.mil/>

MIL-G-5514	Gland Design; Packing, Hydraulic, General Requirements For (inactive for new design)
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3. TECHNICAL REQUIREMENTS:

3.1 Seal Squeeze:

- 3.1.1 General: This document gives a listing of a BASIC language computer program, SQ.BAS, which presents a standardized algorithm for computation of the deflection of the O-ring cross-section when installed in a gland. Work by several independent sources recognized the importance of maintaining squeeze between prescribed limits for maximum life of elastomeric seals. An upper bound is important to prevent deterioration, excessive friction, wear, and occasional spiral failure of O-rings. A lower bound is important to prevent premature compression set of the elastomer due to inadequate installed deflection, hereafter referred to as squeeze.
- 3.1.2 Background: MIL-G-5514 originated using inch fractional increments for gland dimensions and gradually evolved into a document based upon decimal increments which deviated somewhat from the original fractional increment organization. While the document was revised over the years to address various issues, no uniform application of squeeze requirements currently exists in the document. In 1985, the SAE Committee A-6 Seal Panel began work on a document to provide a standard which did provide a uniform standard for installed squeeze. The product was AS4716 which gives a squeeze not less than 0.005 inches when all adverse tolerances are considered, and also had a goal to not exceed 85 percent gland occupancy when minimum gland volume and maximum seal volumes are considered.. In some cases the occupancy exceeds 85 percent when all factors were considered.
- 3.1.3 Computational Basis: The equations used for program SQ.BAS are published in AS4716. The equations are based upon tests using O-rings, but are generally applicable to non-standard elastomeric seals as well, requiring only a knowledge of the seal inner diameter and radial cross-section dimensions in addition to the gland dimensions. AS4716 has tables for glands using AS568 O-ring dimensions which meet established criteria for squeeze and volume. Program SQ.BAS may be used for checking squeeze with other cross-sections and for salvage operations or in special circumstances, the gland and seal dimensions at extreme temperature conditions could be used to determine resultant squeeze at non-standard conditions. Appendix A gives a program listing for SQ.BAS.

3.1.4 Description of Operation:

3.1.4.1 Input of Data: When the program starts, a menu appears on the screen giving the following choices:

```
RUN          (R)
QUIT         (Q)
CHANGE DEFAULTS (C)
REVIEW VARIABLES (V)
ENTER CHOICE?
```

Entering "R" will begin main program.

Entering "Q" will end the program.

Entering "C" will give a menu to allow changing the default advisory values in the program. See 3.1.4.2 for further discussion of advisory default values.

Entering "V" will give a screen listing of the program variables.

Next, the entry of the following input data is requested:

```
0  GLAND (AS568 DASH NO. OR ISO O-RING CODE) - "; SIZE$
1  TYPE - (R)OD OR (P)ISTON                      "; TYPE$
2  SEAL CROSS SECTION - LOW VALUE                  "; WL
3  SEAL CROSS SECTION - HIGH VALUE                 "; WH
4  SEAL ID - LOW VALUE                             "; IDSL
5  SEAL ID - HIGH VALUE                            "; IDSH
```

If gland is piston type, the following two lines appear.

```
6  PISTON DIAMETER - LOW VALUE                     "; DPL
7  PISTON DIAMETER - HIGH VALUE                    "; DPH
```

If gland is rod type, the following two lines appear.

```
6  ROD DIAMETER - LOW VALUE                        "; DRL
7  ROD DIAMETER - HIGH VALUE                      "; DRH
```

The remaining lines are common to both applications.

```
8  BORE DIAMETER - LOW VALUE                       "; DBL
9  BORE DIAMETER - HIGH VALUE                      "; DBH
10 GROOVE DIAMETER - LOW VALUE                     "; DGL
11 GROOVE DIAMETER - HIGH VALUE                    "; DGH
12 GROOVE ECCENTRICITY                             "; ECC
13 CAP SEAL THICKNESS - LOW VALUE                  "; TCAPL
14 CAP SEAL THICKNESS - HIGH VALUE                 "; TCAPH
15 COMMENT:                                         "; COMMENT$
```

COMMENT\$ allows entry of a short note or comment on the case being run. It should be limited to 60 characters in order to fit on one line of the output format.

3.1.4.1 (Continued):

After the last carriage return, the screen shows a listing of the data entered and by choosing the number corresponding to the variable, a new value for any of the input data may be entered. Entering "A", when prompted, will allow entry of all data from the beginning, which sometimes is a time saver when many changes have to be made. Entering "N", when prompted, will execute computation portion of the program.

3.1.4.2 Output: The program output appears on the screen for review prior to printing. By choosing "R", the program will branch to the data review and correction menu. Choosing "P" causes the program output to be directed to a file. Entering "Q" stops the program.

There are two ways to obtain a hard copy of the program output.

1. Before running the program, create a new folder, SEALPRNT on Drive C:. Then, when the program prompts for printout, pressing "P" will direct the output to a editable text file called SQOUT.TXT which can be found at C:\SEALPRNT\.
SQOUT.TXT can be opened with word processor software for printing a hardcopy or cutting and pasting into other documents.
2. Another method of obtaining a hard copy of the output is to press the Print Scrn key while the output is shown on the screen, then open a new file on your word processor software and selecting PASTE from the Edit menu. The output will be pasted as editable text into the file.

Depending upon the default font used for the word processor, the printout will probably not be aligned as shown in the examples. To correct this, the printout format should be set to have a left margin of 1.0 inches and a right margin of 0.7 inches. Set the font to 10 point Courier New. These steps will align the columns and lines of text.

An example printout of the program for a -214 gland is shown on Figure 1. The columns entitled LOW and HIGH are the numerically low and high values entered for the seal and gland variables. The columns entitled AT MIN SQUEEZE and AT MAX SQUEEZE give the calculated results for the variables shown at the minimum squeeze and maximum squeeze conditions.

NOTE: The LOW and HIGH columns are not related to the variable usage for computed results in the AT MIN SQUEEZE and AT MAX SQUEEZE columns.

3.1.4.2 (Continued):

The program has several advisory messages which appear to highlight program results outside the normal accepted range of values for aerospace service gland parameters. Example advisory messages are:

CROSS-SECTION DEFLECTION IS INSUFFICIENT... MIN ALLOWED DEFL = 0.0050 inches
CROSS-SECTION SQUEEZE IS NOT EXCESSIVE... MAX ALLOWED SQUEEZE = 30.0 %
ID STRETCH IS OKAY... MAX ALLOWED STRETCH = 5.00 %
BACKUP HEIGHT IN GLAND IS OKAY... MAX BU = 0.1200 MIN GLAND = 0.1215

The default values are shown which are used for determining the text of the message to be printed. The messages and the default are advisory only, the program user is cautioned to research the industry accepted allowable values for any special circumstances when using the program. If different values are desired, select "C" at program opening menu to obtain a menu allowing the user to change the default minimum deflection, maximum percent squeeze, and maximum percent stretch. These values are advisory only and are used only in the messages at the end of the program output. Lines 480 thru 580 may be edited to change the text of the advisory messages. The program gives a message also when the stretch computed from the data entered exceeds the range established for the cross-section reduction equations. An example of the program output using metric gland dimensions is shown on Figure 2.

3.2 Gland Volume:

- 3.2.1 General: This standard gives a listing of a BASIC language computer program, GV.BAS, for the computation of gland volume, O-ring and backup ring volume and the minimum and maximum percent occupancy. The program algorithm uses exact volumes derived from volumes of revolution using integral calculus for the various shapes resulting from consideration of wall angles and corner radii.
- 3.2.2 Background: The importance of adequate gland volume has been recognized over the years to allow for seal expansion with temperature increase and for seal swell when subjected to hydraulic fluids. MIL-G-5514 made provisions for adequate volume. The work in AS4716 also considered adequate volume and uses a goal of not more than 85 percent occupancy with the most adverse tolerances and dimensions applied.

3.2.3 Computational Basis: Program GV.BAS computes the minimum and maximum volumes for the gland, O-ring, and backup rings. The volumes are combined to compute the minimum and maximum percent occupancy of the gland. The program allows entry of negative wall angle. Appendix B gives a listing for program GV.BAS. While the program is constructed to give the minimum and maximum percent occupancy for the dimensions entered, it may be used to compute the resultant volumes for non-standard seals and salvage situations by entering the same dimensions for the lower and upper values of each component. Appendix C shows the procedure used to derive the volumes for the geometric shapes which constitute a gland when broken down into the simplest geometric elements. The portions of the gland constituting volumes V1, V2, V3, and V4 in the output are shown in Appendix C for rod (ID) and piston (OD) applications. O-ring and backup ring dimension variables are shown in Appendix D.

3.2.4 Description of Operation:

3.2.4.1 Input of Data: When the program starts a message appears on the screen giving a choice of running the program or viewing a list of the program variables. Entering "V" will give a screen listing of the program variables. Entering "R" will begin main program. Next, the entry of the following input data is requested:

```
INPUT " 0 AS568 DASH NUMBER OR ISO O-RING SIZE CODE..... "; SIZE$
INPUT " 1 (R) OD OR (P)ISTON....."; TYPE$
INPUT " 2 GLAND WIDTH - LOW....."; WGL
INPUT " 3 GLAND WIDTH - HIGH....."; WGH
INPUT " 4 GROOVE DIAMETER - LOW....."; DGL
INPUT " 5 GROOVE DIAMETER - HIGH....."; DGH
INPUT " 6 GROOVE WALL ANGLE, DEGREES - LOW....."; AGL
INPUT " 7 GROOVE WALL ANGLE, DEGREES - HIGH....."; AGH
INPUT " 8 GROOVE CORNER RADIUS - LOW....."; RGL
INPUT " 9 GROOVE CORNER RADIUS - HIGH....."; RGH
```

IF TYPE\$ = "P" the following two lines appear

```
INPUT " 10 PISTON BORE DIAMETER - LOW....."; DBL
INPUT " 11 PISTON BORE DIAMETER - HIGH....."; DBH
```

IF TYPE\$ = "R" the following two lines appear

```
INPUT " 10 ROD DIAMETER - LOW....."; DRL
INPUT " 11 ROD DIAMETER - HIGH....."; DRH
```

```
INPUT " 12 O-RING CROSS SECTION DIAMETER - LOW....."; WSL
INPUT " 13 O-RING CROSS SECTION DIAMETER - HIGH....."; WSH
INPUT " 14 O-RING INNER DIAMETER - LOW....."; IDSL
INPUT " 15 O-RING INNER DIAMETER - HIGH....."; IDSH
INPUT " 16 NUMBER OF BACK UP RINGS....."; NB
```

3.2.4.1 (Continued):

IF NB is greater than zero, the following lines appear

```
INPUT " 17 BACK UP RING INNER DIAMETER - LOW....."; IDBUL
INPUT " 18 BACK UP RING INNER DIAMETER - HIGH....."; IDBUH
INPUT " 19 BACK UP RING RADIAL WIDTH - LOW....."; WBL
INPUT " 20 BACK UP RING RADIAL WIDTH - HIGH....."; WBH
INPUT " 21 BACK UP RING THICKNESS - LOW....."; TBL
INPUT " 22 BACK UP RING THICKNESS - HIGH....."; TBH
INPUT " 23 BACK UP RING GAP - LOW....."; GBUL
INPUT " 24 BACK UP RING GAP - HIGH....."; GBUH
INPUT " 25 BACK UP RING GAP ANGLE, DEGREES - LOW....."; ABUL
INPUT " 26 BACK UP RING GAP ANGLE, DEGREES - HIGH....."; ABUH
INPUT " 27 MIN VOLUME OF SPECIAL SEAL (ENTER 0 IF NONE).... "; VSPCL
INPUT " 28 MAX VOLUME OF SPECIAL SEAL (ENTER 0 IF NONE).... "; VSPCH
INPUT " 29 COMMENT: "; COMMENT$
```

NOTE: When entering VSPCL and VSPCH, be sure to use units consistent with dimension entries for other assembly components

- 3.2.4.2 Execution: When the program is run, a screen appears which gives a choice of "R" to run the program or "V" to view a listing of program variable definitions. If the "V" option is chosen, follow the prompts to complete viewing of the list. At the end of the list choose "R" to repeat list or "Q" to quit list and return to main program.
- 3.2.4.3 Program Output: When execution of the program is complete, an output screen appears which allows immediate viewing of results. An option appears giving a choice of "P" to print output to a file, "Q" to quit execution, or "R" to run again. If "R" is chosen a screen appears with the current values for variables to allow rerunning after changing only the values desired.

There are two ways to obtain a hard copy of the program output.

1. Before running the program, create a new folder, SEALPRNT on Drive C:. Then, when the program prompts for printout, pressing "P" will direct the output to a editable text file called GVOUT.TXT which can be found at C:\SEALPRNT\.
GVOUT.TXT can be opened with word processor software for printing a hardcopy or cutting and pasting into other documents.
2. Another method of obtaining hard copy of the output is to press the Print Scrn key while the output is shown on the screen, then open a new file on your word processor software and selecting PASTE from the Edit menu. The output will be pasted as editable text into the file. This operation will have to be performed twice, once for each screen of output.

3.2.4.3 (Continued):

Depending upon the default font used for the word processor, the printout will probably not be aligned as shown in the examples. To correct this, the printout format should be set to have a left margin of 1.0 inches and a right margin of 0.7 inches. Set the font to 10 point Courier New. These steps will align the columns and lines of text.

Figure 3 is an example of the output created using MIL-G-5514F gland dimensions. Figure 4 is an example output using metric gland dimensions. The columns entitled LOW and HIGH are the numerically low and high values entered for the seal and gland variables. The columns entitled MIN PCT and MAX PCT give the calculated results for the variables shown at the minimum squeeze and maximum occupancy conditions.

NOTE: The LOW and HIGH columns are not related to the variable usage for computed results in the MIN PCT and MAX PCT columns.

4. MEDIA AVAILABILITY:

The programs in this document are available on 3.5 inch floppy disks for personal computers from SAE.

5. NOTES:

5.1 Conversion of the BASIC listing to other Software:

For users who do not have access to a BASIC Language interpreter or compiler, the equations used for computing O-ring deflection and squeeze have been successfully used in spread sheet software by several individuals. Also, the equations can be entered into other available math software. The results should be checked against the examples in this document for accuracy. This would be a recommended solution for individuals lacking BASIC Language software or if personal preference are predominant considerations.

5.2 Changes to SQ.BAS for Revision A:

Changed or added lines in SQ.BAS are denoted by “ ‘REV A “ to the right of the line in the program listing.

A critical element of the program is the computation of reduction of O-ring cross-section due to stretch. ARP4727 originally used the quadratic equations from a published O-ring handbook. Beginning with revision ARP4727A, the equation used to compute the reduction in O-ring cross-section due to stretch uses a different equation, identified as the hyperbolic equation, for O-rings whose ID to cross-section ratio is equal to or less than 2.95. The original quadratic equations are still used for O-rings whose ID to cross-section ratio is greater than 2.95. The program results print a message to indicate the equation used, based upon the value of the ratio.

Another significant correction to the program is in the calculation of percent squeeze. The program has been corrected to compute the percent squeeze by taking the ratio of the installed deflection of the O-ring over the original free cross section diameter. This does not effect the computation of the O-ring deflection, but will change the calculated percent squeeze by a small amount from prior versions of the program.

A correction in the program was made regarding the allowance for cap seal thickness effect on stretch of a rod (ID) seal. The correct equation uses $2 \cdot TCAP$ on the diameter. The error, if unchanged, would only effect computation results if the squeeze calculation were being done using a cap seal in a rod (ID) seal installation.

Another revision was made in the definition of the variables STRL and STRH. These now refer to the low numerical value for stretch and the high numerical value for stretch respectively. This change does not effect results of the computed values.

Also, the program was changed so that when the default value for minimum squeeze in inches is altered, the corresponding value for ISO dimensions is revised to agree and vice versa. The default will remain as set until the program has been quit or restarted.

Improved the ease of getting printed output from the program.

5.3 Changes to GV.BAS for Revision A:

Changed or added lines in GV.BAS are denoted by “ ‘REV A “ to the right of the line in the program listing.

A minor correction was made (lines 4420-4440) to give the correct logic when the gland application case is changed from R to P or P to R.

Improved the ease of getting printed output from the program.

```
O-RING SEAL SQUEEZE - USING PGM SQ.BAS      VERSION 3.0

Time: 10:20:31 AM   Date: 03-20-2003

GLAND DASH NUMBER (AS568 OR ISO O-RING CODE) -214      TYPE: PISTON (OD SEAL)
Example of -214 MIL-G-5514 piston seal squeeze.

IDSL/WL = 7.21  RATIO > 2.95:USED QUADRATIC EQUA FOR SEAL CROSS SECT REDUCT
IDSH/WH = 6.95  RATIO > 2.95:USED QUADRATIC EQUA FOR SEAL CROSS SECT REDUCT

*****
                                LOW                HIGH
                                -----
SEAL CROSS SECTION - in.        0.1350            0.1430
SEAL ID - in.                   0.9740            0.9940
PISTON DIAMETER - in.          1.2380            1.2390
BORE DIAMETER - in.            1.2410            1.2430
GROOVE DIAMETER - in.          0.9960            0.9980
GROOVE ECCENTRICITY - in.       0.0000            0.0030

                                AT MIN             AT MAX
                                SQUEEZE            SQUEEZE
                                -----
SQUEEZE - PERCENT               3.66              16.71
O-RING DEFLECTION - in.         0.00494           0.02390
DIAMETRAL CLEARANCE - in.       0.0050            0.0030
STRETCH - PERCENT              2.26              0.40

***** ADVISORY MESSAGES *****
CROSS-SECT DEFLECTION IS INSUFFICIENT... MIN ALLOWED DEFL = 0.0050 inches
CROSS-SECTION SQUEEZE IS NOT EXCESSIVE... MAX ALLOWED SQUEEZE = 30.0 %
ID STRETCH IS OKAY... MAX ALLOWED STRETCH = 5.00 %
BACKUP HEIGHT IN GLAND IS OKAY... MAX BU = 0.1200 MIN GLAND = 0.1215
*****
```

FIGURE 1 - Example Printout from Program "SQ.BAS" Using SAE Dimensions