Designation: F3149 – 15

Standard Practice for Determining the Maintenance Factor (*m*) and Yield Factor (*y*) Loading Constants Applicable to Gasket Materials and Designs[1]

This standard is issued under the fixed designation F3149; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice will establish criteria for determining loading constants that are referenced in the American Society of Mechanical Engineers (ASME) pressure vessel design (Boiler and Pressure Vessel Code, Section VIII, Divs. 1 and 2). These constants are specific to this design criterion for metallic, semi-metallic, and nonmetallic gaskets.

1.2 *Units*—The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D2000 Classification System for Rubber Products in Automotive Applications

F104 Classification System for Nonmetallic Gasket Materials

F868 Classification for Laminated Composite Gasket Materials

2.2 *ASME Standards:*[3]

B16.5 Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard Boiler and Pressure Vessel Code Section VIII, Divs. 1 and 2

PCC-1 Guidelines for Pressure Boundary Bolted Flange Joint Assembly

2.3 *DIN Standard:*

DIN 3535 Gaskets for Gas Supply[4]

2.4 *FSA Standard:*

FSA G 605:11 Standard Test Method for Determining (*m*) and (*y*) Loading Constants Applicable to Gasket Materials and Designs[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *gasket contact area, A_1, n*—gasket area in contact with the flange surfaces and under load.

3.1.1.1 *Discussion*—The gasket contact area described in this practice can deviate from the effective area described in the ASME pressure vessel design.

3.1.2 *leak rate, n*—volumetric leak rate per inch gasket outside diameter.

3.1.3 *maintenance factor, m, n*—factor that is required to calculate the additional flange fastener preload needed to maintain a seal after internal pressure is applied to a joint.

3.1.4 *surface stress, n*—stress applied to the gasket contact area and equal to the applied load divided by gasket contact area.

3.1.5 *yield factor, y, n*—factor that provides the gasket minimum design seating stress required to seal a joint upon assembly.

3.1.5.1 *Discussion*—This assumes no pressure and, therefore, a lack of hydrostatic end load effect on the assembly. Reported in psi.

4. Significance and Use

4.1 The gasket factors are a function of leak rate; therefore, this practice generates curves. Constants for use in the ASME Boiler and Pressure Vessel Code, Section VIII, Appendix 2

[1] This practice is under the jurisdiction of ASTM Committee F03 on Gaskets and is the direct responsibility of Subcommittee F03.40 on Chemical Test Methods.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from the Fluid Sealing Association, 994 Old Eagle School Rd., #1019, Wayne, PA 19087-1866.

code calculations are selected from these data. Specific *m* and *y* values can be selected based on a maximum desired leak rate or derived from these data as described in this procedure. This practice addresses the influence of leak rate and gasket thickness on a gasket's ability to provide a seal initially and in operation. This practice is performed at room temperature; therefore, this practice does not account for all conditions, such as high temperature or thermal cycling or both, that bolted flange connections may be subject to in field application.

4.2 This practice determines two general characteristics that are specific to the ASME design criteria. Caution should be exercised when comparing yield and maintenance factors between gasket materials, and it is recommended that the *m* and *y* curves be compared. Selecting a gasket material for use in an application should not be based exclusively on these two general characteristics. Gasket material selection for a given application should consider additional information not described in this practice, which includes, but is not limited to, chemical resistance, thermal resistance, creep relaxation, compressibility, and accommodation of thermal cycling.

4.3 This practice builds upon work conducted in the Fluid Sealing Association (FSA G 605:11). The associated round robin data is provided for reference in Tables 1-4.

5. Apparatus

5.1 The test apparatus is composed of three elements: test fixture, loading technique, and leak measurement.

5.2 The test fixture may use a flange or platen press. The surface finish of the sealing area shall meet rules stated in ASME B16.5 for acceptable surface finish with a roughness of 125 to 250 µin. (3.2 to 6.6 µm).

5.3 Hydraulically loaded flanges or platen presses are acceptable. (The use of manual loading platens is not acceptable.) If a bolted flange fixture is selected, then loading of the fasteners shall be bolt stretch controlled. (The use of torque controlled loading is not acceptable.) Examples of bolt-stretch-controlled loading include the use of calibrated bolts and ultrasonic devices. In addition, bolted flange fixtures shall be assembled per ASME PCC-1 guidance to minimize variability of test results. Such variables include flange parallelism, bolt loading pattern, and multi-stage tightening levels.

5.4 A leak measurement system is required. Leak measurement methods include differential pressure gage, manometer, flowmeter, and mass spectrometry. The test fixture shall have a containment system to capture leakage outside the gasket, except when flow is measured upstream of the fixture.

NOTE 1—If leak rate is measured with a mass spectrometer, the measured leak rate will be higher because of the higher pressure differential across the gasket, especially in the *y* value portion of the test. This is due to the vacuum created at the gasket outside diameter by the mass spectrometer.

6. Test Specimen

6.1 The test specimen should have a gasket width of 0.5 in. (12.7 mm) or greater. The inside and outside diameter of the gasket should be agreed upon between the producer and user.

6.2 The recommended specimen thicknesses are 1⁄16 and 1⁄8 in. (1.6 and 3.2 mm).

7. Conditioning

7.1 Condition the gasket in accordance with Classification System F104, Classification F868, or as agreed upon between the producer and user.

7.2 Ensure the flange face is clean and free of defects, scratches, or foreign material, or a combination thereof.

8. Procedure

8.1 *Determining Yield Factor, y:*

8.1.1 Measure and record the initial gasket thickness in inches per the procedure described in Classification F104.

8.1.2 Record the surface finish of the flanges or platens (see Section 5).

8.1.3 Center the gasket on the flange face or platen.

8.1.4 Load the gasket to 500 psi (3.45 MPa) surface stress.

8.1.5 Pressurize the fixture to 2 psig (0.14 bar) and record the media.

8.1.6 Hold for 15 min and record the leak rate. If the leak rate cannot be controlled or is in excess of measurement device, proceed to 8.1.7.

TABLE 1 Fluid Sealing Association (FSA) Round Robin Testing of Polytetrafluorethylene (PTFE), Yield Factor

Yield Factor, *y* (psi)	F104 Type 45 – Glass-Filled PTFE							
	Laboratory 1		Laboratory 2			Laboratory 3		
	Test Specimen 1	Test Specimen 2	Test Specimen 1	Test Specimen 2	Test Specimen 3	Test Specimen 1	Test Specimen 2	Test Specimen 3
500	1.14E-04	5.14E-04	9.52E-03	4.30E-03	1.32E-02	1.27E-02	4.09E-03	1.46E-02
1000	5.14E-06	6.29E-05	1.10E-03	6.83E-04	3.20E-04	9.21E-04	1.41E-03	1.28E-03
1500	1.71E-07	9.86E-06				6.79E-04	6.95E-04	6.30E-04
2000	1.63E-07	9.69E-06				5.49E-04	7.59E-04	3.55E-04
2500	1.51E-07	9.54E-06				1.78E-04	1.62E-04	1.62E-04
3000	1.49E-07	8.86E-06				1.62E-04	1.62E-04	1.62E-04
3500	1.46E-07	9.31E-06				1.62E-04		1.62E-04
4000	1.42E-07	7.71E-06						
4500	1.41E-07	8.69E-06						
5000	1.37E-07	8.66E-06						
5500	1.37E-07	5.43E-06						
6000	1.34E-07	4.57E-06						
Selection of yield factor, *y*, based on 0.00085 cm^3/min per inch OD	500	500	1000	1000	1000	1500	1500	1500

TABLE 2 Fluid Sealing Association (FSA) Round Robin Testing of Compressed Non-Asbestos (CNA), Yield Factor

Yield Factor, *y* (psi)	F104 Type 71 – CNA						
	Laboratory 1		Laboratory 2		Laboratory 3		
	Test Specimen 1	Test Specimen 2	Test Specimen 1	Test Specimen 2	Test Specimen 1	Test Specimen 2	Test Specimen 3
500	2.23E-01	2.38E-01	2.50E-02	1.19E-01	8.45E-02	1.41E-01	1.30E-01
1000	7.06E-02	7.03E-02	1.41E-02	1.87E-02	3.02E-02	4.60E-02	4.72E-02
1500	2.95E-02	2.97E-02	5.62E-03	8.35E-03	2.02E-02	2.52E-02	2.97E-02
2000	1.26E-02	1.26E-02	2.33E-03	3.61E-03	4.28E-03	2.94E-03	3.68E-03
2500	4.82E-03	4.80E-03	1.33E-03	1.55E-03	1.52E-03	1.95E-03	1.36E-03
3000	2.11E-03	2.11E-03	1.22E-03	6.48E-04	1.31E-03	7.92E-04	6.62E-04
3500	9.57E-04	9.43E-04	8.17E-04		5.98E-04	4.69E-04	4.36E-04
4000	4.25E-04	4.29E-04					
4500	1.90E-04	1.91E-04					
5000	7.71E-05	7.71E-05					
5500	2.91E-05	2.86E-05					
6000	1.54E-05	1.63E-05					
Selection of yield factor, *y*, based on 0.00085 cm^3/min per inch-OD	4000	4000	3500	3000	3500	3000	3000

TABLE 3 Fluid Sealing Association (FSA) Round Robin Testing of PTFE, Maintenance Factor

NOTE 1—Laboratory 2 increased the surface stress by the hydrostatic end load.

NOTE 2—Per 8.2.16, maintenance factors less than 2.0 are typically reported as 2.0 for use in ASME design calculations for non-elastomeric gaskets.

F104 Type 45 – Glass-Filled PTFE													
Lab 1				Lab 2					Lab 3				
Surface Stress (psi)	Mainte-nance Factor, *m*	Test Specimen 1	Test Specimen 2	Surface Stress (psi)	Mainte-nance Factor, *m*	Test Specimen 1	Test Specimen 2	Test Specimen 3	Surface Stress (psi)	Mainte-nance Factor, *m*	Test Specimen 1	Test Specimen 2	Test Specimen 3
6770	21.5	4.29E-07	6.00E-06	7072	22.6	BDL[A]	BDL	BDL	6770	21.4	BDL	BDL	BDL
6270	19.9	1.77E-06	9.43E-06	6572	20.9	BDL	BDL	BDL	6270	19.8	BDL	BDL	BDL
5770	18.2	1.97E-05	4.86E-05	6072	19.2	BDL	BDL	BDL	5770	18.1	BDL	BDL	BDL
5270	16.5	6.57E-05	1.51E-04	5572	17.6	2.17E-03	6.67E-04	8.00E-03	5270	16.4	2.42E-05	2.91E-04	4.04E-04
4770	14.9	1.43E-04	2.79E-04	5072	15.9	1.33E-03	8.33E-04	9.17E-03	4770	14.8	2.08E-04	7.30E-04	6.30E-04
4270	13.2	2.34E-04	4.30E-04	4572	14.2	1.33E-03	1.17E-03	5.00E-03	4270	13.1	4.36E-04	1.05E-03	7.27E-04
3770	11.5	3.43E-04	6.02E-04	4072	12.6	1.67E-03	6.67E-04	4.67E-03	3770	11.4	3.23E-04	1.32E-03	1.45E-03
3270	9.9	4.57E-04	8.16E-04	3572	10.9	1.83E-03	1.00E-03	7.00E-03	3270	9.8	5.49E-04	1.45E-03	1.63E-03
2770	8.2	6.29E-04	1.08E-03	3072	9.2	1.67E-03	8.33E-04	7.50E-03	2770	8.1	7.75E-04	2.00E-03	2.99E-03
2270	6.5	9.14E-04	1.46E-03	2572	7.6	2.33E-03	1.00E-03	1.12E-02	2270	6.4	1.41E-03	2.55E-03	6.12E-03
1770	4.9	1.49E-03	2.42E-03	2072	5.9	2.67E-03	1.67E-03	1.37E-02	1770	4.8	2.89E-03	4.20E-03	9.53E-03
1270	3.2	1.48E-02	1.83E-03	1572	4.2	3.50E-03	2.67E-03	2.27E-02	1270	3.1	4.12E-03	5.88E-03	1.31E-02
770	1.5	2.23E-02	9.26E-01	1072	2.6	7.50E-03	6.17E-03	5.93E-02	770	1.4	1.49E-02	1.24E-02	1.53E-02
Selection of *m* based on maximum leak rate of 0.085 cc/min-in OD	1.5	3.2			2.6	2.6	2.6			1.4	1.4	1.4	

[A] BDL = below detection limit.

8.1.7 Increase the load in an incremental step of 500 psi (3.44 MPa) surface stress. Larger increments can be used with materials known to require higher seating loads.

8.1.8 Hold for 15 min and record the leak rate.

8.1.9 Repeat 8.1.7 and 8.1.8 until either the leak rate cannot be detected or the desired maximum leak rate is obtained.

8.1.10 Depressurize and disassemble the fixture.

8.1.11 Measure and record the final gasket thickness in inches.

8.1.12 Calculate the yield factor, *y*, for each stress increment:

$$y = W / A_1 \quad (1)$$

where:

W = total compressive force (lbs force) and
A_1 = gasket contact area (in.^{2}).

8.1.13 Plot the leak rate versus the yield factor, *y*.

8.1.14 Select a yield factor based on the maximum desired leak rate (Fig. 1) or the point of diminishing improvements in leak rate (the lowest yield factor at which higher surface stresses do not result in significant leak rate reduction) (Fig. 2). It is acceptable to interpolate between load steps.

8.2 *Determining the Maintenance Factor, m:*

8.2.1 A new gasket shall be used for this section of testing.

TABLE 4 Fluid Sealing Association (FSA) Round Robin Testing of CNA, Maintenance Factor

NOTE 1—Laboratory 2 increased the surface stress by the hydrostatic end load.

F104 Type 71 – Compressed Non-Asbestos												
Lab 1				Lab 2				Lab 3				
Surface Stress (psi)	Maintenance Factor, *m*	Test Specimen 1	Test Specimen 2	Surface Stress (psi)	Maintenance Factor, *m*	Test Specimen 1	Test Specimen 2	Surface Stress (psi)	Maintenance Factor, *m*	Test Specimen 1	Test Specimen 2	Test Specimen 3
6770	21.5	5.71E-04	1.66E-02	7072	22.6	2.05E-02	BDL[A]	6770	21.4	6.62E-04	1.00E-03	2.91E-04
6270	19.9	5.71E-04	1.71E-02	6572	20.9	2.15E-02	1.00E-03	6270	19.8	1.31E-03	1.42E-03	3.23E-04
5770	18.2	5.71E-04	1.83E-02	6072	19.2	2.23E-02	1.17E-03	5770	18.1	1.32E-03	1.60E-03	4.68E-04
5270	16.5	5.71E-04	2.00E-02	5572	17.6	2.35E-02	8.33E-04	5270	16.4	3.13E-03	2.91E-03	5.75E-03
4770	14.9	5.71E-04	2.11E-02	5072	15.9	2.38E-02	1.33E-03	4770	14.8	9.24E-03	3.17E-03	1.44E-02
4270	13.2	5.71E-04	2.26E-02	4572	14.2	2.45E-02	1.33E-03	4270	13.1	1.38E-02	5.86E-03	2.97E-02
3770	11.5	5.71E-04	2.46E-02	4072	12.6	2.48E-02	8.33E-04	3770	11.4	6.16E-02	2.67E-02	6.19E-02
3270	9.9	5.71E-04	2.63E-02	3572	10.9	2.75E-02	1.17E-03	3270	9.8	8.38E-02	7.24E-02	7.91E-02
2770	8.2	5.71E-04	2.89E-02	3072	9.2	2.92E-02	1.50E-03	2770	8.1	1.41E-01	9.60E-02	9.80E-02
2270	6.5	8.57E-04	3.29E-02	2572	7.6	3.33E-02	2.00E-03	2270	6.4	2.09E-01	1.48E-01	1.36E-01
1770	4.9	1.43E-03	3.86E-02	2072	5.9	4.10E-02	2.83E-03	1770	4.8			
1270	3.2	1.00E-02	5.26E-02	1572	4.2	6.05E-02	7.17E-03	1270	3.1			
770	1.5	5.66E-01	3.02E-01	1072	2.6	1.12E-01	3.32E-02	770	1.4			
Selection of *m* based on maximum leak rate of 0.085 cc/min-inch OD	3.2	3.2			4.2	2.6			9.8	9.8	9.8	

[A] BDL = below detection limit.

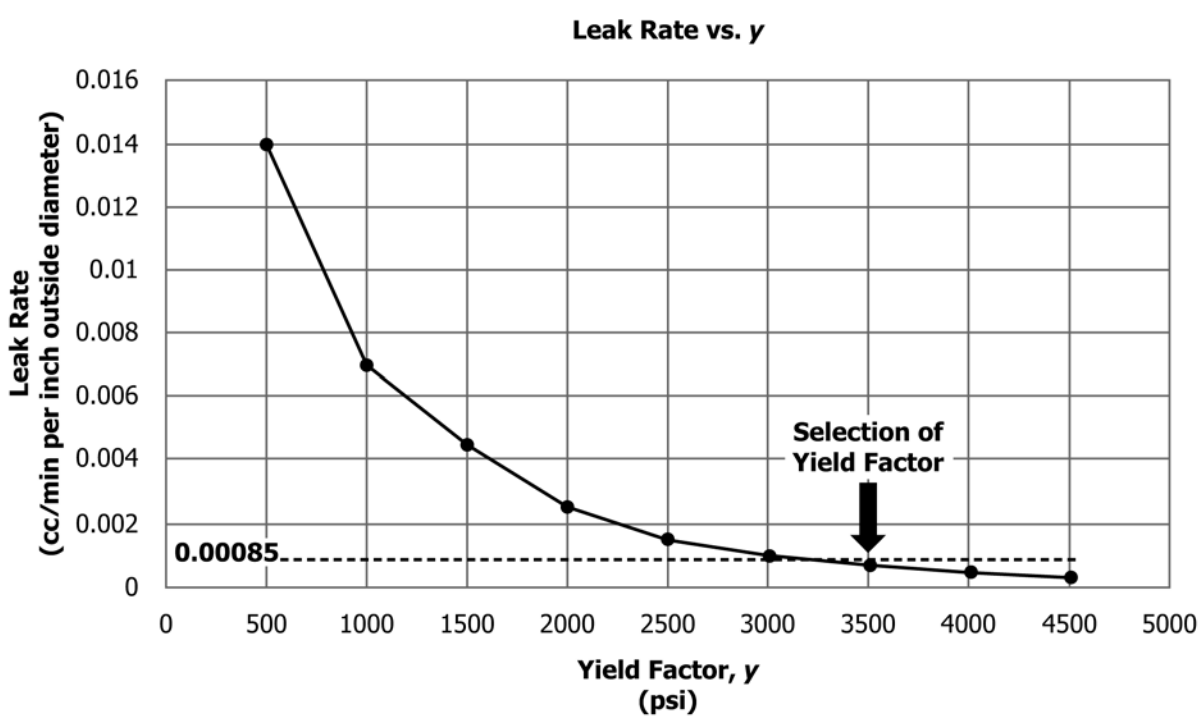

FIG. 1 Selection of Yield Factor, *y*, Leak Rate of 0.0085 cm^3/min per inch OD

8.2.2 Measure and record initial gasket thickness in inches.

8.2.3 Record the surface finish of the flanges or platens (see Section 5).

8.2.4 Ensure flange facing is clean and free of contaminants and debris from the previous section of testing.

8.2.5 Center the gasket on the flange face or platen.

8.2.6 Load the gasket to 6770 psi (46.7 MPa) surface stress.

8.2.7 Pressurize the fixture to 300 psig (20.7 bar) and record the media.

8.2.8 Hold for 15 min and record the leak rate. If the leak rate exceeds maximum measurable leak rate or is above the maximum desired leak rate, increase the stress to 10 000 psi (68.9 MPa), then hold for 15 min, and record the leak rate.

8.2.9 Decrease the load in an incremental step of 500 psi (3.44 MPa) surface stress. Increments can be varied based on material characteristics and performance in previous tests.

8.2.10 Hold for 15 min and record the leak rate.

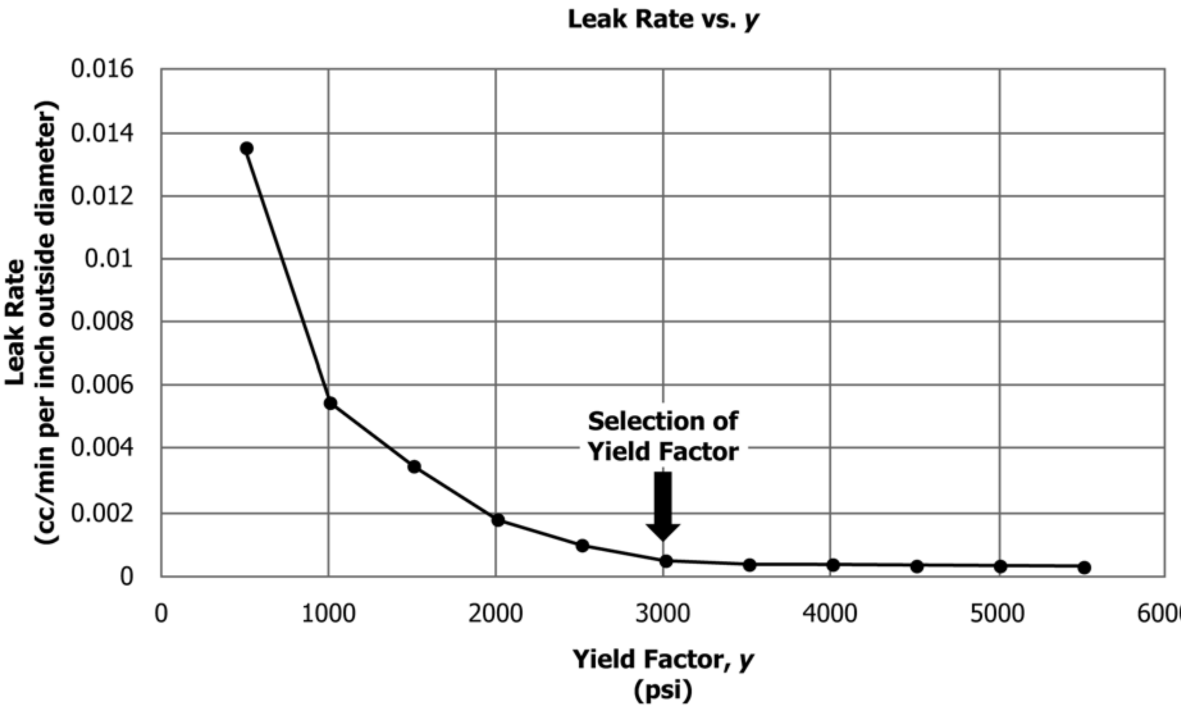

FIG. 2 Selection of Yield Factor, *y*, Point of Diminishing Improvements

8.2.11 Repeat 8.2.9 and 8.2.10 until either the leak rate cannot be controlled or the desired maximum leak rate is exceeded.

8.2.12 Depressurize and disassemble the fixture.

8.2.13 Measure and record the final gasket thickness in inches per the procedure described in Classification F104.

8.2.14 Calculate the maintenance factor, *m*, for each stress increment:

$$m = (W - A_2 P)/A_1 P \quad (2)$$

where:

W = total flange loading force (lb),
A_1 = gasket contact area (in.^{2}),
A_2 = inside area of gasket (in.^{2}), and
P = test pressure (psig).

NOTE 2—The m factor calculation (Eq 2) subtracts the hydrostatic end force from the total flange loading force.

8.2.15 Plot the leak rate versus the maintenance factor, *m*.

8.2.16 Select a maintenance factor based on either the maximum desired leak rate (Fig. 3) or through derivation (Fig. 4), in which the surface stress level before an additional reduction in surface stress results in significantly higher leak rate. It is acceptable to interpolate between load steps. Maintenance values less than 2.0 are typically not used in ASME designs except for elastomeric gaskets (Classification D2000).

9. Report

9.1 The following shall be reported (see Table 5):

9.1.1 Leak rate versus yield factor and leak rate versus maintenance factor curves and, as appropriate, *m* and *y* recommended values for the desired maximum leak rate as agreed upon between producer and user;

9.1.2 Test specimen material and/or ASTM type designation, for example, Classifications F104 and F868;

9.1.3 Test specimen dimensions (inside diameter, outside diameter, and initial thickness in inches);

9.1.4 Surface finish of the flange or platen;

9.1.5 Description of pressurized test media used, for example, nitrogen, helium, water, and air;

9.1.6 Description of test fixture including the following applicable specifics: flange material, flange description (nominal pressure class and nominal diameter), or platen;

9.1.7 Description of loading technique including the following applicable specifics: calibrated bolts (including bolt size and material), ultrasonic measurement, or hydraulic loading; and

9.1.8 Description of leak measurement method including the following applicable specifics: differential pressure gage, manometer, flowmeter, or mass spectrometry.

10. Keywords

10.1 gasket designs; gasket materials; loading constants; *m*; maintenance factor; *y*; yield factor

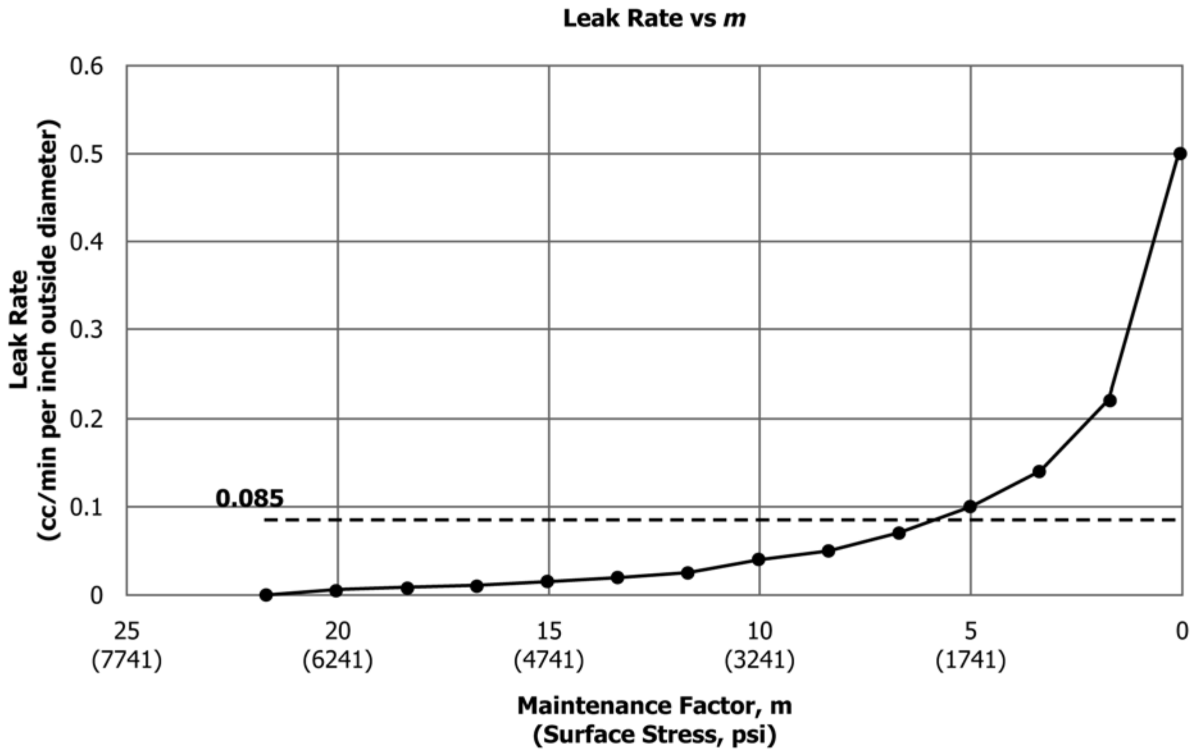

FIG. 3 Selection of Maintenance Factor, *m*, Leak Rate of 0.085 cm^3/min per inch OD

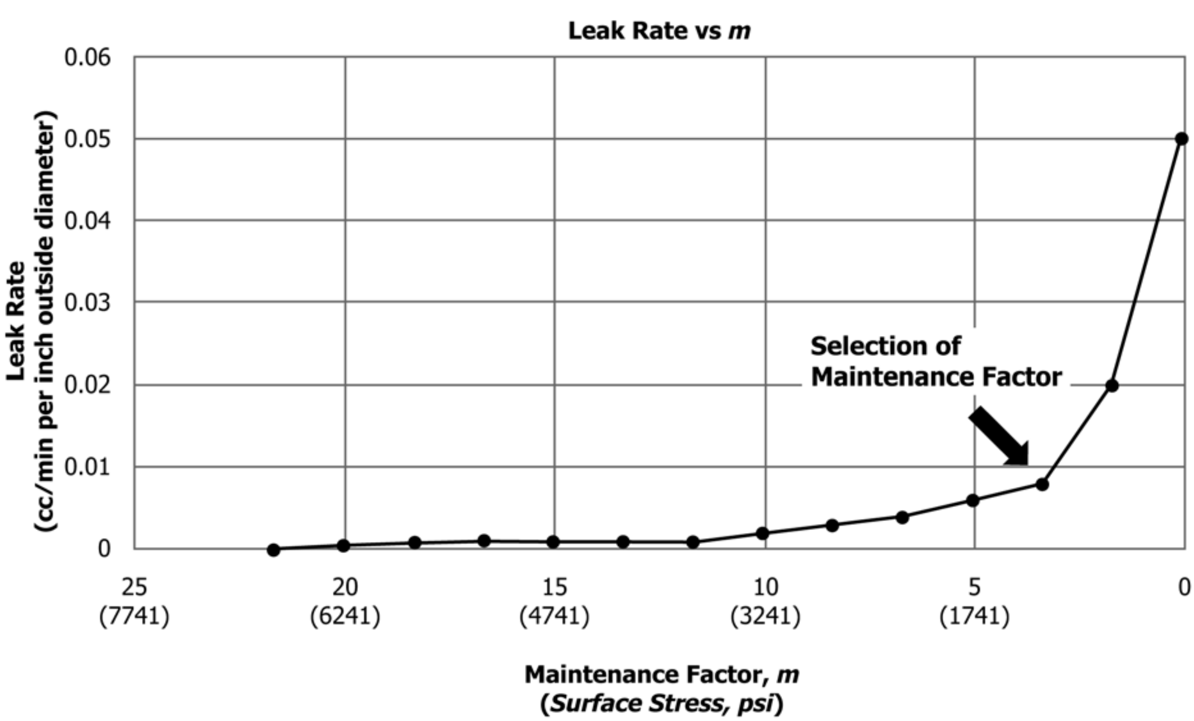

FIG. 4 Selection of Maintenance Factor, *m*, Derivation

TABLE 5 Report and Data Table Examples

Report	Laboratory 1	Laboratory 2	Laboratory 3
Test specimen dimensions	2.5 by 3.5 in.	4.25 by 6 in.	4.5 by 6.19 in.
Surface finish	50 μ-in. non-serrated	242 μ-in. non-serrated	125 μ-in. non-serrated
Pressurized test media	Nitrogen	Nitrogen	Nitrogen
Test fixture description	Platen	Platen	Platen
Loading technique description	Hydraulic (DIN 3535)	Hydraulic (AMTEC)	Hydraulic stand
Leak measurement system description	Manometer	Pressure decay	Manometer